Evaluating human-centered approaches for geovisualization

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We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time

Eliot (1943b)

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SPELLING CONVENTION

There are two American spellings adopted throughout the thesis to align with the commonly used names for major domains of study. These are "visualization" for "visualisation" (including versions with the "geo" prefix) and "human-centered" for "human-centred".

DECLARATION

ABSTRACT

Working with two small group of domain experts I evaluate human-centered approaches to application development which are applicable to geovisualization, following an ISO13407 taxonomy that covers context of use, eliciting requirements, and design. These approaches include field studies and contextual analysis of subjects' context; establishing requirements using a template, via a lecture to communicate geovisualization to subjects and by communicating subjects' context to geovisualization experts with a scenario; autoethnography to understand the geovisualization design process; wireframe, paper and digital interactive prototyping with alternative protocols; and a decision making process for prioritising application improvement.

I find that the acquisition and use of real user data is key; that a template approach and teaching subjects about visualization tools and interactions both fail to elicit useful requirements for a visualization application. Consulting geovisualization experts with a scenario of user context and samples of user data does yield suggestions for tools and interactions of use to a visualization designer. The complex and composite natures of both visualization and human-centered domains, incorporating learning from both domains, with user context, makes design challenging. Wireframe, paper and digital interactive prototypes mediate between the user and visualization domains successfully, eliciting exploratory behaviour and suggestions to improve prototypes. Paper prototypes are particularly successful at eliciting suggestions and especially novel visualization improvements. Decision-making techniques prove useful for prioritising different possible improvements, although domain subjects select data-related features over more novel alternative and rank these more inconsistently.

The research concludes that understanding subject context of use and data is important and occurs throughout the process of engagement with domain experts, and that standard requirements elicitation techniques are unsuccessful for geovisualization. Engagement with subjects at an early stage with simple prototypes incorporating real subject data and moving to successively more complex prototypes holds the best promise for creating successful geovisualization applications.

ABBREVIATIONS

Abbreviation	Meaning (multiple meanings are context specific)
A	Start point for research (no existing application)
AHP	Analytic Hierarchy Process
AOT	All Other Theft (a crime category)
ar	absolute and relative
ASB	anti-social behaviour
B	Start point for research (existing application)
C	context of use
C	computer focus
C1, C2, C3	crime & disorder reduction subjects
C123	C1, C2 and C3
C3+18	(response by) C3 eighteen months after first interviews
CDR	crime and disorder reduction
CDRP	crime and disorder reduction partnership
CHI	computer-human interaction
CI	Contextual Inquiry
COVVE	Commission on Visualization and Virtual Environments
CR	consistency ratio (AHP)
CS	Community Services (LCC department that contains Libraries)
CSP	Community Safety Partnership
D	design
D	domain experts
D	data focus
D	a geovisualization expert, a geovisualization developer
DF	degrees of freedom
E	usability engineering
E	evaluation
EDA	exploratory data analysis
Geovis, GeoVis, G	geovisualization
GI	geographic information
GIS, GISystem	geographic information system
gm	multiple glyph
gs	single glyph
H	user goals focus
HC	human-centered
HCI, H	human-computer interaction
HCID	human-computer interaction design
HF	human factors
HMI	human-machine interface
I	interaction focus
ICA	International Cartographic Association
InfoVis. I	information visualization
ISO	International Standards Organisation

KDD	knowledge discovery through databases
KWIC	Keyword-in-context
L1, L2, L3	libraries subjects
LCC	Leicestershire County Council
LSOA	lower super output area
MILC	multi-dimensional in-depth long-term case study
MMI	man-machine interface
MySQL	a open source database
O	others
OA	output area
OAC	output area classification – a geodemographics system
OMI	operator-machine interface
P1, P2 … P9	geovisualization researchers consulted with a scenario
PCP	parallel coordinates plot
PLM	Public Libraries Marketing
QDA	qualitative data analysis
QUIS	Questionnaire for User Interface Satisfaction
R	requirements
R	a senior research officer and a 'lead user' for geovisualization within LCC
r	risky development
RQ	Research Question
S	students
sb	crime sub-category
SE	software engineering
sig	significance
SOM	self-organising map
sp	spatial pan
sr	spatial resolution
STV	Spatio Temporal Visualizer
SUMI	Software Usability Measurement Inventory
SVG	scalable vector graphics
sz	spatial zoom
TALIS	a proprietary library database system
TFV	Theft From Vehicle (a crime category)
U	usability expert
UCD	user-centered design
UE, E	usability engineering
UID	user interface design
V	visualization/spatial experts
VAST	Visual Analytics Science and Technology
Vis	visualization
ViSC	visualization in scientific computing
X	unknown
x	dependency on another possible improvement


GEOVISUALIZATION
VISUALIZATION
HUMAN-CENTERED
INFORMATION
APPROACHES
RESEARCH
design
user
usability
APPROACH
methods
requirements
users
data
al
application
evaluation
researchers
experts
techniques
domain
tools
use
tasks
context
et
Table
studies
interaction
case
real
software
expert
geovis
domains
ANALYSIS
Spatial
number
study
NATURE
subject
process
applications
students
exploration
InfoVis
LITERATURE
prospective
different
engineering
work
focus
DEVELOPMENT
HCI
used
knowledge
using
papers
ISO
field
may
visual
HC
one
need
types
UCD
testing
interface
human
Slocum
Dykes
Marsh
Results
analytics
Common
task
issues
three
often
four
new
Kraak
provide
user-centered
employed
important
problems
interactive
paper
Maps
exploratory
tool
develop
appropriate
human-computer
subjects
real/user
Andrienko
two

1 INTRODUCTION, RATIONALE AND RESEARCH QUESTIONS

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INTRODUCTION TO THE THESIS

A knowledge gap separates domain experts and the visualization domain. Visualization solutions have their expression in the form of applications through which domain experts interact with their data to explore, hypothesize, gain insight, and confirm or confound expectations. Given the complexity of different domains and of subject data and tasks, no single solution can fit all users and all data, and customization is inevitable. While significant advances in information visualization and geovisualization have been made without user engagement, human-centered approaches that focus on user context and requirements and on user involvement through an iterated process of design, prototyping and evaluation, as outlined in ISO13407, represent an opportunity to bridge the knowledge gap.

While human-centered approaches have been used in a wide variety of domains with a range of data, their applicability to geovisualization, which combines multiple tools and interactions in a simultaneous and space-constrained manner, is not well established. There is a need to determine the extent to which such approaches are applicable, and in what way standard human-centered approaches need to change for geovisualization. These human-centered approaches can only be studied *in vivo*, in the context of real prospective users, situated in their work environment, and preferably over time, building a visualization application for them from first principles. As part of a long term case study, for three years I have worked with two sets of domain experts in a leading UK local authority - research officers with responsibility for researching crime and disorder reduction, and managers seeking to market public library services.

The value of this research is in the broad range of human-centered approaches evaluated in a visualization context engaging with users spanning a significant period. Results are triangulated where possible with evidence from multiple strands of inquiry, with qualitative and quantitative analysis, and give confidence in the findings.

INTRODUCTION TO THIS CHAPTER

In this chapter, I explore the nature of geovisualization, explain why geovisualization applications are different from other applications, and set the context relative to neighbouring disciplines, such as information visualization. I outline the main tools, techniques and interactions of geovisualization.

I summarise the development of geovisualization and the challenges that face the discipline. Among these is the need to work closer with real end-users in different domains to see what aspects of geovisualization work *in vivo*. Working with end users means using tools that have been developed in various human-centered disciplines. There is a need to determine how well these tools work in a geovisualization context, whether they need to be changed, how they might be modified, which tools work better and which work differently. **This challenge is at the crux of my thesis.**

I explain human-centered approaches to the creation of applications and set these in the context of other disciplines, such as software engineering. I outline the main approaches of human-centered approaches under the headings of context of use, requirements and design.

I review pertinent research in geovisualization and information visualization that has used human-centered methods, and draw inferences about the way that visualization researchers have applied human-centered methods from a literature review.

1.1 GEOVISUALIZATION AND INFORMATION VISUALIZATION

1.1.1 THE NATURE OF GEOVISUALIZATION

Spatial data

Anselin (1989) asks, "what is special about spatial data?", and it is appropriate to begin by posing another alliterative question addressed to the nature of geovisualization - 'what is gee-wizz about geovis?' The raw material of geovisualization – its distinguishing feature from other forms of visualization, such as information visualization – is the inclusion of spatial data. Anselin (1989) identifies spatial dependence and spatial heterogeneity as the 'special' aspects of spatial data, and Andrienko et al (2008) identify scale effects as another. Openshaw (1999) expands on this outlining the special features of geoinformation:

> "observations are not independent; data uncertainty and errors are often spatially structured; whole map statistics are seldom helpful; non-stationarity is to be expected;

> relationships are often geographical localised - rather than global; non-linearity is the norm; data distributions are non-normal; high levels of multivariateness but with redundancy; time often interacts with space; most GIS data layers are categorical; the locational element is important; the modifiable nature of all spatially aggregated data; results reflect definitional dependencies; there can be a fair proportion of junk data."

Geovisualization

To deal with and interpret the special features of spatial data, MacEachren (1992) proposes using human abilities, in the then new discipline of geovisualization defined as: "the use of concrete visual representation - whether on paper or through computer displays or other media - to make spatial contexts, and problems visible, so as to engage the most powerful human information-processing abilities, those associated with vision." MacEachren (1994b) develops the concept of 'cartography3' where the polar natures of communication and exploration are set out and where geovisualization is characterised as having high interactivity, a highly exploratory nature and being 'privately pursued'. This builds on the work of DiBiase (1990) who illustrates the "range of functions of visual methods in an idealized research sequence" in a seminal graphic (Figure 1.1).

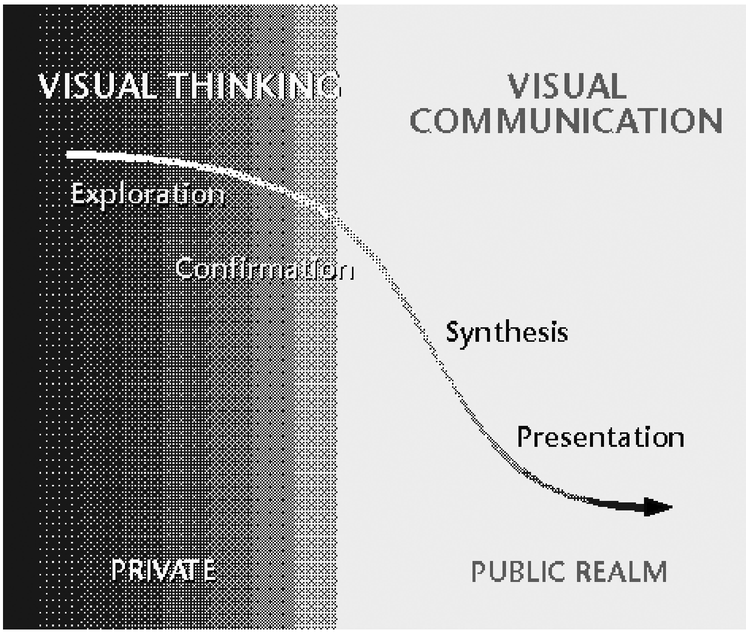

Figure 1.1: The "range of functions of visual methods in an idealized research sequence" from DiBiase, 1990

MacEachren and Kraak (2001) provide the canonical description of geovisualization`s origins and purpose: “Geovisualization integrates approaches from visualization in scientific computing (ViSC), cartography, image analysis, information visualization, exploratory data analysis (EDA), and geographic information systems (GISystems) to provide theory, methods, and tools for visual exploration, analysis, synthesis, and presentation of geospatial data", and also an outline of its use in exploration in practice: "…display use starts without hypotheses about the geospatial data, and the visualization tools assist in an interactive, unencumbered search for structures and trends, with one goal being to prompt hypotheses. Maps and graphics in this context do more than “make data visible,” they are active instruments in the users’ thinking process."

Principal examples of geovisualisation applications from the last decade include cdv (Dykes, 1998), Descartes (Andrienko and Andrienko, 1999), later Common GIS (Andrienko et al., 2002), SAGE (Haining, Wise and Signoretta, 2000), GeoVista Studio (Gahegan et al., 2002; Takatsuka and Gahegan, 2002), GGobi (Swayne et al., 2003), SomVis (Guo et al., 2005), GeoDa (Anselin, Syabri and Kho, 2006), Improvise (Weaver, 2006b) and GAV (Jern et al., 2007). Commercial visualisation software such as DecisionSite (Spotfire, 2009), Instant Atlas (Geowise, 2009) and SpatialKey (Spatialkey, 2009) is becoming increasingly available. Recent developments such as geovisualization mashups (Slingsby et al., 2007; Wood et al., 2007; Wood and Dykes, 2008) and internet-wide visualization (Viégas et al., 2007; Viégas et al., 2008) demonstrate that innovation is continuing, indeed accelerating. Dykes (2005a) and Nöllenburg (2007) provide overviews of the geovisualization domain. Marsh (2007) conducted research to identify efficient, effective and reliable ways to evaluate geovisualization tools and when these might be valid, and identifies a number of aspects that characterise geovisualization: small number of users, high level of expertise required, high cognitive load (user related); high software interaction/complexity, low task predictability, long task time (interaction-related); small number of tools, moderate technological change (tool-related); high reliance on multiple views, high display constraints, multiple scales, high anisotropic space, limitation of cartographic legacy (layout-related).

From a search of the geovisualization literature and from the geovisualization applications above, I list some techniques employed prior to visualization, geovisualization tools and interactions (Table 1.1). It excludes 3-dimensional representations given the advice of (DiBiase et al., 1994) that "two-dimensional representations ought to be preferred for two-dimensional data." The list gives an indication of the breadth of methods employed in this thesis, and it forms the basis for communicating geovisualization to prospective users and as a crib for geovisualization experts (see Chapter 4). The individual techniques, tools and interactions that are employed in this thesis are described as they occur in Chapters 3-7.

Techniques

Pre-filtering techniques (things to consider doing before geovisualizing)

* correlation matrix (are my attributes correlated? Can I eliminate some?)
* data cleansing; outlier detection (is my data sensible?),
* data transform
* factor analysis, principal component analysis (which attributes are most important?)
* k-means analysis (what clusters are there?)
* lag/lead (are thing happening simultaneously, or not?)
* clustering (what clusters are there?)

Pre-calculation techniques (reduce complexity; calculate beforehand, possibly)

* cartograms, insets and other maps (inc underlying navigational maps)
* treemaps
* statistical results (e.g. correlation coefficients)

Tools

Exploratory data analysis/non-spatial tools

* barchart
* box plot
* conditional box plot, conditional histogram, conditional scatterplot
* glyphs
* histogram
* mosaic plot
* parallel coordinate plot
* pie chart
* scatterplot
* scatterplot matrix
* small multiples
* star plot (attribute glyphs)
* stem plot
* table browser
* time plot path
* time series plot
* tree and leaf plot
* treemap (and other hierarchical plots)

Spatial/mapping tools

* cartograms - discontinuous; continuous; rectangular
* density maps
* generalisation
* insets
* map distortions
* self-organising maps
* symbology
* thematic/choropleth maps

Interactions

* animation
* brushing
* categorising/aggregation
* conditioning
* distortion (table lens; fisheye)
* extracting
* filtering
* linking
* manipulation (rotation, separation)
*multiple views
* panning
* query
* reordering
* semantic zooming
* sorting
* zooming

Table 1.1: List of geovisualization techniques, tools and interactions sourced from geovisualization literature and geovisualization applications

Geovisualization emerges as a composite enterprise, integrating a cartographic heritage with inputs from other fields - it is clearly a **spatial** domain, inheriting, and attempting to address and reveal, issues of spatial dependence, spatial heterogeneity and scale. It envisages the use of **multiple components** compromising both spatial and non-spatial elements to achieve the **exploratory** objectives of its users. **Interactivity** has become a key component. This combination of characteristics creates a knowledge gap (van Wijk, 2006) between its practitioners and potential end users who are experts in their own domains.

1.1.2 THE NATURE OF INFORMATION VISUALIZATION

Information visualization (InfoVis) is "the use of computer-supported, interactive, visual representations of abstract data to amplify cognition" (Card, Mackinlay and Shneiderman, 1999). InfoVis is a cognate discipline of geovisualization and shares many of the tools of exploration. InfoVis tools such as graph drawing (Rodgers, 2005) have been suggested for inclusion in geovisualization applications. Self-organising maps (Kohonen, 1997) have featured in a number of designs (Gahegan et al., 2002; Guo et al., 2006; Guo et al., 2005; Koua and Kraak, 2005). In the same way, spatial representations are employed in InfoVis applications. Fabrikant and Skupin (2003) report that "Spatial metaphors are typically used in Information Visualization as semantic vehicles for the spatialization process", and in Skupin and Fabrikant (2003) they set out a cartographic research agenda for non-geographic information visualization (spatialization). Some other examples of spatial representations employed in information visualization research are treemaps (Shneiderman, 1992), themescapes (Wise et al., 1995), and Kohonen maps (Kohonen, 1997; Spence, 2001).

Kraak (2008) states that "Information visualisation has always been the sub discipline to which the [ICA] Commission [on Geovisualisation] has felt most attracted." And Marsh and Dykes (2008) suggest that "geovisualization evaluation may not differ in nature to that of evaluation in other exploratory domains in which graphical exploration plays a key role." In Keim, Panse and Sipps (2005), the authors demonstrate "the application of InfoVis methods to provide new ways of analyzing geospatial data" and provide further evidence of the degree of convergence between information visualization and geovisualization. Considering the integration of visualization domains, Kerren et al (2007) found that:

> "the case of GeoVis seemed much closer to InfoVis. Some common properties of GeoVis that are perhaps familiar to InfoVis are that errors in data are common, scale and form are very important, and interpretations are typically subjective, imperfect, and incomplete. In GeoVis, maps help by providing a common structure for visual synthesis

and an artifact on which to project tacit knowledge…Cartography has good theories that InfoVis could better exploit."

The literature contains a number of taxonomies of InfoVis tools and techniques - (North and Shneiderman, 1997; Shneiderman, 1996), (Tweedie, 1999), (Chi, 2000), (Morse and Lewis, 2000), (Pfitzner, Hobbs and Powers, 2003), (Chengzhi, Chenghu and Tao, 2003), (Tory and Möller, 2004) and (Keim, Panse and Sipps, 2005). Card, Mackinlay and Shneiderman (1999) and Spence (2001) give overviews of the InfoVis domain.

Although geovisualization and information visualization may be close cousins, (Tobon, 2005) finds experimentally that "there may be fundamental differences between the cognitive processes required to participate in the visualization of geographic spaces and those required for visualization of information spaces that are not spatial." Marsh (2007) examines geovisualization and information visualization along dimensions concerned with users, tools, interaction and layout, and finds a number of differences, shown in Figure 1.2.

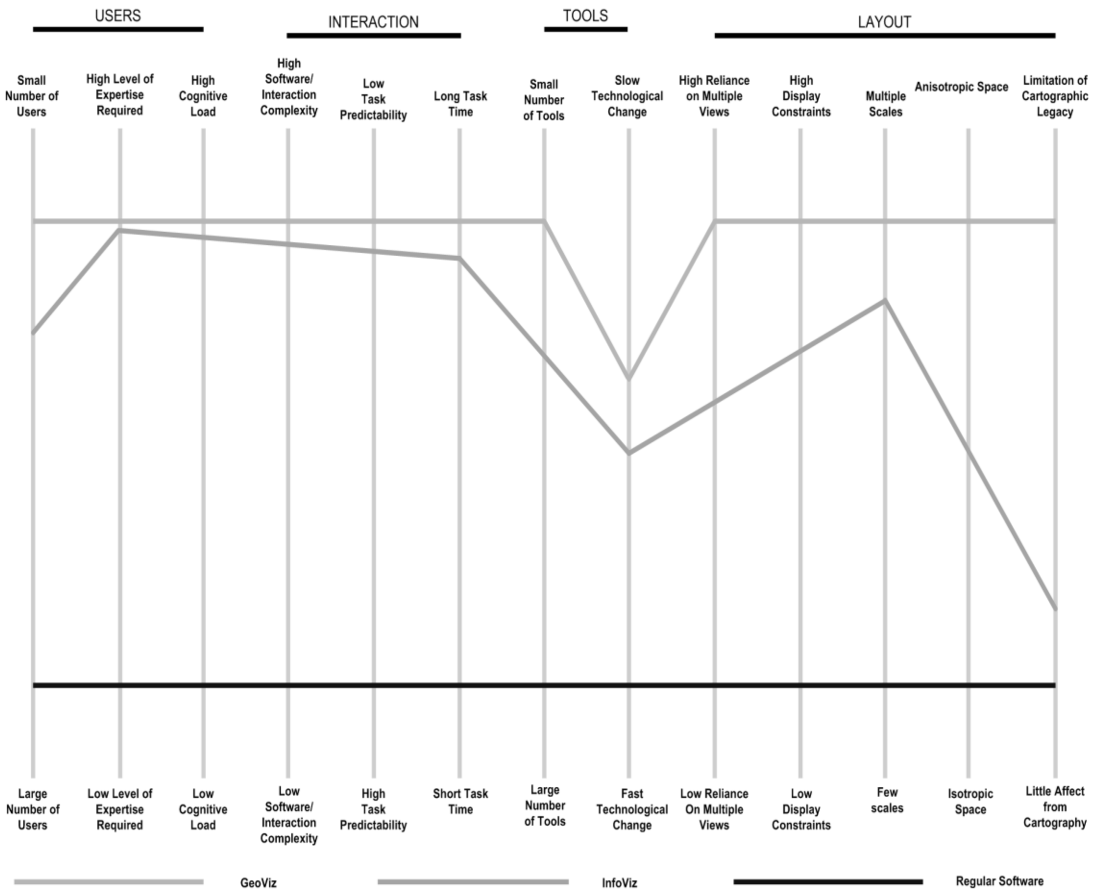

Figure 1.2: Qualitative representation of the differences between geovisualization (top line), information visualization (middle line) and regular software (bottom line) (Marsh, 2007).

Finally, it is well to distinguish between visualization domains and the neighbouring fields of data mining and knowledge discovery through databases (KDD). Shneiderman (2002) states: "Information visualization researchers believe in the importance of giving users an overview and insight into the data distributions, while data mining researchers believe that statistical algorithms and machine learning can be relied on to find the interesting patterns."

1.1.3 DEVELOPMENTS IN GEOVISUALIZATION

Andrienko et al (2005) consider the motivations that have driven and continue to drive the development of geovisualization applications and tools:

> "1. New technology continues to appear and it often enables us to do things that were not possible before.
> 2. We may be able to acquire data of a new form or quality that cannot be analyzed with existing tools as the data sets may be so large, dense or contain so many dimensions that no current tool supports interactive investigation effectively.
> 3. As geovisualization becomes more popular and exploited more widely, we encounter new tasks that cannot be performed using existing tools. Effectively geovisualization may be used to address new societal requirements.
> 4. The particular needs of specific users (from this growing user base) are likely to vary and tools may serve a new or changing user base.
> 5. Accessing expertise from cognate disciplines may contribute to what already exists and enhance it further.
> 6. Collaboration between researchers may improve our ability to visualize geographic information and to develop the various instruments that support this process. The notion of interoperability underlies our efforts to develop ideas and generate knowledge from our data using instruments for ideation"

These motivations have enabled geovisualization researchers to create a substantial body of work over the last 15 years or so. “Providing geographers and other researchers…these sorts of tool for exploratory analysis of their data has been a theoretical and practical goal of geographic information scientists for at least the last decade” (Edsall and Roedler, 2002). The fields of visual analytics and geovisual analytics have developed in the last five years in response to the need to "synthesize information and derive insight from massive, dynamic, ambiguous, and often conflicting data; detect the expected and discover the unexpected; provide timely, defensible, and understandable assessments; and communicate assessment effectively for action." (Keim et al., 2008). These fields integrate the approaches described above by Shneiderman (2002). **Visual analytics** is defined as “the science of analytical reasoning facilitated by interactive visual interfaces” (Thomas, 2005), although Keim et al (2008) offer a more specific definition: "visual analytics combines automated analysis techniques with interactive visualizations for an effective understanding, reasoning and decision making on the basis of very large and complex data sets." Keim et al (2006) explain that "visual analytics is more than just visualization and can rather be seen as an integrated approach combining visualization, human factors and data analysis...With respect to the field of visualization, visual analytics integrates methodology from information analytics, geospatial analytics, and scientific analytics." Not only does this emphasise the close links between the information visualisation and geovisualization domains, but also the important role of human-centered approaches – "the visualization of these processes will provide the means of communicating about them, instead of being left with the results…" (Keim et al., 2008)

Andrienko et al (2007) see **Geovisual Analytics for Spatial Decision Support** as a "sub-area of Visual Analytics with its specific focus on space and time posing specific research problems and calling for special approaches to solving more generic research" and define it as "the research area that looks for ways to provide computer support to solving space-related decision problems through enhancing human capabilities to analyse, envision, reason, and deliberate." Tomaszewski et al (2007) state "Geovisual Analytics is an emerging interdisciplinary field that integrates perspectives from Visual Analytics (grounded in Information and Scientific Visualization) and Geographic Information Science (growing particularly on work in geovisualization, geospatial semantics and knowledge management, geocomputation, and spatial analysis)."

Both visual analytics and geovisual analytics contribute to the notion that the former information visualization and geovisualization approaches must be enhanced by an increased focus on **communication, decision making** and **human-centered approaches**. Armstrong and Densham (2008) encapsulate this in Figure 1.3 to define: "three intersecting 'spaces' in which maps are used during decision making...The private realm conforms to individual map creation and analysis. Public spaces are for sharing results with others. The evaluative realm is where group deliberation occurs. In any process of iterative "generate and evaluate" decision-making style...the evaluative space is where political processes assume the greatest prominence."

In spite of the many achievements of geovisualization in the last 15 years and the repositioning of the discipline with the emergence of geovisual analytics, there are also a large number of challenges that face geovisualization researchers, one of which is the relevance and use of human-centered approaches to the discipline.

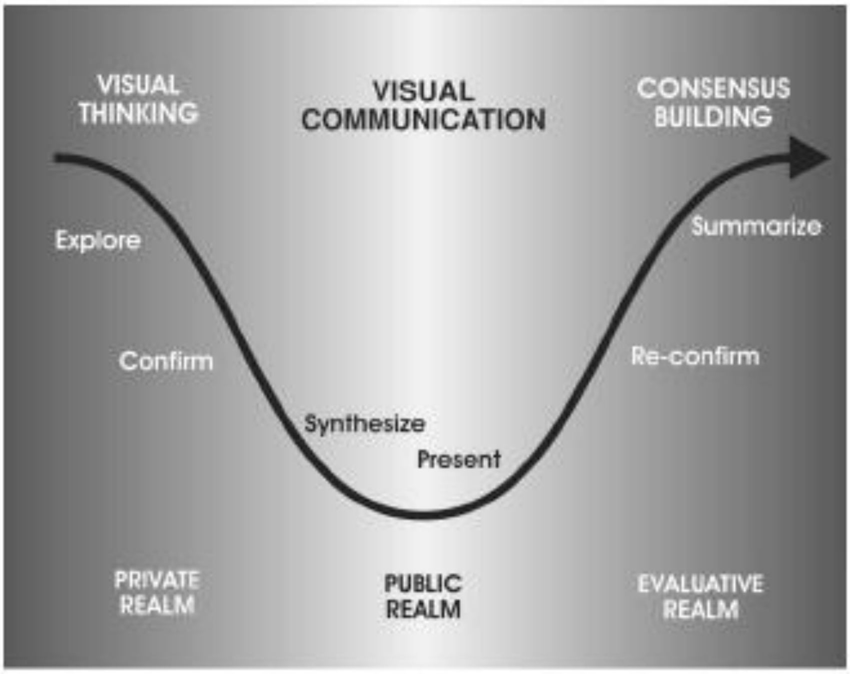

Figure 1.3: "Extending the conceptual model of DiBiase from the public, presentational realm into the evaluative realm" from (Armstrong and Densham 2008)

1.1.4 GEOVISUALIZATION CHALLENGES AND THE HUMAN-CENTERED APPROACH

In 1999, the International Cartographic Association Commission on Visualization and Virtual Environments (ICA COVVE) met to identify a research agenda for geovisualisation with "four primary themes: representation, integration with knowledge construction and geocomputation, interface design, and cognitive usability issues… A crosscutting challenge that underpins [these] is to develop a human centered approach to geovisualization." (MacEachren and Kraak, 2001).

> "A key issue here is to move beyond the current “build and they will come” and “one tool fits all” approaches to geoinformation technology. There is a compelling need to address individual and group differences and to develop both the theory and practice needed to support universal access and usability for geospatial data and, at the same time, enable greater personalization of geovisualization tools to meet both task and user needs." (MacEachren and Kraak, 2001).

Wilson et al (2008) interpret MacEachren and Kraak's challenge as giving rise to a complementary research challenge "to develop and formalize usability design guidelines for typical end users dealing with different task goals in interactive mapping environments." Virrantaus, Fairbairn and Kraak (2009) set out a ICA Research Agenda on Cartography and GI Science and state that "the focus of research in Geovisualization is not on the technical execution of the representation...but is more directed to the data management to enable this, to possible tasks and application areas, and most notably to the role of the user in the visualization process."

In a parallel paper to MacEacren and Kraak, Slocum et al (2001) state "evidence for the successful adoption of geovisualisation techniques has been limited" and propose that

> "cartographers, cognitive scientists, usability engineers, and others should collaborate to develop an appropriate methodology for examining the effectiveness of geovisualisation methods [and]…propose extensive testing of geovisualisation methods, both in the controlled setting of the research laboratory and in the real world….As geovisualization applications expand from their early focus on facilitating scientific investigation by experts to a broader range of users and uses, assessing usability becomes more complex. The standard usability engineering practice of observing potential users working with current tools provides limited (and sometimes misleading) insight on what they might do with geovisualization (because there is often no analogous situation using current tools to the kinds of data exploration that dynamic geovisualization can enable)."

Slocum et al (2001) state "facilitating work related to ill-structured problems may make it difficult to apply standard usability engineering principles" when applied to the particular nature of geovisualization, and that "the key problem is that a clear specification of tasks (and sometimes of users) is often not possible due to the exploratory and interactive nature of geovisualization." Slocum et al (2001) conclude that a research effort was required and that "cartographers, cognitive scientists, usability engineers, and others should collaborate to develop an appropriate methodology for examining the effectiveness of geovisualization methods."

Dykes (2005a) expands on this:

> "it is essential that we develop knowledge of whether the geovisualisation techniques, tools and solutions that are produced actually work and under what circumstances this is the case. We must also be able to explain and even predict such outcomes. We can begin to achieve these objectives by studying the ways in which different users react to a range of new and established geovisualisation methods…Methods drawn from human computer interaction (HCI), such as the concept of 'usability' may enable us, with associated knowledge, to both develop solutions for particular types of user and task"

At the Visualization Summit 2007, an important finding was that the majority of the challenges identified for geovisualization "are common to many areas of information visualization" (Burkhard et al., 2007). Chen and Czerwinski (2000) comment that "despite the proliferation of information visualization techniques, user-centred design of information visualization is rare in the literature." Chen (2005) says:

> "We need new evaluative methodologies. The majority of existing usability studies heavily relied on methodologies that predated information visualization. Such methodologies are limited because we cannot expect them to address critical details

> specific to information visualization needs. There might be an even more profound reason for the shortage of usability studies. Information visualization is a visual exploration tool that enables the user to interact with the visualized content and comprehend its meaning. The comprehension process is often exploratory in nature"

Marsh and Dykes (2008) conduct a mixture of *in vivo* and *in vitro* experiments with varied user groups and conclude there is "strong evidence that useful knowledge can be gained by employing HCI methods in geovisualization." and that their research "provides empirical evidence upon which geovisualization researchers may select and adapt HCI techniques for developing geovisualization applications and evaluating their use." Wassink et al (2008) provide an overview of the application of user-centered approaches in interactive visualization design.

It is in response to this identified need for research that funding was sought to address the issue of the applicability of human centered approaches in geovisualization. While the primary focus of this thesis is on geovisualization, it is clear that information visualization has parallel concerns and that therefore some outcomes will be of use in both domains. The aims and research questions for my research are outlined in section 1.5.

Progress in relevant human-centered research in the geovisualization, geographic information and information visualization domains is reviewed in section 1.3, and this is prefaced by an examination of human-centered approaches in section 1.2.

1.2 THE HUMAN-CENTERED APPROACH

1.2.1 POSITIONING THE HUMAN-CENTERED APPROACH

The **human-centered** approach has developed in response, and in parallel, to the **software engineering** field. The former is focused on the human user; the latter on the technology, however there can be a confusion of terminology; for example, a key book of the human-centered approach bears the title "Usability Engineering" (Nielsen, 1993). Seffah and Metzker (2004) comment:

> "During the past 15 years, the human-computer interaction (HCI) community developed a large variety of user-centered design (UCD) techniques. However, these methods are still underused and difficult to understand by software development teams and organizations. This is because these techniques have been developed independently from the software engineering community, which has its own techniques and tools…"

Both software engineering and human-centered approaches have large but separate bodies of literature and a degree of nomenclature in common, although they can mean different things to each discipline. For example, Seffah and Metzker (2004) assert that "The term usability has been used with different meanings, making it a very confusing concept, especially for software developers." Figure 1.4 summarises the difference in approach across the divide of these two disciplines.

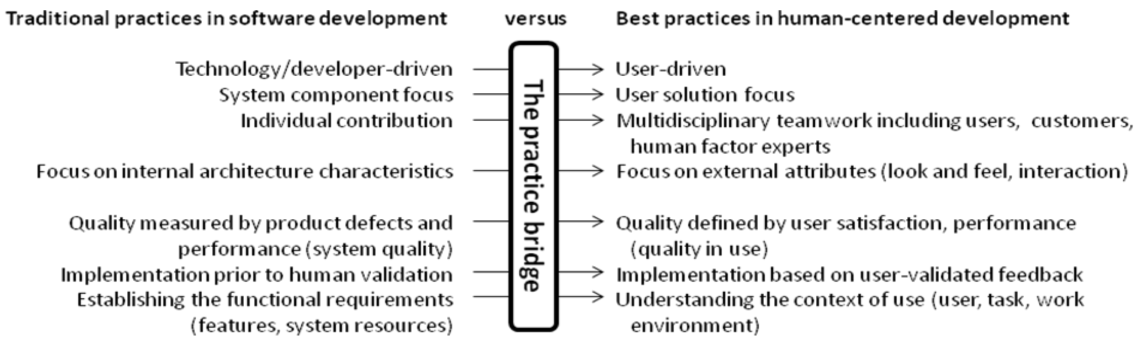

Figure 1.4: Practices in software engineering and human-centered design, original source: IBM Ease of Use website: www.ibm.com/easy,adapted from Seffah and Metzker, 2004.

Brown (1997) states "There is a basic fundamental difference between the approaches taken by software engineers and human-computer interaction specialists. [HCI] specialists are user-centered and software engineers are system-centered." Carroll (2000) expands upon these differences in the software engineering and human-centered approaches:

> "Most software engineering methods belong to a methodological tradition that seeks to control the complexity and fluidity of design through techniques that alter the information considered and decompose the problems to be solved. A complementary tradition seeks to exploit the complexity and fluidity of design by trying to learn more about the structure and dynamics of the problem domain, by trying to see the situation in many different ways, and by interacting intimately with the concrete elements of the situation".

The focus of software engineering is on "the disciplined application of engineering, scientific, and mathematical principles and methods to the economical production of quality software" (Humphrey, 1989). **Requirements engineering** appears later and "focuses on improvements to the front-end of the system development life-cycle." (Finkelstein, 1994). It is defined as "the systematic process of developing requirements through an iterative co-operative process of analysing the problem, documenting the resulting observations in a variety of representational formats, and checking the accuracy of the understanding gained" (Macaulay, 1996). Influenced by developments in the field of human-centered methods, a further development has been the appearance of so-called **lightweight**, **agile** or **Xtreme** software development methods that "attempt a useful compromise between no process and too much process, providing just enough to gain a reasonable payoff. [They are] adaptive rather than predictive … people-oriented rather than process-oriented." (Fowler, 2000)

With the evolution of agile methods, software engineering practice has edged closer to human-centered approaches, and attempts have been made to bridge the divide. Patton (2002) gives details on the practical application of agile user-centered methods, and Constantine (2002) outlines "a streamlined and simplified variant of the usage-centred process that is readily integrated with lightweight methods." Similarities and differences between the Xtreme software development approach and UCD approach are discussed by (Sharp, Robinson and Segal (2004), while Chamberlain, Sharp and Maiden (2006) develop a framework to "integrate UCD practices with agile development."

Karat and Karat (2003) sum this up:

> "In 20 years, we have seen a movement from focusing on specialists (e.g., computer operators or programmers) to examining how technology impacts us all. The user of technology tended to be viewed as the human (perhaps error prone) necessary to complete some task with a system. Now we are attempting to view the user more complexly: as a human in a social system in which the computer plays an increasingly important role….These different communities are brought together by the shared goal of producing technological systems that are better for humans, and by the shared belief that no one view of how to do so holds the answer."

1.2.2 DEVELOPMENT OF HUMAN-CENTERED APPROACHES

Over the last 20 years the International Standards Organisation (ISO) has published standards that "define the general principles of user-centred design and good practice in user interface design" (Bevan, 2001). ISO standard 13407 is on human-centered design processes for interactive systems (ISO, 1999) and characterises a **human centered** approach as:

> "a) the active involvement of users and a clear understanding of user and task requirements;
> b) an appropriate allocation of function between users and technology;
> c) the iteration of design solutions;
> d) multi-disciplinary design"

and identifies "…four human-centered design activities that should take place during a system development project…

> a) to understand and specify the **context of use**,
> b) to specify the user and organizational **requirements**,
> c) to produce **design** solutions,
> d) to **evaluate** designs against requirements."

The challenges, benefits and use of a defined human-centered design process as outlined in ISO13407 are considered in Earthy, Jones and Bevan (2001).

If the software engineering domain has thrown up new techniques under the influence of human-centered methods, then the human-centered world shows an evolving repertoire of tools, a range of approaches and nomenclature. Nielsen (1993) observes that: "The field itself is known under names like CHI (computer-human interaction), HCI (human-computer interaction), UCD (user-centered design), MMI (man-machine interface), HMI (human-machine interface), OMI (operator-machine interface), UID (user interface design), HF (human factors), ergonomics, etc."

While usability engineering has had a large influence on the development of the field, today the human-centered approaches with greatest influence are user-centered design, and human-computer interaction.

Usability engineering (UE) is "a process through which usability characteristics are specified, quantitatively and early in the development process" (Hix and Hartson, 1993) and - despite its name - is a human-centered approach. It is set out in detail in Nielsen (1993).

Gould and Lewis (1985) describe **user-centered design** as possessing three principles of system design: "…early and continual focus on users; empirical measurement of usage; and iterative design whereby the system (simulated, prototype, and real) is modified, tested, modified again, tested again, and the cycle is repeated again and again. This approach is contrasted to other principled design approaches, for example, get it right the first time, reliance on design guidelines." Cockton (2008) revisits and revaluates the foundations of Gould and Lewis's work.

Placing the user at the centre has been a controversial proposition. Karat (1996) asserts that "…design involves participants, each of whom brings both knowledge of a domain and ignorance of other domains to the process. No one perspective is really at the center." "Placing anything at the 'center' can lead to a perception that the other elements are somehow less important." (Karat and Karat, 2003)

Human-computer interaction is a "discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" (Hewett et al., 1992). Preece, Rogers and Sharp (2002) define an enhancement of HCI, human-computer interaction design (HCID), as "designing interactive product to support people in their everyday and working lives…"

Adopting a "human-centered" (HC) approach in this thesis does not imply an overly narrow interpretation or an adherence to any one school of thought, but rather to draw upon the common techniques within UE, UCD, HCI and HCID that contribute to a human-centered approach. This is supplemented as necessary by additions from other fields such as knowledge acquisition (Mittal and Dym, 1985) and decision making (Simon, 1978) applied in a human-centered way. This pragmatic approach is adopted by others, for example Karat (1996) in the context of UCD:

> "I suggest we consider UCD a nice, fluffy little catch phrase. It captures a commitment that the usability community supports—that you must involve users in system design—while leaving fairly open how this is accomplished. Techniques that involve users in design can be called UCD techniques. However, we must keep in mind that developing usable software involves more than involving users…we must…[keep] in mind the difficult necessity of multi-disciplinary communication in design."

1.3 HUMAN-CENTERED APPROACHES IN GEOVISUALIZATION AND INFORMATION VISUALIZATION

In this section, I review the engagement of the geovisualization and information visualization communities with human-centered approaches and highlight the issues raised by researchers. I outline and analyse relevant research papers that demonstrate the use of human-centered methods in visualization, relating these to the identified issues.

1.3.1 VISUALIZATION COMMUNITY ENGAGEMENT WITH HUMAN-CENTERED APPROACHES

Some work in geovisualization or information visualization, conducted prior to 2001 and the publication of the ICA COVVE, which demonstrates particular engagement with HC approaches is worth noting. MacEachren et al (1998) engage with domain experts participants (individuals doing research on the analysis of health data and/or demographic data) to assess a component of a geovisualization prototype. Brewer et al (2000) demonstrate an environmental processes prototype collaborative geovisualization and interview domain experts as well as geography faculty and senior students about the ways in which collaborative geovisualization might enable group work at a distance. Both provide an example of employing approaches appropriate to the Design section of ISO13407. Harrower, MacEachren and Griffin (2000) assess an educational geovisualization tool firstly in a short free exploration and group interview with experienced geovis researchers, followed by formal user testing with undergraduates, an example of employing an approach appropriate to the Evaluation part of ISO13407.

Also noteworthy are three post-2001 examples of HC techniques used in a geographic information (but not geovisualization) context. Aditya and Kraak (2005) use two hypothetical 'problem' scenarios of an existing geoportal to assess current user requirements for a future geoportal. Nivala, Sarjakoski and Sarjakoski (2007) undertake field study interviews with companies developing commercial map applications to determine how usability methods are included in development. Nivala, Brewster and Sarjakoski (2008) evaluate four Web mapping sites in a combination of eight usability and eight cartographic expert evaluations, and eight user tests of general users in a usability lab, to identify usability problems.

Visualization literature post- 2001 raises a number of issues for the community as it seeks to engage with human-centered approaches. These are:

- the paucity of visualization researchers adopting a human-centered approach
- the lack of breadth of human-centered approaches in visualization research
- the over-reliance on evaluative methods by visualization researchers
- the need for case studies conducted *in vivo* with real users
- the need for real data and real tasks
- the choice of subjects and the number used in visualization research
- the techno-centered approach in visualization and how it conflicts with a human-centered one

There are some other aspects that have not been discussed to date in visualization literature but which can be discerned from a 2001-8 review of visualization papers (Table 1.2):

- the choice of which human-computer school of thought to follow in visualization
- the different motivations for, and result outcomes of, human-centered visualization research

One strand of thinking from the HC domain is relevant to this section, which relates to the knowledge gap between visualization experts and prospective application users. That gap may be so large as to make the elicitation of requirements from prospective users formidable since such requirements may be 'un-dreamed of' (Robertson, 2001).

Visualization literature on these issues – where it exists - is explored below and in Section 1.3.2 where I conduct a review of visualization/human-centered research 2001-8 and relate my findings about these issues.

Paucity of human-centered approaches

This research is concerned with human-centered approaches in visualization, but it is worth noting that such a perspective excludes a far larger and hidden world where HC approaches are absent. Ellis and Dix (2006) ask:

> "How often do we come across a paper describing a new visualisation technique and the future work section at the end states 'we intend to undertake a thorough user evaluation' or words to that effect? This is certainly what one of the authors found whilst undertaking a survey of the 170 or so papers in his collection, mostly concerned with information visualisation. He discovered that out of 65 papers describing new visualisation application or techniques, 11 did indeed state that a user evaluation was part of the future work. However a more surprising finding was the fact only 12 out of the 65 papers described any evaluation at all."

Roberts (2007) comments that "Researchers are now including usability studies with the description of their tools, but in many instances they seem to be afterthoughts with few test subjects and little detail presented." Plaisant (2004) conducts a literature survey of about fifty user studies of information visualization systems and finds four thematic areas of evaluation: "controlled experiments comparing design elements…usability evaluation of a tool…controlled experiments comparing two or more tools...[and] case studies of tools in realistic settings. This [last] is the least common type of studies".

Breadth of HC approaches

As ISO 13407 sets out, human-centered methods are grouped into four main areas – context of use, requirements, design and evaluation. The value of the human-centered approach is in the integration of all four. In an early spatial example (a virtual environment), (Gabbard, Hix and Swan II (1999) used a breadth of HC approaches and recommended a "structured, iterative methodology for the user-centered design and evaluation of user interaction… recommend[ing] (1) user task analysis, followed by (2) expert guidelines-based evaluation, followed by (3) formative user-centered evaluation, and finally by (4) summative comparative evaluation." This paper is influential in early geovisualization work exploring human-centered methods (although later work by some of its authors consider it limited in providing guidance for design activities (Gabbard and Swan, 2008)). In particular, Slocum et al (2001), cite Gabbard, Hix and Swan II (1999) as a key influence, as they focus on the breadth of approach issue: "Cartographers have conducted a number of studies on the effectiveness of geovisualization methods, but these studies generally have dealt with just a limited portion of the software design-testing process, applying one or two techniques, rather than [a] broad range of methods…"

Over-emphasis on usability evaluation

If the lack of breadth of application of human-centered approaches is a concern, then a clearer manifestation is the over-emphasis on evaluation (that is, the final section of ISO 13407). Greenberg and Buxton (2008) perceive:

> " an unquestioning adoption of the doctrine of usability evaluation by interface researchers and practitioners. Usability evaluation is not a universal panacea. It does not guarantee user-centered design. It will not always validate a research interface. It does not always lead to a scientific outcome….HCI ≠ Usability Evaluation; it is far more than that."

And Faisal et al (2008) assert that:

> "Usability is not enough when it comes to evaluating InfoVis tools. Usability is designed for evaluating the interface, and hence is not solely suitable for evaluating InfoVis tools. InfoVis is not just an interface; it is an experience that needs to be fully understood in order to be effectively evaluated. Qualitative methods… are appropriate for understanding such experiences."

Need for case studies *in vivo*

Plaisant (2004) considers that "…to be convincing, utility needs to be demonstrated in a real setting, that is a given application domain and set of users." And that case studies are desirable because "they report on users in their natural environment doing real tasks, demonstrating feasibility and in-context usefulness…"

Shneiderman and Plaisant (2006) review evaluation methods and advocate multi-dimensional in-depth long-term case studies (MILC), which "have been embraced by the small but growing community of researchers" for information visualization. They explain that:

> "the multi-dimensional aspect refers to using observations, interviews, surveys, as well as automated logging to assess user performance and interface efficacy and utility. The in-depth aspect is the intense engagement of the researchers with the expert users to the point of becoming a partner or assistant. Long term refers to longitudinal studies that begin with training in use of a specific tool through proficient usage that leads to strategy changes for the expert users. Case studies refers to the detailed reporting about a small number of individuals working on their own problems, in their normal environment."

Marsh and Dykes (2008) conclude that "Longitudinal in vivo studies with experts are important for understanding how geovisualization supports truly complex ideation. The detailed case study approach may be the most appropriate as geovisualization takes time, requires expertise and the most effective solutions are likely to be data, task and user dependent."

Real data, own data. Real task, own task

Plaisant (2004) states that "using real datasets with more than a few items, and demonstrating realistic tasks is important." Faisal et al (2008) argue strongly "that it is crucial for the evaluation process to be as realistic as possible. This ranges from the design of the high-level evaluation task to the completeness of the dataset used and its close correspondence to similar real world situations." Todd et al (2008) comment that "In usability testing…We often place less importance on the data with which we ask participants to interact. Commonly, test data are fabricated, created for participants to imagine as their own. But relating to artificial data can be difficult for participants, and this difficulty can affect their behavior and ultimately call our research results into question."

Subjects and subject numbers in human-centered visualization

Visualization researchers use a number of different types of subject when adopting human-centered approaches such as domain experts, usability experts, visualization experts or students. Marsh and Dykes (2008) found that the "inclusion of students in evaluation is only appropriate if evaluating pedagogic tools. Students are often used as a substitute for experts to increase the numbers of participants in geovisualization evaluations…Any results derived from studies that use students as expert surrogates should be treated with extreme caution." Robinson (2007) found a need to "shift emphasis to actual end-users rather than the graduate students we had enlisted for…initial evaluation." Varied numbers of subjects are used when adopting human-centered approaches. To detect usability problems, Dumas and Redish (1999) advise "3 to 5 participants…to feel comfortable you are seeing the problems." In user testing situations where statistical validation is sought for, say, comparisons between different visualization components, subject numbers need to be much higher. In case studies, working with a single user or small groups is not uncommon where the information collected is qualitative, not quantitative in nature. It is important to distinguish between these very different purposes, subject numbers and the nature of the research. Marsh and Dykes (2008) comment:

> "If we are to use HCI techniques and methodologies in geovisualization, then we must accept that results are subjective and when applied to small user groups, not statistically significant. However, this does not mean that the results are not scientifically important. The key is not to attempt to gain statistically valid results from geovisualization evaluation by using large numbers of potentially inappropriate users."

Techno-centric approach

Fuhrmann et al (2005) comment "The design of geovisualization tools is not only a technical research question. For many years geovisualization tool design was largely technology driven, where system designers and final users were mostly one and the same. Nowadays geovisualization tools are applied in and developed for a broader geosoftware market…"

While this may be so, the techno-centric nature of a great deal of visualization research is at odds with a human-centric approach. For many researchers, their starting point is a pre-existing application and the application of an HC approach is predicated upon this state of affairs. Two papers illustrate the problems that can ensue from this. Slocum et al (2003) respond to the call of Slocum et al (2001) by beginning to experiment with usability engineering principles in the context of geovisualization in decision-making." They create an application to visualize uncertainties in the future global water balance using a variant on Gabbard et al's approach. This variant deviated significantly from Gabbard et al and from established human-centered approaches. (Slocum et al., 2003) show a techno-centric bias by saying "as a first step...we developed the present software for a wrap-around wall-size display..." and "rather than attempt to analyse potential user tasks, we chose to develop a software prototype." Following a heuristic evaluation of the software by usability experts, it is tested on a number of decision makers. The key findings from the process describe what the researchers learn about the users' context of use (or likely non-use) and requirements for such software - "[we] should have considered getting our decision makers involved earlier." This experience is paralleled in Andrienko et al (2006) where geovisualizers learn about domain experts' (foresters') context of use only as a consequence of the difficulties experienced as the geovisualizers introduce the foresters to "the concept and principles of exploratory data analysis and to the use of visualization for systematic and comprehensive data exploration."

Figure 1.5, adapted from Isenberg et al (2008), encapsulates what happened in the cases of Slocum et al (2003) and Andrienko et al (2006). The human-centered approach begins properly at point "A" and follows the arrows through establishing context of use and requirements *before* designing software and evaluating it with prospective users. Starting from point "B" with a pre-conceived design which is then offered to users may indeed result in generating information about context of use and requirements as in cases of Slocum et al (2003) and Andrienko et al (2006). Reflection on and sharing of their initially unexpected experiences is insightful - but this was not their primary aim when they commenced their research.

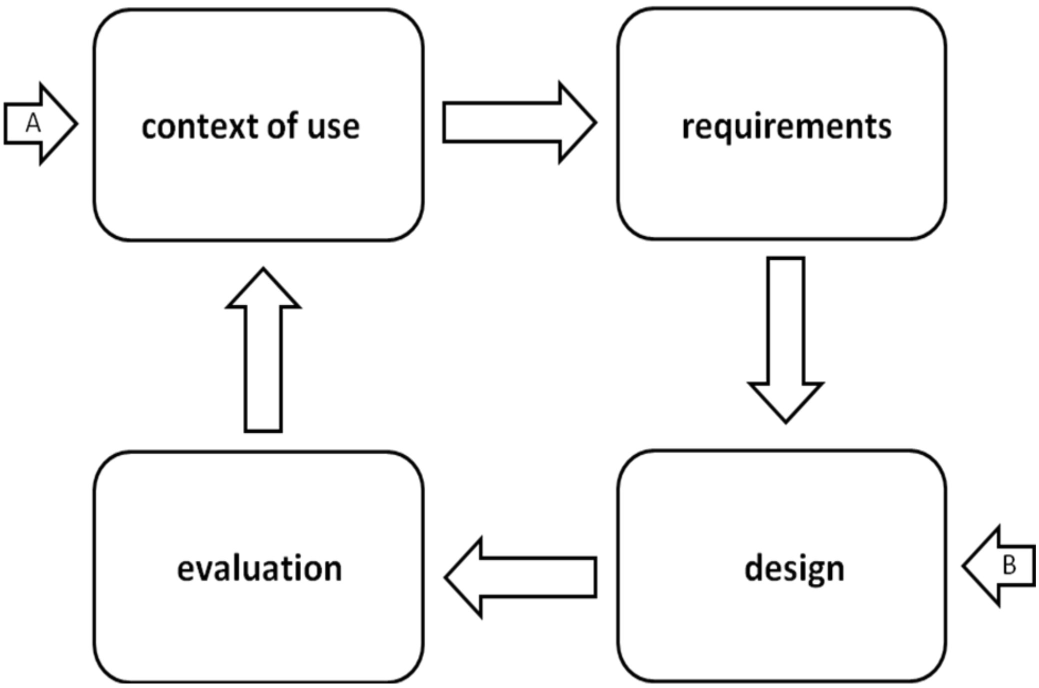

Figure 1.5: Progress through the four parts of ISO 13407. Alternative start points.
Adapted from Isenburg et al., 2008

The inherent problem with "starting at B" is that it is extremely difficult to go back and revisit the decision to begin with a pre-existing application. Cooper (1999) comments that "After code is written it is very difficult to throw it out. Like writers in love with their prose, programmers tend to have emotional attachments to their algorithms" and Cohen et al (2004) that "Many developers view their code as an extension of themselves and thus take it personally when someone finds fault with it."

Human-centered school followed – UCD v HCI

I have adopted an ecumenical approach to different schools of the human-centered approach in this thesis. There appears to be no published research on whether either geovisualization, or information visualization, or both domains should follow a particular HC school such as user-centered design or human-computer interaction, and, if so, which one.

Research metrics

The richness of human-centered methods means that results from research with them in visualization domains can be interpreted and employed in a number of different ways. Research can yield information about **data** (the results of exploration); about an **application** (bugs, design issues, iterations of prototypes); about the **interaction** between users and application (usefulness, effectiveness, satisfaction and so on, as described in (Nielsen, 1993)) and about meeting higher level-related **user goals** (hypothesis generation, ideation, and the like). No literature exists on exploring the motivations of visualization researchers systematically in respect of these differences.

1.3.2 ANALYSIS OF VISUALIZATION LITERATURE WITH HUMAN-CENTERED APPROACHES

Table 1.2 summarises relevant research in these domains since 2001, when ICA COVVE met to identify a research agenda for geovisualisation (MacEachren and Kraak, 2001), up to 2008. These were selected from a bibliographic database containing nearly 900 references. Each reference was coded according to a scheme that recorded type of visualization (information visualization or geovisualization), if present, and a range of human-centered categories. Selection was made using the criteria [information visualization OR geovisualization] AND [contextual/participatory OR requirements OR scenarios OR task analysis OR prototyping OR design OR ethnographic OR workplace studies OR card sorting OR content analysis OR case study OR experts OR usability OR evaluation]. The resulting selections are tabulated in Table 1.2 with categories formed from the issues raised by visualization researchers.

The categories are:

- Visualization research area (G=geovisualization, I=information visualization)
- ISO13407 activity (C=Context of Use; R=Requirements; D=Design; E=Evaluation)
- Human-centered framework (if any) (H=human-computer interaction; U=used-centered design; E=usability engineering)
- Subject types employed (S=students; V=visualization/spatial experts; D=domain experts; U=usability experts; O=others; X=unknown) plus their number
- Start point for research (A=with Context; B=with Design)
- Whether a Case Study approach is adopted (Y = yes; N = no)
- Whether own/real user data was used (if appropriate) (Y = yes; N = no)
- Whether own/real user tasks was used (if appropriate) (Y = yes; N = no)
- Metric for the research (C = computer focus (bugs, design issues, usability problems, prototype problems etc.); I = interaction focus (usefulness, usability, user satisfaction etc.), G = user goals focus (hypothesis generation, ideation etc.), D = data focus)

Paper, year and summary of contents	Vis field	ISO13407 category				HC Frame -work	Subject types & number	Start point	Case study	User /real data	User /real tasks	Metric
		C	R	D	E							
Ahonen-Rainio and Kraak (2005) employ user testing of three forms of geospatial metadata - sample maps, a parallel coordinate plot, star glyphs - describing six road datasets with 12 defense force personnel experts.	G				✓	U	D (12)	B	N	N	N	I
Allendoerfer et al (2005) use a modified form of the cognitive walkthrough (a heuristic evaluation method) to examine a knowledge domain visualization tool with student users.	I				✓	H	S (6)	B	N	N	N	C
Andrews (2006) employs eight tasks of four different kinds on each of four hierarchy browsers with user testing on computer science students.	I				✓		S (32)	B	N	N	N	C
Andrienko et al (2002) test five exploratory interactive techniques employing Common GIS, a geovis application, with nine domain expert users over two stages plus a follow-on study of 200 internet-based, self-selected people, to determine learnability, memorability and satisfaction.	G				✓	U	D (9) O (200)	B	N	N	N	I
Andrienko et al (2006) report the difficulties engendered when context of use is not explored fully between geovisualization experts and domain experts (in this case foresters) when considering a geovis prototype.	G			✓		U	D (-)	B	Y	Y	Y	I
Bhowmick et al (2008) conduct an expert evaluation of a geovis application (a new cancer atlas) using four different groups of distributed users (graduate students, cartographic and InfoVis experts, health domain experts, health officials) to suggest improvements to its usability and assess its utility for public health professionals.	G				✓	U	S (7) V (4) D (7) O (6)	B	Y	N	N	C I D

Paper, year and summary of contents	Vis field	C	R	D	E	HC Frame -work	Subject types & number	Start point	Case study	User /real data	User /real tasks	Metric
Buering, Gerken and Reiterer (2006) conduct user tests of two interaction designs for displaying scatterplots on a PDA. Subjects are 23 students plus one domain expert (an engineer)	I				✓		S (23) D (1)	B	N	N	N	I
Chung et al (2005) use interviews to define hypothetical crime scenarios created in association with domain experts to build tasks to evaluate use of a visualization tool for crime analysis with tests using students.	G				✓	H	S (30) U (6)	B	N	Y	Y	C I
Demšar (2006) reports three case studies with geovisualization applications that explore (variously) paper and computer-based prototypes, focus groups, interviews, questionnaires, heuristic evaluation; working with a domain expert; formal evaluation and exploratory usability testing.	G	✓		✓	✓	H	D (1) S (6)	A B	Y	Y	Y	D
Demšar (2007a) evaluates an existing geovis application with data on emergency response employing GIS domain experts with both formal user testing and free exploration.	G				✓	H	D (6)	B	N	Y	N	C I
Demšar (2007b) uses testing with students to exploring freely the well-known iris data set (including its spatial aspect) using an existing geovis application.	G				✓	H	S (6)	B	N	N	N	I G D
Edsall (2003) evaluates geovis applications using students and epidemiologist domain specialists performing formal user and free exploration tests with emphasis on results from interaction logs.	G				✓	U	S (31) D (6)	B	Y	Y	Y	H
Faisal et al (2008) apply qualitative methods during a small user test of an InfoVis system to understand users' experiences of interaction with visualization tools; user observation is used.	I				✓	U	X (7) X (6)	B	N	N	N	I G
Griffin (2006) observes/evaluates domain expert tool use patterns in a geovis environment and then tests if these can be replicated in other domains to understand how viewing geovisualizations helps to construct new knowledge about a modelling problem.	G				✓		D (18)	B	Y	Y	Y	G

Paper, year and summary of contents	Vis field	C	R	D	E	HC Frame -work	Subject types & number	Start point	Case study	User /real data	User /real tasks	Metric
Heer, Card and Landay (2005) set computer programmers three tasks to create visualizations using an InfoVis toolkit and then interviewed them about the experience.	I				✓		S (4) V (1) O (3)	B	N	N	N	I
Henry and Fekete (2006) select important tasks to explore a visual table and evaluate how data layout affects user understanding using a mixture of sketching, closed and open questioning.	I			✓	✓		S (-) V (-) D (-)	B	N	N	N	C
Hetzler and Turner (2004) train 24 domain experts to use an application to visualize text document content, questioning them before and after to gain insight into application improvements.	I				✓	H	D (24)	B	N	Y	Y	C G
Isenberg et al (2008) describe three case studies that use a mix of field studies involving observation, interviews and questionnaires, participatory observation and paper-based prototyping.	I	✓		✓		U	D (10)	A	Y	Y	Y	C G
Kobsa (2004) describes user testing of students with tasks measuring completion times, correctness and satisfaction supplemented with video recording, to compare five tree visualization systems.	I				✓	H	S (48)	B	N	N	N	I
Koua, MacEachren and Kraak (2006) evaluate effectiveness/user performance, usefulness, and user reactions to a geovis application by formal user testing using a task taxonomy.	G				✓	H	V (20)	B	N	N	N	I
Marsh (2007) conducts a range of experiments investigating the effectiveness and validity of candidate techniques for geovis in research and education involving field studies, diary keeping, interviews, focus groups, diary keeping, affinity diagramming, paper prototyping, user testing.	G	✓	✓	✓	✓	H	S (-) V (-) E (-) O (-)	B	C	N	N	C I G
Mazza (2006) evaluates an information visualization course management system using a focus group of 5 people plus a controlled experiment with 6 course instructors as subjects supported by a semi-structured interview.	I				✓	H	V (6)	B	N	-	-	C

Paper, year and summary of contents	Vis field	C	R	D	E	HC Frame -work	Subject types & number	Start point	Case study	User /real data	User /real tasks	Metric
Perer and Shneiderman (2008) use a MILC approach to engage four individual researchers with their own data to work with a prototype application mixing statistics and social networking visualization. Approaches are interview with expert; tailored prototype use; observation; summative interview.	I			✓		H	D (4)	B	Y	Y	Y	G
Robinson (2007) builds on earlier work with epidemiologists and employs tasks for user testing of a geovis application with a digital prototype, plus focus groups as well as post experience focus sessions.	G			✓		U	D (5)	B	Y	Y	Y	D G
Robinson et al (2005) interview a domain expert (an epidemiologist) to determine needs for a geovis application after an initial prototype had been built, and also conduct prototyping sessions with 17 students with user tasks, some free exploration and focus groups for feedback.	G			✓		U H	S (17) D (1)	B	Y	Y	Y	C
Seo and Shneiderman (2006) describe three case studies working with domain expert individuals in molecular biology, statistics and meteorology who were trained then observed and interviewed about their use of a hierarchical clustering application in order to determine benefits and suggest improvements particularly for a rank-by-feature. A follow-up email survey of 57 users complemented the case studies.	I			✓		H	D (3) O (57)	B	Y	Y	Y	C
Siirtola and Raiha (2006) perform user tests to compare the performance of a parallel coordinate plot InfoVis application with data access using SQL with IT professionals.	I				✓		D (16)	B	N	N	Y	C I
Slocum et al (2003) develop prototype geovis software; iterate after input from domain experts; conduct expert evaluation and decision maker evaluation.	G			✓	✓	U	D (6) U (4) O (4)	B	N	Y	N	C I

Paper, year and summary of contents	Vis field	C	R	D	E	HC Frame -work	Subject types & number	Start point	Case study	User /real data	User /real tasks	Metric
Slocum et al (2004) provide a user evaluation of MapTime, a software package for exploring spatiotemporal data associated with point locations using animation and small multiples with novice/experienced geography students and also domain experts.	G				✓		S (12) D (5)	B	N	N	N	C
Suchan (2002) undertakes a field study of Census analysts, interviewing them to understand their data, tools and analysis tasks in order to gain insight into geovis tools that would be useful for a future application.	G	✓				E	D (3)	A	Y	-	-	-
(Tobon (2002) conducts user testing among GIS experts of acceptance and problems encountered with a combined InfoVis and GIS system using free exploration, open tasks.	G				✓		D (9)	B	N	N	N	C I
Tory and Moller (2005) use heuristic evaluation by 3 HCI graduate students (usability experts) of a volume rendering tool, plus user exploration of a data exploration application with two usability, a volume visualization, a graphic design expert, and one end user.	I				✓	H	U (3) U (2) V (1) O (2)	B	N	N	N	CI
Valiati, Freitas and Pimenta (2008) report MILC studies. Users explore to determine questions, insights, discoveries and usability problems. Techniques include task & experience pre- and post-experience interviews, plus free exploration of tool prototypes.	I	✓		✓			D (3)	B	Y	Y	Y	C G

Table 1.2: Relevant research in visualization with a human-centered approach, 2001-2008

An analysis of the 30 research papers and three PhD theses (hereafter both referred to collectively as "papers") in Table 1.3 – eighteen from a geovisualization, and fifteen from an information visualization perspective - reveals insightful details on ISO13407 approaches.

	Geovisualization (n=24)	Information visualization (n=18)
Context of Use	3	2
Requirements	1	0
Design	6	5
Evaluation	14	11

Table 1.3: Categorisation of the 42 instances of ISO 13407 approaches, by visualization domain

The preponderance of research that focuses on usability evaluation is not unexpected, but a concern, as indicated by Greenberg and Buxton (2008) and Faisal et al (2008). Of the 33 papers, only six have embraced more than one HC approach - three from geovisualization: Demšar (2006); Marsh (2007); Slocum et al (2003), and three from information visualization: Henry and Fekete (2006) ; Isenberg et al (2008); Valiati, Freitas and Pimenta (2008). There are 42 instances of ISO13407 categories approaches appearing in the 33 papers. Table 1.3 shows that the distribution of research by ISO 13407 categories is very similar in both domains and that evaluation approaches are by far the most common, with little research on requirements approaches, and relative little on context of use.

As discussed in Section 1.2.2, this thesis does not adhere to any particular HC tradition. It is instructive to examine which schools of human-centered thought are followed by the researchers in the 33 papers, and this is shown in Table 1.4. 30% of the papers do not indicate a particular tradition. Usability engineering is referenced only once, with thirteen referencing HCI (evenly split between visualization domains) and nine UCD. Of the latter, seven are from geovisualization practitioners and just two from information visualization. There is no explanation in the literature why information visualisation researchers appear to favour HCI over UCD. If the details of the 33 papers are examined, what the followers of one school of HC are doing by way of techniques is fairly similar to what followers of another school are doing - or indeed what researchers who espouse no school at all are doing.

	Geovisualization (n=18)	Information visualization (n=15)
Usability engineering	1	0
Human-computer interaction	6	7
User-centered design	7	2
HCI and UCD	1	0
Not stated	3	6

Table 1.4: Categorisation of 42 ISO 13407 approaches by visualization domain

As Robinson (2007) and Marsh and Dykes (2008) indicate, whether or not students are subjects in human-centered visualization research is important. The distribution of the use of different types of subject (student, visualization expert, domain expert, usability expert and others) in geovisualization and information visualization is shown in Table 1.5. Use of multiple types of subject is common (53 instances from 32 papers (one paper does not indicate subject type). Domain experts are the most widely used as subjects with students second. There are no material differences between the two visualization domains in this area.

	Geovisualization (n=32)	Information visualization (n=21)
Student	8	6
Visualization expert	3	4
Domain expert	14	7
Usability expert	3	1
Other	4	3

Table 1.5: Distribution of subject type by visualization domain

In Table 1.6, the incidence of the ISO 13407 categories is tabulated against the distribution of subject types. The total number of instances in the table is 68, as both variables can occur with multiple values in an individual paper. Domain experts are the most common subject type in total and in all ISO 13407 categories, except Requirements. Usability experts are the least common subject type employed.

(n=68)	Context of Use	Requirements	Design	Evaluation
Student	1	1	2	9
Visualization expert	1	1	2	7
Domain expert	4	0	8	13
Usability expert	1	1	2	3
Other	1	1	4	6

Table 1.6: Distribution of subject type by ISO 13407 category

The total number of subjects in papers is given in Table 1.7. Given that multiple types of subject are employed in 16 out of 32 papers, where there are often multiple interactions with different groups of subjects, these results will tend to overstate the size of a subject numbers in an individual interaction, but they are nevertheless instructive. There are no great differences between the two visualization domains. Total subject numbers show that qualitative methods are employed predominantly, and only in a few cases are attempts made to use quantitative methods to calculate statistically robust results. This is in line with Marsh and Dykes (2008).

	Geovisualization (n=16)	Information visualization (n=14)
Up to 5	3	2
6-10	4	5
11-15	1	1
16-20	4	1
21+	4	5

Table 1.7: Distribution of total subject numbers by visualization domain

Out of the 33 papers, 30 describe work which had a pre-existing visualization application as its focus, showing the dominance of a techno-centric approach to HC in both geovisualization and information visualization domains.

Table 1.8 illustrates whether researchers characterise their research as being a case study or not. Geovisualization researchers are more likely to take a case study approach than information visualization researchers are.

	Geovisualization (n=18)	Information visualization (n=15)
Case study approach	9	4
No case study approach	9	11

Table 1.8: Research described as a "case study" by visualization domain

Table 1.9 shows whether researchers characterise their research as being a case study or not by ISO 13407 category. Studies including evaluations are predominantly not case studies, and as might be expected, a case study approach is far more likely in studies involving Context of Use, Requirements or Design, than Evaluation. The single example to capture requirements as part of the geovisualization research (Marsh, 2007), used geovisualization and HCI experts and not domain experts representative of possible end users. This indicates that Requirements with end users is an under-investigated area in a geovisualization context.

	Context of Use	Requirements	Design	Evaluation
Case study approach	5	1	9	5
No case study approach	0	0	2	20

Table 1.9: Research described as a "case study" by ISO 13407 category

Table 1.10 demonstrates the distribution of papers taking a case study approach by year of publication. It shows an increase in the latter part of the 2001-8 period of the literature review. This is the only variable considered that shows an effect over time.

Year	2002	2003	2004	2005	2006	2007	2008
Case study approach	1	1	0	1	4	2	4
No case study approach	3	1	3	4	6	2	1

(n=33)

Table 1.10: Distribution of case study approach by date of publication

Plaisant (2004) stresses the importance of real datasets and realistic tasks. Table 1.11 shows how often datasets with user data (or real domain data relevant to a prospective user) and user tasks (or real domain tasks relevant to a prospective user) are employed, by visualization domain. The incidence of the use of real/user data is less in information visualization than in geovisualization, although this does not extend to real/user tasks where the visualization domains have a similar pattern.

	Geovisualization (n=17)		Information visualization (n=14)	
	Real/user	No real/user	Real/user	No real/user
Data	9	8	5	9
Tasks	7	10	6	8

Table 1.11: Research based on real/user data and tasks

Table 1.12 illustrates the use of real/user data by ISO 13407 category and shows that studies including evaluations predominantly do not contain real/user data, indicating the potential for their incorporation and for engaging with domain experts earlier in the process of application creation. Studies including Context of Use and Design are more likely to contain real/user data. The pattern for real/user tasks is strikingly similar and is not shown for that reason.

	Context of Use	Requirements	Design	Evaluation
Real/user data	3	0	9	7
No real/user data	1	1	2	17

Table 1.12: Use of real/user data by ISO 13407 category

The 33 research papers provide information about the kind of information researchers are seeking when they interact with experts, prospective users or test subjects. As discussed in Section 1.3.1 , these divide into four types of information: about data; about the application; about the interaction between users and application; and about meeting higher level related user goals. A number of researchers seek information across these four types, and 48 instances occur in the 33 papers. Their distribution is shown in Table 1.13 and appears to be fairly even across the two visualization domains. However, information visualization has a larger proportion of research focused on seeking application information than on data and interaction. Both domains have researchers working to elicit information about users' high-level goals.

	Geovisualization (n=26)	Information visualization (n=22)
Data	4	1
Application	8	10
Interaction	9	6
High level goals	5	5

Table 1.13: Type of information focus of researchers by visualization domain

1.4 DISCUSSION

In this chapter I define and explore the characteristics of geovisualization - its spatial nature, inheriting issues of spatial dependence and spatial heterogeneity, using multiple components of both spatial and non-spatial origin to achieve the exploratory goals of its users, and where interactivity has become a key component. I give evidence for the close parallels between geovisualization and information visualization in terms of common techniques, tools and challenges. I outline the nature of the challenge facing geovisualization researchers in engaging with human-centered methods.

I outline the development of human-centered approaches such as usability engineering, user-centered design and human-computer interaction, and differentiate them from parallel software engineering developments. I consider the ISO standard on human-centered approaches and tabulate the tools that are appropriate for each of the four parts of the standard – context of use, requirements, design and evaluation.

I elicit and discuss issues considered key in recent geovisualization and information visualization literature - the paucity of visualization researchers adopting a human-centered approach; lack of breadth of human-centered approaches in visualization research; over-reliance on evaluative methods by visualization researchers; need for case studies conducted *in vivo* with real users; need for real data and real tasks; the approach to application design and collaboration by visualization researchers; choice of subjects and the number used in visualization research; the techno-centered approach in visualization and how its adoption conflicts with a human-centered one.

I analyse 33 individual papers from geovisualization and information visualization that feature human-centered methods and draw a number of conclusions. These are: just six papers embrace more than one ISO 13407 approach with evaluative approaches far and away the most used; different HC schools of thought are cited by visualization researchers but reasons for preferring one over another are not given, although there are no substantive differences in HC tools and techniques employed in practice; domain experts are the most widely used as subjects with students second and usability experts used least; subject numbers were generally low with 70% of studies employing 20 or fewer people and just less than half ten or fewer; 90% of papers have a pre-existing visualization application as their focus, showing the dominance of a techno-centric approach; 40% of studies adopt a case study approach and this is more common in geovisualization than information visualization; studies including evaluations are predominantly not case studies; the incidence of visualization HC-related case studies increases broadly over time; the use of real/user data is less in information visualization than in geovisualization, but the use of real/user tasks is the same in both domains; evaluatative approaches predominantly do not contain real/user data or tasks; information visualization has a larger proportion of research than geovisualization focused on seeking knowledge about applications themselves.

Human-centered methods have been accepted and adopted by some geovisualization and information visualization researchers, but these are in the minority. Few researchers have tackled the issue of the extent to which human-centered approaches are valid in the field of geovisualization, especially in the particular parts of ISO 13407 dedicated to context of use, requirements and design. These are under-represented in the literature and represent a good focus for research. The aims and research questions of this thesis follow from this rationale.

1.5 AIMS AND RESEARCH QUESTIONS

The aim of this thesis is to be able to give geovisualization application designers:
a roadmap of which of these human-centered approaches are and are not useful,
an indication of under what circumstances they are useful and when they are not, and
suggestions as to where some changes or alternatives to standard human-centered approaches may help.
The research therefore aims to:

- determine how the nature of geovisualization affects the application of human-centered techniques in the context of creating geovisualization applications for prospective users.
- determine the applicability of different human-centered techniques when used in the context of creating geovisualization applications.

The research aims to explore these questions:
RQ1: How well do human-centered approaches concerned with establishing context of use work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of establishing context of use from prospective users?

RQ2: How well do human-centered approaches concerned with establishing requirements work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of establishing requirements from prospective users?

RQ3: How well do human-centered approaches concerned with mediating between the geovisualization domain and prospective users work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of mediation between the geovisualization domain and prospective users?

RQ4: How well do human-centered approaches concerned with design work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of design of geovisualization applications with prospective users?

RQ5: How well do human-centered approaches concerned with prototyping work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of prototyping of geovisualization applications with prospective users?

RQ6: How well do human-centered approaches concerned with the process of prioritising possible improvements to geovisualization applications work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of prioritising possible improvements to geovisualization applications with prospective users?


thesis
prototypes
domain
information
section
method
ISO13407
CONTEXT
CASE
HC
APPROACH
sketching
aloud
disorder
REQUIREMENTS
qualitative
ANALYSIS
possible
evaluation
Software
think
used
Leicestershire
members
gathering
Digital
CHAPTER
geovisualization
APPROACHES
active
particular
Experts
user
LCC
HUMAN-CENTERED
Paper
geovis
questionnaires
number
libraries
detail
nature
tasks
research
design
different
using
tools
many
points
prospective
local
AHP
within
PROTOTYPING
observation
understanding
DATA
SUBJECTS
one
crime
prototype
process
example
improvements
also
may
time
card
team
way
EVIDENCE
exploration
techniques
ISO
STUDY
METHODS
VALIDITY
interviews
application
sorting
subject
reduction
planning
users
USE
CDR
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Department
development
studies
work
Figure
range
Establishing
determine
evaluate
transcription
DESIGNING
COLLECTION

2 METHODOLOGY

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ABSTRACT

This chapter sets out the methodological framework for the thesis, setting out the details of the research focus that is based on 'human centered approaches' as the focus. The research is differentiated from the process of building a geovisualization application, which is merely the vehicle by which the research aims are investigated. Research is conducted *in vivo*, comprises a series of individual cases studies that link to form the thesis, relies on both qualitative and quantitative analysis, although with a preponderance of the former.

A section on human centered approaches surveys those have been widely employed and focuses on the approaches that will be assessed in the context of geovisualization in this thesis and the reasons for their inclusion and the exclusion of others. Human centered approaches and their associated data gathering and data analysis techniques are defined, explained and their strengths and weaknesses outlined. This leads to a section on drawing conclusions and assessing validity.

A section on accessing the subjects and data describes how UK local authority workers in Leicestershire County Council (LCC) were selected and taken through the process of constructing a geovisualization application using the ISO13407 template, in order to learn about the use of a range of human-centered approaches. The subjects' domains of interest are crime and disorder reduction and public libraries, respectively. The case study approach to the research is outlined in a final section, relating it to the taxonomy of Gerring (2004). Individual case studies interlink to give good coverage of three of the four areas of ISO13407 (context of use, requirements and design) with design covered in special detail.

RESEARCH FOCUS

Clearly, the 'subjects' of this thesis are the human centered approaches. These HC approaches can only be studied *in vivo*, in the context of real prospective users of geovisualization, situated in their work environment. These users are not the subject of the thesis. The construction of geovisualization applications is not the point of this thesis. Prospective users' requirements for a geovisualization application, their views on what should be included in a design, how various prototypes might be improved and which improvements should be prioritised are only of interest in so far as they cast light on how the HC approaches that are being deployed work in a geovisualization context. Figure 2.1 shows in diagrammatic form the orthogonal orientation of the research aims and the stages on the path to the construction of a geovisualization application. In this research, a range of human centered approaches is employed to understand users and their requirements, to design and build prototypes and to evaluate final products with end users.

This range of HC approaches has arisen and been honed in a range of conditions – different organisations with different kinds of people engaged in different activities encountering new products and applications, some an extension of what they already knew, but many novel. The HC approaches have been applied to products, services and applications. The last of these range from the simple (such as the content of a webpage), to others more complex, such as spreadsheets or drawing programs. And while these HC approaches are successful in helping designers (as is clear by their continued use and development), it is unclear how effective they are in the case of very different applications such as those from the field of geovisualization.

As outlined in Chapter 1, geovisualization applications aim at exploration, have high complexity, multiple components usually linked interactively, and a focus on spatial data with its attendant issues of scale, spatial dependence and heterogeneity. Geovisualization exploration can involve long task times, tasks that are hard to define, are broad in nature, have uncertain ends and are difficult to learn and master. Geovisualization tools are various, complex and unfamiliar to most potential users, present data in novel ways, are linked together and combined in a way that makes cognitive demands on users. Given the range of tool possibilities, there is unlikely to be a perfect match between a particular geovisualization application and a prospective user's context and data, and application tailoring may be needed. For all these reasons, some HC approaches may work differently or not at all in geovisualization. I hypothesise that the nature of geovisualization will mean that some of the established HC approaches will be deficient, may work differently and/or that modifications may be necessary to them. The research aims outlined in section 1.5 are a consequence of this hypothesis.

Figure 2.1 shows the final view of the methods reflected on during the course of the research. As HC approaches were evaluated and results obtained, new methods were considered and assessed as a consequence, reflecting the iterative approach adopted, where progressive findings suggest new hypotheses (Silverman, 2000).

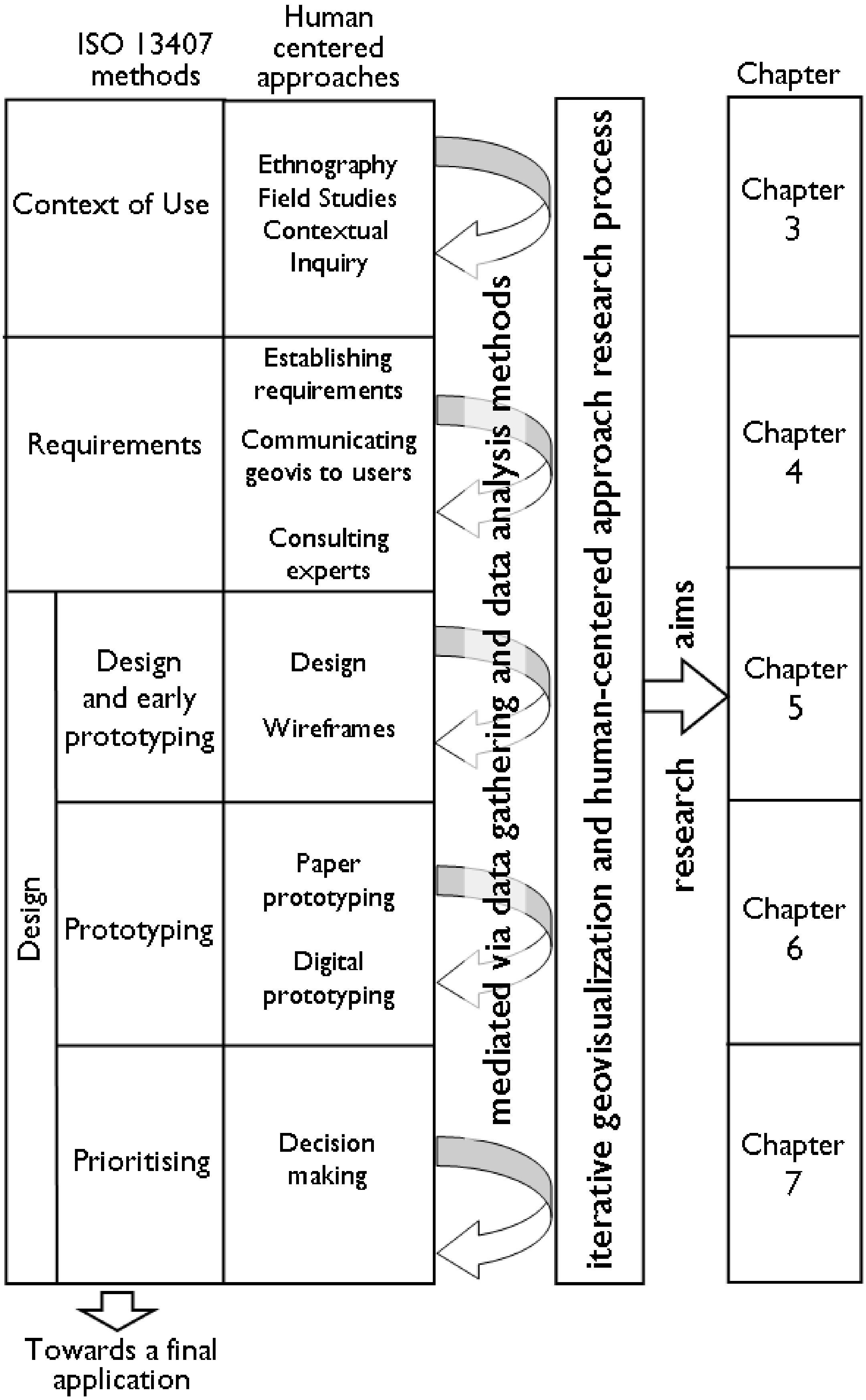


Figure 2.1: Outline of thesis methodology showing the iterative nature of the research and analysis methods and the orthogonal orientation of the research aims and application building

The methods used to gather and analyse data about the interaction between the HC approaches and prospective users in a geovisualization context are not complex, and are accessible, with care, to a non-social scientist. They generate a mixture of qualitative and quantitative data. While some of the approaches may be the subject of long-running and continuing debate in sections of the social and qualitative research communities, their use, with care, does not depend on adopting a particular doctrine or position. To reiterate, the subjects of this research are the approaches and methods, not people. This is not social research. The data gathering methods are observation, interviews, studying documents, card sorting, questionnaires, sketching and think aloud. The data analysis methods are transcription, coding and content analysis, and section 2.2 describes each in detail.

I work with subjects over time by necessity (because the HC approaches under consideration are tied into the process of developing an application via the ISO 13407 route). I aim:

- to journey through the HC approaches associated with the ISO 13407 methods, beginning with Context of Use and proceeding through Requirements to Design with subjects who might be prospective users of a geovisualization application.
- at each point along the ' journey', to look at the information I receive from the various ways in which I have gathered data (such as observation, questionnaires, interviews as so forth – described in detail in Section 2.2.2).
- to consider how well each HC approach has worked and determine what are the issues or problems, and to determine whether the approach worked as well as standard HC literature suggests.
- If there have been issues or problems, to determine whether there is any evidence that they can be ascribed to the nature of geovisualization (complex, spatial, and so forth – see Section 1.1.1) or not.
- If a geovisualization component is present, to assemble the evidence and assess its strength and validity. To determine factors such as whether the same thing is seen in different subjects, different domains, and whether the same thing is seen in different methods of data gathering and whether they support each other or not. To determine if there is any quantitative evidence that can be used to triangulate with the qualitative evidence. To determine what alternative explanations there are other than 'the nature of geovisualization'.

2.1 HUMAN-CENTERED APPROACHES

The different HC, data collection and analysis approaches are described below, with fuller details in the Methods sections of Chapters 3-7.

2.1.1 SCOPING HUMAN-CENTERED METHODS

Maguire (2001) considers and tabulates 34 methods and activities that support ISO 13407 under the four ISO headings of context of use, requirements, design and evaluation - see Figure 2.2. Maguire's categorization has some weaknesses. General methods are not differentiated from specific data collection techniques. In particular, some tools categorised under one heading can be used in a number of different contexts. For example, while "satisfaction questionnaires" may be a useful method for summative evaluation, questionnaires in general can be employed to help determine context of use, to elicit user requirements, or as a way to establish user reactions after prototyping. The same is true of interviewing and focus groups. User testing can occur in prototyping as well as in evaluation. Scenarios can be employed in both requirement and design activities (Alexander and Maiden, 2004). Experts can be consulted as part of design or evaluation, and so forth. Nevertheless, Maguire's tabulation can serve as the basis for a categorisation of HC methods.

The approaches and data collection focii of this thesis are shown in Figure 2.3 that adapts and expands Maguire's list by

- excluding ISO13407 Evaluation approaches, as they have already received disproportionate interest from geovisualization researchers (see Chapter 1 Discussion).
- separating out the methods themselves (section 2.1.2) from the means of data gathering (section 2.1.3). The means of qualitative data analysis and the underpinning process of verifying and drawing conclusions (Miles and Huberman, 1994) are also considered separately (section 2.1.4)
- supplementing it with additional approaches from the mainstream HC field developed since Maguire's publication - for example, sketching (Tohidi et al., 2006)
- supplementing it with additional approaches that are human-centered but which are outside the mainstream - for example, using decision-making methods for prioritising
- splitting the "Design" category into three sub-categories to reflect the broad scope of this topic and make the thesis structure more tractable

- excluding methods that are more appropriate to larger scale and scope projects that are infeasible given the resources available in a the context of this study. ISO 13407 itself indicates that "small projects…could…use a more limited range of methods and techniques to support the activities." (ISO, 1999)

ISO 13407 Human-centered design methods			
Context of use	**Requirements**	**Design**	**Evaluation**
Identify stakeholders	Stakeholder analysis	Brain storming	Participatory evaluation
Context of use analysis	User cost-benefit analysis	Parallel design	Assisted evaluation
Survey of existing users	User requirements interview	Design guidelines and standards	Heuristic or expert evaluation
Field study/user observation	Focus groups	Storyboarding	Controlled user testing
Diary keeping	Scenarios of use	Affinity diagram	Satisfaction questionnaires
Task analysis	Personas	Card sorting	Assessing cognitive workload
	Existing system/ competitor analysis	Paper prototyping	Critical incidents
	Task/function mapping	Software prototyping	Post-experience interviews
	Allocation of function	Wizard of Oz prototyping	
	User, usability and organisational requirements	Organisational prototyping	

Figure 2.2: ISO 13407 methods for human-centered design (Maguire, 2001)

The approaches and data collection methods in Figure 2.3 are supported by data analysis. The majority of data in this thesis are qualitative in nature, and analysis is carried out using transcription, coding and qualitative data analysis (QDA) techniques. These in turn are underpinned by approaches for generating meaning and testing and confirming findings (Miles and Huberman, 1994). Section 2.2.2 defines and discusses these HC approaches, data collection and analysis methods in detail.

ISO 13407 Human-centered design methods					
	Context of use	**Requirements**	**Design**		
			Design+early prototyping	**Prototyping**	**Prioritising**
	(Chapter 3)	**(Chapter 4)**	**(Chapter 5)**	**(Chapter 6)**	**(Chapter 7)**
APPROACH	Ethnography Field Studies Contextual Inquiry	Establishing Requirements: with a template by consulting experts using a scenario by communicating geovisualization to users with a lecture Existing system/ competitor analysis	Design Wireframing	Paper prototyping Digital prototyping (With different protocols – user testing with active intervention, and free exploration)	Analytic hierarchy process 0-1 knapsack process
DATA COLLECTION	Observation	Interviews	Observation	Observation	Observation
	Interviews		Interviews	Interviews	Interviews
	Studying documents	Studying documents	Studying documents		
	Card sorting	Card sorting			
		Questionnaires		Questionnaires	Questionnaires
		Sketching	Sketching	Think aloud	

Figure 2.3: ISO 13407 approaches and data collection methods for human-centered design in this thesis (adapted from Maguire, 2001)

2.1.2 HUMAN-CENTERED APPROACHES AND DEFINITIONS

2.1.2.1 CONTEXT OF USE

Ethnography, Workplace Studies and Contextual Inquiry

ISO 13407 considers context of use in which a system is used, to embrace "The characteristics of the users, tasks and the organizational and physical environment" (ISO, 1999). Relevant user characteristics include "knowledge, skill, experience, education, training, physical attributes, habits, preferences and capabilities"; tasks is self-explanatory and includes overall goals; the environment includes "hardware, software and materials to be used" plus "relevant characteristics of the physical and social environment". However, ISO 13407 does not mention explicitly gathering user data or examining its attributes as part of considering context of use.

To determine these characteristics, HC approaches have evolved, with most tracing their origins to the anthropological domain of ethnography. However, "there is no one method of ethnographic analysis" (Hughes, Randall and Shapiro, 1992), and Anderson (1994) sees "a misunderstanding of ethnography's role in social science" and that "getting to know users and their knowledge and practices" requires "just minimal competency in interactive skills and a willingness to spend time, and a fair amount of patience." Ethnographic fieldwork is discussed as a research technique for user-centered design by Sperschneider and Bagger (2003). Nilsson (2005) describes 'workplace studies' as "a vague, tentative neologism that denotes a wide range of studies: some ethnographic, others design-oriented, and still others carried out under the methodological auspices of something that only, on the face of it, has any familiarity with ethnographic fieldwork." Dourish (2006) summarises "the dominant view of ethnography is that it provides to HCI researchers a corpus of field techniques for collecting and organizing data…for investigations that are, to some extent, in situ, qualitative, or open-ended…the term is often used to encompass particular formulations of qualitative research methods such as Contextual Inquiry".

Contextual Inquiry (CI) is an influential methodology for understanding users' context of use, and part of a wider approach to organising a customer-centered design approach called Contextual Design (Beyer and Holtzblatt, 1997). They describe the core premise of CI as "go where the customer works, observe the customer as he or she works, and talk to the customer about the work." CI has four principles that operate within a framework of a master/apprentice model of working in the field and "guide the adoption and adaptation of the technique – context, partnership, interpretation and focus" (Beyer and Holtzblatt, 1997). (Dourish, 2006) describes CI as aimed at "those with neither the training nor the time to conduct ethnographic work; instead, it provides a set of methods whereby designers can move out from laboratory settings to the real world as a basis for design inspiration." Wixon et al (2002) say "Contextual Inquiry…offer[s] quick and simple ways to match the methods to resources and needs… if your team has limited resources and time, you might simply perform a Contextual Inquiry with a limited number of users."

The outline of ethnography and workplace studies, above, indicates adopting a pragmatic approach to establishing subjects' Context of Use is appropriate.The influential Contextual Inquiry is selected as methodology of choice to study the LCC subjects (Chapter 3) and act as an enabler to the work in later chapters. Results from this are unlikely to impact directly on the geovisualization domain, although clearly the spatial aspects of subjects' work, data, current tools and expertise is relevant.

A variant ethnographic approach is autoethnography. "Autoethnography…is an autobiographical genre of writing and research that displays multiple layers of consciousness…Usually written in first-person voice…Social scientists often use the term now to refer to stories that feature the self or that include the researcher as a character" (Ellis, 2004). Autoethnography's strength is as a research framework to describe, analyse and criticise the process of creating the initial designs for a geovisualization application, and it is explained in more detail in Chapter 5, section 5.2.3.

2.1.2.2 REQUIREMENTS

Establishing Requirements with a template

Preece, Rogers and Sharp (2002) define a requirement as "a statement about an intended product that specifies what it should do and how it should perform". The process whereby such statements are generated participates in the general plethora of human-centered nomenclature – "requirements gathering, requirements capture, requirement elicitation, requirements analysis, and requirements engineering" (Preece, Rogers and Sharp, 2002) are all used. The term "establishing requirements" does not assume that requirements are already 'out there' and is preferred. Central to such a process is engagement with and questioning of prospective users. Robertson (2001) suggests techniques to do this by ‘trawling’ for requirements using a template for guidance in the form of the Volere Requirements Specification Template (Robertson and Robertson, 2006a; Robertson and Robertson, 2006b), one of a number of different methods for establishing requirements, compared by Nikula and Sajaniemi (2002). The Volere template is used to elicit requirements for a new geovisualization application from one group of LCC subjects, and is described in more detail in Chapter 4, section 4.2.1.

Consulting experts using scenarios

Robertson (2004) indicates that "There are a number of situations when scenarios are the best tool for requirements discovery". Scenarios "support reasoning about situations of use, even before those situations are actually created. Scenarios are stories. They are stories about people and their activities" (Carroll, 2000). Alexander and Maiden (2004) identify 14 different scenario types and their varied uses through the development of a product or application. Scenarios capture particular user tasks or behaviours that "allow exploration and discussion of contexts, needs and requirements." (Preece, Rogers and Sharp, 2002) They are therefore a method of communicating the context of users to others. So a different approach to establishing requirements is to use the understanding gained of prospective users and their context of use, and represent that - using a 'scenario' as a data gathering tool - to a group of experts (in this case geovisualization experts) with the intent that they will collectively be able to propose geovisualization solutions (or at least narrow down the solution space).

A body of literature around consulting experts has grown up around the desire to elicit information from experts within fields such as the construction of expert systems and giving evidence in legal proceedings. Another area where a HC approach has been widely used to consult experts is via inspection methods such as cognitive walkthrough and heuristic evaluation (Nielsen and Mack, 1994). These approaches are employed in the Evaluation stage of ISO 13407 which is not the subject of this research. Scenarios should be distinguished from personas, another HC approach. Personas are "hypothetical archetypes of actual users" (Cooper, 1999) and are one approach used to drive the design process. The process of consulting geovisualization experts with a scenario is described in more detail in Chapter 4, section 4.2.2.

Communicating geovisualization to prospective users using a lecture

van Wijk (2006) suggests attempting to bridge the gap between visualization researchers and domain experts by "educat[ing] domain experts to define visualizations themselves." This prompts employing a different human-centered approach to the potential difficulties implicit in establishing requirements where prospective users might be confronted with novelty, such as geovisualization tools. Employing a lecture on geovisualization tools and interactions has the potential to narrow the gap between prospective users and the geovisualization domain. The understanding of prospective users is gauged using the data collection technique of card sorting, and their input to the process of establishing requirements via sketching. Both card sorting and sketching are described in Section 2.2.2, and the lecture communication process in more detail in Chapter 4, section 4.2.3.

Existing system/competitor analysis

In the context of this thesis, to speak of existing or competitor (geovisualization) systems is inappropriate, but the body of existing geovisualization applications represents a source for possible requirements and design ideas. Maguire (2001) states "evaluating an existing or competitor version of the [user's] system can provide valuable information about the extent to which current systems meet user needs and can identify potential usability problems to avoid in the new system. Useful features identified in a competitor system can also be fed into the design process." Davis (1982) suggests some analysts "prefer to delay its use until after their primary analysis method has provided an initial set of requirements" and to employ it as "a secondary method for deriving requirements….to avoid being overly influenced by the concreteness of the existing system". This approach is used to determine the choice of application for one group of LCC subjects and is described in Chapter 6, section 6.2.2.3.

2.1.2.3 DESIGN AND EARLY PROTOTYPING

ISO13407 (ISO, 1999) advises that there exists "a substantial body of scientific knowledge and theory from ergonomics, psychology, cognitive science, product design and other relevant disciplines that can indicate potential design solutions. Many organizations have internal user interface style guides, product knowledge and marketing information…" Visualization, geovisualization and their antecedents have additional contributions to make to the design process by virtue of work in graphics (Bertin, 1983; Tufte, 1986), exploratory data analysis (Tukey, 1977) and visualization heuristics (Shneiderman, 1996) plus the extensive cartographic heritage and its extensions to geographic information science and to geovisualization. This is outlined in Chapter 5, sections 5.2.1 and 5.2.2. While these antecedents assist, the actual process of designing relies on creativity by the designer, and the practicalities of creating designs for a geovisualization application is considered using an autoethnographic approach, described in section 5.2.3.

Wireframing

There is a need to communicate early designs to prospective users to assess their utility and acceptability, and an appropriate approach is to use a "wireframe" prototype. The approach was first outlined by Tullis (1998). A wireframe is designed to provide an early approximation to a software idea" and they "range from the classic sketch on the back of a napkin to full design comprehensives used for documenting the design for programmers." (Arnowitz, Arent and Berger, 2007). Greenberg and Buxton (2008) contend that such early designs are "…best considered as sketches. They illustrate the essence of an idea, but have many rough and/or undeveloped aspects to it. When an early design is displayed as a crude sketch, the team recognizes it as something to be worked on and developed further." Wireframe designs are discussed further in Chapter 5, section 5.2.3 and their communication to LCC subjects in section 5.2.4.

2.1.2.4 PROTOTYPING

Typically, a more realistic prototype is developed from a wireframe before committing resource and emotion to writing code (Cohen et al., 2004). ISO13407 suggests a number of approaches including paper prototyping, software prototyping and Wizard of Oz prototyping (see Figure 2.2).

Paper prototyping

Paper prototyping (Rettig, 1994) is described by Snyder (2003) as a "variation of usability testing where representative users perform realistic tasks by interacting with a paper version of the interface that is manipulated by a person 'playing computer' who doesn't explain how the interface is supposed to work." With paper prototyping, "complex or subtle interaction usually can't be simulated perfectly" (Snyder, 2003), but the technique does have the potential to show a range of functionality at an earlier stage of development than coded prototypes.

Digital interactive prototyping

A software, or digital interactive, prototype is "almost a digital version of the paper prototype. Except, digital prototypes can range from a series of low-fidelity, narrative click-through screens for quick visualization of a design concept to a high-fidelity interactive portrayal of an evolved design…there can be some gaps in a digital prototype that cannot be solved like they can be on a paper one." (Arnowitz, Arent and Berger, 2007)

Protocols for prototyping: user testing with active intervention and free exploration

Both paper and digital interactive prototypes represent appropriate HC approaches to communicate aspects of a design to prospective users after eliciting feedback from wireframes. Prototypes can be employed in number of different ways.They can be used to evaluate applications as part of controlled usability testing protocol, or to iterate and improve an application in the final stages of the process described in ISO 13407, for example to record times to complete certain tasks. Maguire (2001) makes it clear that usability testing is also appropriate "during the early stages of prototype development", and in this respect Dumas and Redish (1999) refer to **active intervention** "in which a member of the [research] team sits in the room with the participant and actively probes the participant's understanding of what is being tested." North (2006) argues that user tests do not have to be task based and "researchers [should] observe what insights users gain on their own", prompting the notion of an open, **free exploration**, protocol with prototypes. Both user testing with active intervention and free exploration protocols are used with a digital interactive prototype to explore LCC subject ideation with a geovisualization prototype. More on paper and digital interactive prototyping, and on these protocols, is in Chapter 6, section 6.2.

2.1.2.5 PRIORITISING

Prioritising: Decision support

Once prospective users work with prototypes, suggestions for improvements are likely to arise which will need to be prioritised for development. Some form of decision support approach is required to facilitate prioritisation, and the Analytic Hierarchy Process (AHP) (Saaty, 1977) is a well established (Wasil and Golden, 2003) method to achieve this. The AHP relies on participants' scoring preferences of every possible pair of combinations from a list, and constructs an overall score and ranking for every list member. The AHP process also produces a quantitative measure of user consistency in pairwise scoring. The AHP has been applied in many domains including the prioritizing of software development (Karlsson and Ryan, 1997). I evaluate the AHP as a human-centered way to prioritise possible improvements to a geovisualization prototype, with details in Chapter 7, sections 7.2.1 and 7.2.2.

Prioritising: constrained by cost

An extension of using decision support techniques such as AHP to include the effects of cost constraint - the developer time and effort required to implement particular improvements in this case - is desirable to ground prospective user priorities. Karlsson and Ryan (1997) suggest an approach that employs developer costs and AHP results (without any further interaction with prospective users) to achieve this (see Chapter 7, section 7.2.2). An alternative, human-centered, approach would engage with prospective users so that costs could be included in the prioritisation process. Such an approach would be to employ the classic 0-1 knapsack problem that concerns the filling of a knapsack with items from a population of n, each with value v_j and weight w_j (j = 1 to n) such that the knapsack contains the maximum value subject to a fixed weight limit. The '0-1' refers to the uniqueness of the items (no duplicates). I evaluate a human-centred approach using the structure of the 0-1 knapsack problem to maximise the value of possible improvements to a geovisualization prototype for prospective users the constraint of different value improvements (v_j) and different developer costs (w_j) where developer costs are limited. Details are in Chapter 7, sections 7.2.3 and 7.2.4.

2.1.3 DATA GATHERING APPROACHES

Data gathering approaches are the ways human-centered methods are mediated between subjects and the researcher. In this work, these are:

Observation

Observation of a subject(s) can occur from a range of perspectives, from that of an insider to an outsider. Ethnography is one extreme of the insider approach, spending extended time with subjects; participatory observation implies intensive involvement but not with the same degree of commitment to spending time with subjects as ethnography. At the other end of the spectrum is 'quick and dirty' observation: "[observation that] can occur anywhere, anytime…ways of finding out what is happening quickly and with little formality." (Preece, Rogers and Sharp, 2002) The advantage of observation is the ability to provide insights unobtainable by other methods, but the major disadvantage is that it is time-consuming – there is a clear insight obtained/time taken trade-off here.

Interviews

Kahn and Cannell (1957) describe interviewing as a "conversation with a purpose". Fontana and Frey (1994) identify different kinds of interview - structured, semi-structured and unstructured - by degree of adherence to a pre-prepared set of questions. Interviews are a quicker way to extract information than observation, but still time-consuming and interviews can be artificial and intimidating to the subject.

Studying documentation

Preece, Rogers and Sharp (2002) recommend the study of user documentation as "procedures and rules are often written down in manuals..." and for "getting some background information on the work. It also doesn't involve stakeholder time, which is a limiting factor on…other techniques." User documentation - particularly in the form of reports produced (that is, the outputs of users rather than instructional inputs to them) – also has the potential to reveal a good deal about users' data, how they explore and analyse it, and methods of representation and presentation, that appear germane in a visualization context. Literature on domains that is external to the organisation studied - for example, government and academic publications - may also aid understanding of users' situations and provide insight into whether subjects' contexts can be generalised.

Card sorting

Nielsen and Sano (1995) describe card sorting as "a common usability technique that is often used to discover users' mental model of an information space." Hannah (2005) reviews different card sorting methodologies comprehensively. Typically, index cards with marked items are given to subjects to be sorted, either within a closed format (where the categories are given to the subjects in advance), or an open format (where subjects can select their own categories). The method is "fairly quick and easy to create once the list or candidate terms have been established." (Arnowitz, Arent and Berger, 2007)

Questionnaires

"Questionnaires are a well-established technique for collecting demographic data and users' opinions. They are similar to interviews and can have closed or open questions…can reach many people with low resource" but "design is crucial…[and] responses may not be what you want" (Preece, Rogers and Sharp, 2002) There has been research into producing standardised questionnaire instruments for user satisfaction and interaction design. Among them are the Questionnaire for User Interface Satisfaction (QUIS) (Chin, Diehl and Norman, 1988), and the Software Usability Measurement Inventory (SUMI) that measures software quality from a user perspective (Kirakowski, 1994).

Sketching

Sketches allow for "a dialog between the sketch and the viewer (even if the viewer is the sketcher himself) that facilitates better understanding of the problem and in turn generation of new ideas" (Tohidi et al., 2006), who also find that "enabling users to sketch their ideas facilitated reflection, and provided a rich medium for discovery and communication of design ideas…[in] a fraction of the time and money required to facilitate, record, and analyze the think aloud protocol, interview and questionnaire data." Buxton (2007) emphasises the difference between sketches and prototypes - "sketches dominate the early ideation stages [of design], whereas prototypes are more concentrated in the later stages". Sketching has been used in an information visualization context - Craft and Cairns (2006) discover that "the use of sketching as an integral part of a collaborative design process aided creativity, communication, and collaboration." While sketches can be swift to elicit and execute, they can be difficult to interpret.

Think aloud

The think aloud method (Ericson and Simon, 1984) consists of "asking people to think aloud while solving a problem and analysing the resulting verbal protocols." (van Someren, Barnard and Sandberg, 1994) There is no agreement on a standard way of conducting think aloud, and Nielsen, Clemmensen and Yssing (2002) review the "many names, uses and modifications of the classical think aloud technique". Boren and Ramey (2000) find "there is no detailed description in the usability literature of theoretically motivated rules of practice for thinking aloud; some sources cite a theory, but then suggest theoretically inconsistent procedures. Most others do not describe think-aloud practice at all." The quality of information obtained via the think aloud method can be affected in a number of ways. Where subjects are asked to report their thoughts simultaneously with their actions, then this disturbs their cognitive processes, particularly when they are prompted or questioned about their actions. Where the think aloud is retrospective, then the process gathers information about the subject's interpretation of a past event rather than a current event. Retrospective think aloud entails the possibility that events will be forgotten, or even falsely reported. Reilly and Inkpen (2007) discuss the implications for validity of a study of subjects' recall in the context of geovisualization.

2.1.4 DATA ANALYSIS APPROACHES, VALIDITY AND EVIDENCE

Miles and Huberman (1994) define [qualitative] analysis as consisting of "three concurrent flows of activity: data reduction, data display, and conclusion drawing/verification. Data reduction refers to the process of "selecting, focusing, simplifying, abstracting, and transforming the data that appears in written-up notes or transcriptions." Data display is "an organized, compressed, assembly of information that permits conclusion drawing and action." Conclusion drawing is "beginning to decide what things mean…noting regularities, patterns, explanations, possible configurations, causal flows and propositions". Verification is the testing of "the meanings emerging from the data" for "plausibility,…sturdiness, 'confirmability' – that is, their validity."

This research employs transcription and coding as the primary vehicles for data reduction. Data display is achieved using methods such as content analysis and qualitative data analysis tools such as networks and keyword-in-context analysis. Conclusion drawing is achieved using tactics on generating meaning (Miles and Huberman, 1994) and validity from their advice on testing or confirming findings. These data analysis approaches and tools are outlined below.

Transcription

Atkinson and Heritage (1984), quoted in McLellan, MacQueen and Neidig (2003), "stressed that the production and use of transcripts are 'research activities' and should not be approached as merely a 'technical detail' that precedes analysis." Lapadat and Lindsay (1999) review the place of transcription in qualitative inquiry and Mergenthaler and Stinson (1992) outline seven principles for developing transcription rules. Transcription is a process that takes considerable time, and practical guidance is essential. Bird (2005) outlines the practicalities of transcription; Maloney and Paolisso (2001) review transcription software; and Zick and Olsen (2001) transcription voice recognition software. After a number of iterations I chose to use Start-Stop transcription software (HTH Engineering Inc., 2004) and a foot pedal with Dragon Naturally Speaking version 9 voice recognition software (Nuance Commuications Inc., 1993-2004) to produce transcripts from my own voice repeating the words of all subjects for this thesis. I transcribed all audio recordings – that task was not outsourced to a third party. Pragmatically, cost is an issue, but more importantly, going through the often laborious transcription process gives the researcher an immersion in, and good understanding of, the textual data.

Coding

Lewins and Silver (2007) define qualitative coding as "the process by which segments of data are identified as relating to, or being an example of, a more general idea, instance, theme or category." They identify the factors that influence code development as research aims; methodology and analytic approach; amount, kinds and sources of data; level and depth of analysis; constraints and research audience", and "codes can be generated from themes or topics; ideas or concepts; language or terminology used in the data." Lewins and Silver (2007) differentiate between codes generated "inductively (from salient aspects identified in the data)" and "deductively (according to predefined areas of interest)" but caution that "the two methods should not be viewed as dichotomously opposed or mutually exclusive."
Crittenden and Hill (1971) provide a relevant study of validity in coding. Robinson (2007) provides an example of an approach to coding information in a geovisualization context and comments that "It is also common to allow schemes to emerge after an initial pass through the data." This approach is used in this research.

Content analysis

"Content analysis is a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use" (Krippendorff, 2003). Particular techniques employed in the thesis are calculating word frequencies and showing keywords-in-context (KWIC) (Luhn, 1960) using concordance software (Hüning, 2003) and constructing networks of relationships between concepts using qualitative analysis software (Muhr, 2004). While content analysis provides useful quantitative information (like the number of times a word is used), it provides the starting point to understand subjects, their context and to generate meaning.

Conclusion drawing - generating meaning

Miles and Huberman (1994) summarise tactics for generating meaning that are pragmatic and independent of any particular theory of social research:

> "Noting patterns, themes, seeing plausibility, and clustering help the analyst 'see what goes with what.' Making metaphors, like the preceding three tactics, is a way of achieving more integration among diverse pieces of data. Counting is also a familiar way to see 'what's there.' Making contrasts/comparisons is a pervasive tactic that sharpens understanding. Differentiation sometimes is needed, too, as in partitioning variables. We also need tactics for seeing things and their relationships more abstractly. These include subsuming particulars into the general, factoring, an analogue of a familiar quantitative technique; noting relationships between variables; and finding intervening variables. Finally, how can we systematically assemble a coherent understanding of data? The tactics discussed are building a logical chain of evidence and making conceptual/theoretical coherence."

Validation – testing or confirming findings

Brewer (2000) identifies three forms of validity – external, internal and ecological. Internal validity "refers to the truth value that can be assigned to the conclusion that a cause-effect relationship between an independent variable and a dependent variable has been established within the context of the particular research setting." External validity "refers to the question of whether an effect (and its underlying processes) that has been demonstrated in one research setting would be obtained in another setting, with different research participants and different research procedures." Ecological validity is "whether an effect has been demonstrated to occur under conditions that are typical for the population at large."

In this research, I work with small numbers of people from LCC over extended periods employing an *in vivo* approach, the rationale for which is made in Chapter 1. I assure **ecological validity** by studying effects in conditions that are typical of those under which the methods being studied are used. **Internal validity** is about establishing the link between methodology, data gathering and analysis, results and conclusions, and this chapter sets out the way that is done. Two groups of LCC domain experts are used for some parts of the research to permit comparisons, but the long-term nature of the research with small teams of individual domain specialists, and the particular datasets and tasks, inevitably means that the research focus is narrow. In terms of **external validity**, conclusions drawn may be limited in scope, but will nevertheless contribute to work with similar studies from other domains that will, over time, build a broader evidence base.

The necessity for conducting work *in vivo* introduced 'ecological reality' at many points in the study that challenge the researcher. Examples include a subject absenting himself or herself at short notice; another who resigned their job and moved to a new organisation; and a subject who spontaneously invited their manager to observe the research process.

Miles and Huberman (1994) summarise tactics for testing or confirming findings, many of which are employed in this research:

> "Data quality can be assessed through checking for representativeness, checking for researcher effects on the case, and vice versa; and triangulating across data sources and methods. These checks also may involve weighting the evidence, deciding what kinds of data are the most trustworthy. Looking at "unpatterns" can tell us a lot. Checking the meaning of outliers, using extreme cases, following up surprises, and looking for negative evidence are all tactics that test a conclusion about a 'pattern' by saying what it is not like. How can we really test our explanations? Making 'if-then' tests, ruling out spurious relationships, replicating a finding, and checking out rival explanations are all ways of submitting our beautiful theories to the assault of brute facts… The tactic of getting feedback from informants concludes our list"

Evidence

Evidence, where it is present, is graded from "some" to "good" to "strong" to "very strong" according to a points scheme:

- Observed in multiple subjects (2 points); in one subject (1 point)
- Observed in CDR and Libraries, or observed in one case at two or more points in time (2 points); in just one case at one point in time (1 point)
- Observed in multiple methods – for example think-aloud *and* questionnaire (2 points); in just one method (1 point)

This gives a possible scale from three to six which is scaled to the "some" to "very strong" range above, so "very strong" evidence requires six points, "strong" evidence five points, "good" evidence four points, and "some" evidence requires 3 points.

2.2 ACCESS TO SUBJECTS AND DATA

This research was a consequence of a successful application for funding to the Engineering and Physical Sciences Research Council (EPSRC) and Leicestershire County Council (LCC) that aimed to advance research into the use of innovative human-centered techniques for designing and evaluating software for the visualization of multivariate geographic information. The research is applied in the context of a requirement for evidence-based policymaking in LCC.

The largest employer In the UK is local government, which provides work for 2.9m people (Office of National Statistics, 2008). Research conducted in this domain has the prospect to reflect the situation of a large number of similar cases throughout local government in the UK. Leicestershire County Council is an administrative county local authority responsible for providing a range of services (Local Government Association, 2006) to the 610,000 residents of Leicestershire. The services include trading standards, libraries and museums, primary and secondary education, building and planning controls, waste management, leisure and tourism, road maintenance, and social care services. Leicestershire represents a "typical case" administrative county – it has a mix of rural and urban areas and its population is the median for administrative counties. Where Leicestershire is a "special case" is in respect of the quality of its service - it is ranked 4* (4* is the highest rating, and only 37% of English councils are so rated) and "strongly improving" (also the highest rating, achieved by only 16% of English councils and by only five administrative counties)(Audit Commission, 2008). If novel geovisualization tools and techniques are to be accepted in UK local government, then LCC is a candidate to be among the early adopters and therefore represents a good choice of place to conduct this research.

LCC has five operational departments plus a Chief Executive's Department. Within the latter lies the LCC Research and Information Team, and it was from here that the interest came to support the PhD research. The team in turn sits within a wider unit concerned with Information Management, Policy, Research and Information. This unit has two major roles, that of coordinating activities of other departments linking that to the work of partner organisations; and that of community leadership (for example, community partnerships; local authorities as leaders for their communities). The Research and Information Team (Leicestershire County Council, 2006) consists of about 14 individuals and has a number of functions. The majority of these support a range of partnerships, focusing on issues such as the maintenance of a business database, compiling business and economic information, analysing and producing reports on crime and disorder, and balancing changing demography and land availability.

Although LCC has primary responsibility for a number of services, many are delivered in partnership with other agencies and groups. For example, the Leicestershire Rural Partnership comprises 19 member organizations ranging from the East Midlands Development Agency, district and borough authorities, and Leicestershire Constabulary, to the Countryside Agency as well as LCC. In many partnerships, LCC takes a lead role, often providing administrative support. Complex funding arrangements between partners are the norm. This mode of partnership working implies satisfying a range of different interest groups with different competences, constituencies and priorities, and is fundamental to the way in which many research officers within LCC approach their work.

As a part-LCC sponsored study, access to possible subjects was facilitated within LCC by a senior research officer (R) who had produced reports of high graphical sophistication, embracing the design guidelines of (Tufte, 1986) in particular, and had participated in previous geovisualization work in LCC by a City University London masters student (Attilakou, 2005). R can be considered as a "lead user" for geovisualization within LCC. von Hippel (1986) describes lead users as "users whose present strong needs will become general in a marketplace months or years in the future…moreover, since lead users often attempt to fill the need they experience, they can provide new product concept and design data as well." R was able to facilitate access to people, data and resources within LCC in an effective way, giving a significant advantage to this research, not replicated in other ecological situations. Other researchers, without such an introduction to, and support from, within a subject organisation, would have had to work harder to overcome issues of access and trust.

It is intended that the human subjects of this research should be real workers in local government, in their own contexts, who might be prospective users of a geovisualization application. They should use their own data and tasks, as suggested by Plaisant (2004) and Shneiderman and Plaisant (2006). Many visualization researchers have engaged with domain experts or leaders in their field - see Table 1.8. In order to go beyond this rather narrow category, I wished to choose subjects who were typical of low to middle-ranking managers working with data within a large employer; subjects who were competent in their own domain but not leading experts. Two units contributed subjects for the study cases making up this thesis – one a team of crime and disorder reduction (CDR) analysts, the other a public libraries marketing and communities services team. They represent 'divergent' cases with many differences. While both possess large and rich datasets, the CDR analysts have complete access to their data and sophisticated tools (such as geographic information system software) and experience and skills with which to explore and extract information. The public library subjects have difficulty accessing their data, limited tools (no GIS for example), and a limited tradition of, and skills for, data exploration. Chapter 3 gives a fuller description of these teams as part of understanding "context of use". A further group of subjects - nine 'geovisualization experts' - are consulted in an attempt to determine requirements for a geovisualization prototype.

In order to comply with City University London's code of ethics, whenever subjects had their words recorded or were asked to take part in evaluations of prototypes, they received a written statement. This contained the title of the project, the name and contacts details of the principal researcher, the purpose of the study, the inclusion criteria, the benefits of participating, the process to be followed, a request for consent, and a statement on confidentiality. Subjects were asked to sign a consent form that outlined the conditions of use, when the data would be destroyed and that informed them of their right to withdraw at any time without penalty. A sample copy of a written statement and consent form are in the Appendix to this thesis.

2.3 CASE STUDY APPROACH

The research is structured as a series of case studies conducted at different scales that link together in a cohesive way. The case study research design typology (Table 2.1) is taken from Gerring (2004) and offers a critique of the “definitional morass” of the approaches to case study research to date and offers an alternative definition and typology.

		Temporal variation	
		No	**Yes**
Spatial Variation	None (1 unit)	[Logically impossible]	(a) Case study I
	Within-unit	(b) Case study II	(c) Case study III
	Across-unit	(d) Cross-sectional	(e) Time-series cross-sectional
	Across- and within-unit	(f) Hierarchical	(g) Hierarchical time-series

Table 2.1: Research Designs: A Covariational Typology (from Gerring, 2004)

Gerring (2004) defines a case study as “an intensive study of a single unit for the purpose of understanding a larger class of (similar) units” and defines terms as follows: “A ‘population’ is comprised of a ‘sample’ (studied cases), as well as unstudied cases. A sample is comprised of several ‘units’, and each unit is observed at discrete points in time, comprising ‘cases.’ A case is comprised of several relevant dimensions (‘variables’), each of which is built upon an ‘observation’ or observations.” Gerring indicates that “the most important point is that all these terms are definable only by reference to a particular proposition and a corresponding research design….[an item] may function as a case, a unit, a population, or a case study.”

Table 2.2 shows the sections of the research arranged according to Gerring’s typology and related to the sections of ISO13407, the human-centered and data collection processes, and the research questions. The research follows this case study approach with one exception, which is section 5.2.3 of Chapter 5 that uses autoethnography, and for which the 'case' is the researcher himself.

Case No.	ISO 13407 methods	Population	Sample	Units	Objective	Research Design	Research Question
1	**Context of use** (Ethnography, field studies and contextual inquiry using observation, interviews, study of documents and card sorting)	Prospective geovis application users in LCC Research and Planning department	Crime & Disorder reduction (CDR) Team	CDR team members	Understand CDR subjects context of use; evaluate ISO13407 approaches	(b) Case Study II	**RQ1**
2		Prospective geovis application users in LCC Libraries and Community Services department	Library Team	Library team members	Understand Library subjects' context of use; evaluate ISO13407 approaches		
3		Prospective geovis application users in LCC Research and Planning department and geovis experts	Crime & Disorder reduction (CDR) Team and geovis experts	Library and CDR teams and one geovis expert	Compare CDR and a geovisualization expert view of context of use	(d) Cross-sectional	
4	**Requirements** (Establishing requirements with a template; communicating geovisualization to subjects with a lecture; consulting geovisualization experts with a scenario, using observation, interviews, card sorting, sketching and questionnaires)	Prospective geovis application users in LCC Research and Planning department	Crime & Disorder reduction (CDR) Team	CDR team members	Establishing requirements with Volere template sections; evaluate templating approach	(c) Case Study III	**RQ2**
5		Geovisualization experts	Nine geovis experts	Individual geovis experts	Response to CDR scenario; geovis tools, and interactions suggested; evaluate scenarios approach	(b) Case Study II	**RQ3**
6		Prospective geovis application users in LCC Research and Planning department	Crime & Disorder reduction (CDR) Team	CDR team members	Communicating geovis to CDR subjects via lecture to elicit requirements; evaluate this approach		
7	**Design and early prototyping** (wireframes)	Prospective geovis application users in LCC Research and Planning department	Crime & Disorder Reduction team	CDR team members	Understand CDR subject reactions to different wireframe designs; evaluate wireframing.	(b) Case Study II	**RQ4**

Table 2.2 (1 of 3): The sections of this research showing case study details by type according to Gerring (2004)

Case No.	ISO 13407 methods	Population	Sample	Units	Objective	Research Design	Research Question
8	**Prototyping** (paper and digital interactive prototypes, with users tests with active intervention protocol and free exploration protocol, using observation, interviews, questionnaires and transcribed and coded think aloud)	Prospective geovis application users in LCC Research and Planning department	Crime & Disorder reduction (CDR) Team	CDR team members	Evaluate reactions to conducting tasks using a paper prototype using user testing with active intervention	(b) Case Study II	RQ5
9					Evaluate reactions to conducting tasks using a digital prototype using user testing with active intervention		
10					Compare CDR subject reactions to conducting tasks using paper and digital prototypes using user testing with active intervention	(d) Cross-sectional	
11					Evaluate reactions to with free exploration protocol using a digital prototype	(b) Case Study II	
12					Compare CDR subjects' experiences of conducting tasks using user testing with active intervention and free exploration protocols using a digital prototype	(d) Cross-sectional	
13		Prospective geovis application users in LCC Libraries	Libraries Team	Libraries team members	Evaluate Library subject reactions to conducting free exploration using a digital 'prototype'	(b) Case Study II	
14		Leicestershire County Council (LCC) departments	Libraries and Research & Planning departments	Libraries and CDR teams	Compare CDR and Library subjects' experiences of conducting free exploration using digital prototypes	(d) Cross-sectional	

Table 2.2 (2 of 3): The sections of this research showing case study details by type according to Gerring (2004)

Case No.	**ISO 13407 methods**	Population	Sample	Units	Objective	Research Design	**Research Question**
15	**Prioritising** (analytic hierarchy process (AHP) using possible improvements from results of prototyping plus observations, interviews and transcribed and coded think aloud). Use of 'value v cost' plot inspection and a human-centered approach to determine priorities for possible improvements constrained by cost of development	Prospective geovis application users in LCC Research and Planning department	Crime & Disorder reduction (CDR) Team	CDR team members	Evaluate CDR user reactions to using the analytic hierarchy process (AHP) to prioritise improvements to a prototype	(b) Case Study II	**RQ6**
16		Geovisualization experts	Geovis experts	Individual geovis expert / developer	Evaluate Geovis expert / developer reactions to using the AHP to prioritise improvements to a prototype		
17		Prospective geovis application users in LCC Research and Planning department	Crime & Disorder reduction (CDR) Team	CDR team members plus individual geovis expert / developer	Compare CDR and geovis expert experiences to using the AHP to prioritise improvements to a prototype	(d) Cross-sectional	
18				CDR team members	Evaluate 'value v cost' plot inspection to determine priorities for possible improvements constrained by cost of development	(b) Case Study II	
19					Evaluate a human-centered approach to determine priorities for possible improvements constrained by cost of development		
20					Compare 'value v cost' plot inspection and human-centered approach to determine priorities for possible improvements constrained by cost of development	(d) Cross-sectional	

Table 2.2 (3 of 3): The sections of this research showing case study details by type according to Gerring (2004)

2.4 DISCUSSION

In this chapter I set out the methodology for the thesis. I outline the nature of the research, looking to see how well particular human-centered approaches work in a geovisualization context. In order to see the effect of HC approaches on human subjects, these subjects wish to explore spatial data and hence might find use for a geovisualization application. They are taken through a number of ISO13407 stages from understanding contexts of use, eliciting requirements and designing and prototyping an application. The research aims of the thesis are realised through the study of human subjects using HC approaches in a geovisualization application context. The subjects and geovisualization applications are a means to an end, and not the end themselves - this is not social research.

I set out a number of HC approaches associated with ISO13407 (Figure 2,2) and indicate the ones I research in this thesis (Figure 2.3), which I omit, and the reasons for the choices. I identify and include novel HC methods that emerge from findings as the research progresses, indicating its iterative nature. The HC approaches are defined and discussed in detail in section 2.2.2 along with the main data gathering and data analysis methods. I focus on widely used, robust, pragmatic and effective data gathering and analysis methods that do not depend on adopting the precepts of any particular qualitative or social school of thought.

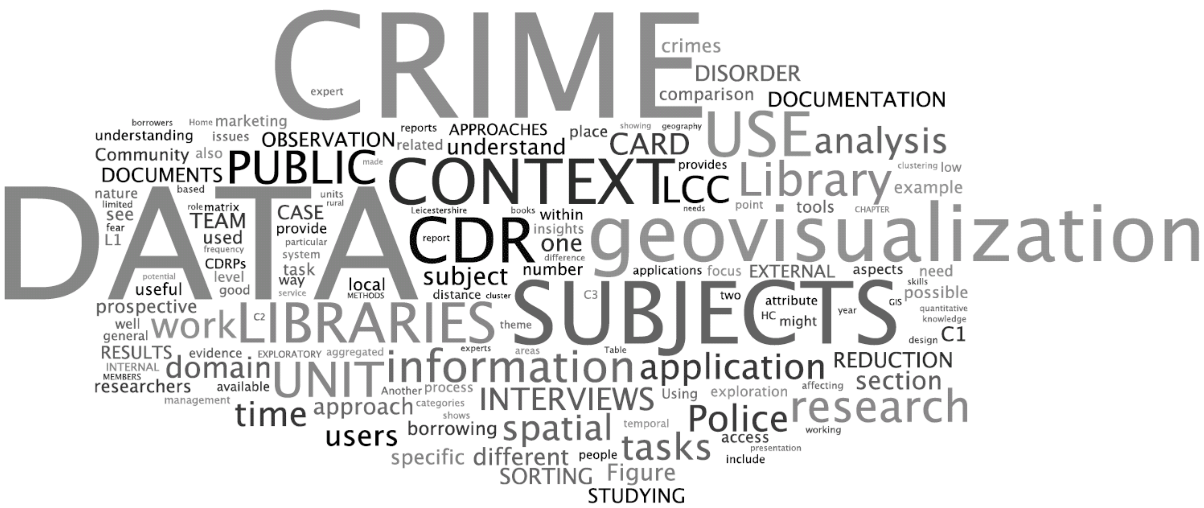
I set out the ways in which I make sense of the data and how I weigh evidence and draw conclusions that are valid, defining what I mean by 'validity'. The strengths of this research are its ecological and internal validity and the contribution it makes to add to parallel studies in other subject domains to construct a broader evidence base.

The research data is mainly qualitative in nature, although there are useful quantitative contributions that enable a triangulated approach and strengthen evidence.

I describe how I obtain access to the subjects used in this thesis who are UK local authority workers in Leicestershire engaged in crime and disorder reduction and in the marketing of public libraries. These subjects, between them, represent two diverse groups in terms of their skills, tools, access to and facility with their key data, their experience of exploring data and prior exposure to visualization. Ethical considerations in dealing with subjects in test situations or in recording words are outlined along with information given to subjects and consents sought. The importance and advantages of having a local contact to provide access to the subjects is commented upon.

The thesis relies upon individual case studies of different types using the taxonomy of (Gerring, 2004). The case studies cover three of the four areas of ISO13407 (context of use, requirements and design) with design covered in special detail to embrace designing, prototyping and priotising.

The next Chapter - Context of Use - outlines the results obtained covering the first of the ISO13407 groups.


CRIME
DATA
geovisualization
SUBJECTS
CONTEXT
CDR
PUBLIC
LIBRARIES
UNIT
USE
Library
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application
research
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Police
tasks
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3 CONTEXT OF USE

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ABSTRACT

In this section, I explain that the methodology for the choice of prospective users for a possible geovisualization application is not well explored in the literature. Using a UK local authority as an example, I obtain a viable understanding of prospective users of geovisualization, propose variables that are important in choosing prospective users, and select teams to work with in this research. Four data gathering approaches (interviews observation, studying documentation and card sorting) and a number of data analysis approaches (frequency counts, keyword-in-context, network analysis, scenarios) are used with a Contextual Inquiry methodology to study how well they perform in the context of subjects seeking to use a geovisualization application. Keyword-in-context analysis and extending studying documents to external as well as internal documents yield good insights. An important finding is the crucial role of acquiring, understanding and manipulating domain attribute and spatial data and metadata, an area not highlighted in ISO13407. Another finding relates to the usefulness of card sorting to give quantitative information for subjects' conceptual thinking about tasks. This yields quantitative comparisons between subjects' sorts, and subjects plus a geovisualization designer card sort, permitting comparison between them.

3.1 INTRODUCTION

Research Question 1 asks: **How does the nature of geovisualization affect the selection of prospective users for a geovisualization application and the information we need to gather to understand them and, their context?**

The literature on geovisualization is replete with examples of applications built for, and tested on, people who are either prospective users or proxies for them. Rarely, if ever, does the author indicate how the choice of prospective user domain is made, or outlines the process whereby the choices were winnowed down to the domain selected. In a human-centered approach to building an application, the choice of prospective user domain prefaces other considerations. Clearly the researcher must choose the domain – but the reasons for that selection should be soundly based and transparent.

Geovisualization is complex, and its practitioners have sought to concentrate their efforts mainly on domains where the problem space is one that is consonant with the toolset the practitioner believes he can bring to bear, and where users are engaged primarily in exploratory tasks, such as in academia and among information professionals. Examples include epidemiologists (Robinson et al., 2005); forestry researchers (Andrienko et al., 2006); census analysts (Suchan, 2002); and defence personnel (Ahonen-Rainio and Kraak, 2005) – see further examples in Table 1.4. Typically, these are domain researchers in their own right, or domain professionals. Using such subjects represents either "typical" or "extreme" cases in the case typology of Seawright and Gerring (2008), depending on whether the underlying population for geovisualization applications is regarded as "experts" or a more general population. Either way, current geovisualization researchers, concerned as they are with seeking to learn about the usability, efficiency and acceptability of their designs, will wish to choose subjects whose domain and professional interests make them likely early adopters of geovisualization tools and applications. Noting this not unreasonable affinity for domain researchers and professionals, and understanding the practical limitations involving access to any body of workers over a long period, there appear to be no examples in the literature that consider the processes that lead to the selection of prospective users by geovisualization researchers.

Given access to a large, diverse organisation (see Section 2.3) with a wide range of possible subjects, this chapter considers the aspects of employing various human centered (HC) data collection methods (observation, interviews, studying documents and card sorting) within a Contexual Inquiry approach in the 'context of use' phase of ISO13407. There is a challenge in working in domains where exploration may be more peripheral to the work and where information skills are not as specialised, but it has the potential to provide an indication of how geovisualization can penetrate these larger organizations using HC approaches.

The work proceeded by contacting a wide group of possible subjects in LCC's research and information team, where it was already known from past work with this unit (Attilakou, 2005) that exploration of spatial data was undertaken. After filtering candidate subject domains, the crime and disorder reduction domain was selected after developing criteria for choosing. Subsequently, public libraries was selected as a second, diverse, case. Data gathered is analysed using Qualitative Data Analysis (QDA) techniques.

3.2 METHODS

3.2.1 DATA GATHERING APPROACHES

In order to determine the context of use of a possible geovisualization application, the HC approach adopted was Contextual Inquiry (CI), described in Section 2.2.2. CI is aimed at "those with neither the training nor the time to conduct ethnographic work; instead, it provides a set of methods whereby designers can move out from laboratory settings to the real world as a basis for design inspiration" (Dourish, 2006). Appropriate data gathering methods are observation, interviews, studying documents and card sorting. Possible collection methodologies (see p376 of Preece, Rogers and Sharp (2002) for a comparison) are notes and camera; audio plus camera and video. Video is unsuitable because of its intrusive nature with the selected subjects, and the practical difficulties in transporting bulky equipment into the field. An audio recording is preferred to note taking for a solo researcher engaged in simultaneously asking questions, attending to an interviewee's responses and focusing the direction of the interview. In these circumstances, it is extremely difficult to take complete and meaningful notes. After early attempts at note taking that were inadequate to capture significant aspects of context of use, I took the decision to audio record for the majority of my interactions with LCC people. Heritage and Atkinson (1984) commend the use of recorded data as it "serves as a control on the limitations and fallibilities of intuition and recollection…[and] provides some guarantee that analytic conclusions will not arise as artifacts of intuitive idiosyncratic, selective attention or recollection, or experimental design." After a period of time, I gained sufficient experience to take notes competently in some situations, for example when prospective users were employing a 'think aloud' protocol and significant interpersonal interaction was not required. I used two audio recording methods simultaneously for security, one with an obvious microphone that gave an on-going visual cue to subjects that recording was taking place. The redundancy turned out to be necessary in practice. The use of audio recording of necessity entails subsequent transcription and coding before analysis.

Section 3.3.2.1 describes the choice of a specific unit as an initial research focus – the LCC crime and disorder reduction team. Interviews and email exchanges as well as a number of observation activities refined and clarified my knowledge of their work. A corpus of textual information was created from transcripts of interviews and emails plus the transcribed responses to interviews with team members to elicit information about requirements (see section 4.3). The interviews and their transcriptions provide useful 'direct' information, for example descriptions of people's skill and experience, of their aims and objections, about inputs and outputs (where work and data come from, and what form they take; what are the outputs and where they go). Another unit from another part of LCC – public libraries - was chosen subsequently as a 'diverse' case (Seawright and Gerring, 2008) to compare with it, that lacked many of the skill, tool and data advantages of the first unit, see section 3.2.2.

Interview data gathered is analysed using Qualitative Data Analysis (QDA) and techniques such as Content Analysis (Krippendorff, 2003), key-word-in-context (KWIC), (Luhn, 1959) with the TextStat application (Hüning, 2003).

Observing LCC subjects increases the chance of discovering information that lies outside the central foci of interviews that centre on the most frequent occurrences in terms of tasks, customers, tools, skills and so forth. It also duplicates a good deal covered by interviews and its unfocused nature can lead to the observation of routine or unimportant aspects of the work. But while it does not provide a *systematic* overview, it shines a moving light into a selection of topic areas, occasionally illuminating "sapphires in the mud" (Eliot, 1943a).

'Studying documents' in the context of ISO13407 refers primarily to subject's own, internal documents. However, external documents may also offer insights into a subject domain or context by giving a more generalised account of a specific insight or issue.

Card sorting is frequently used at the start of a prototyping process to “discover users’ mental model of an information space” (Nielsen and Sano, 1995). "Free" or open sorting is defined as “[a methodology] in which subjects can determine their own groupings by first sorting the cards and then labelling the resulting piles”(Deaton, 2001). I do this for the LCC crime and disorder reduction (CDR) team by compiling a list of plausible tasks in the card form and asking team members to sort these into 'similar' piles, giving each a name. I hypothesise that card sorting will give insights into the subjects context of use, and especially how they categorise spatial tasks that are relevant to geovisualization compared to other tasks. Subjects from CDR are given a set of 35 cards bearing plausible crime tasks. I prepare these in advance from my knowledge of CDR work from interviews, observation and studying documentation. R validated them as being plausible tasks given R's detailed knowledge of the CDR domain. The cards are randomised, and subjects asked to group them freely according to their notions of similarity, give each group a name, and then select the 'most typical' case from each of the categories.

The card sorting task took about 30 minutes of subject time to complete once an explanation had been given. The results are analysed using hierarchical cluster analysis (Hill and Lewicki, 2006) and displayed as tree diagrams. The purpose is to understand how card sorting performs as an approach for understanding context in use. It also assists by focusing thinking within the complex and heterogeneous crime domain to identify plausible crime research tasks the CDR subjects might perform with a geovisualization application.

The CDR task card sorting is repeated with a geovisualization expert (D) with a good knowledge of the CDR unit (without seeing the results of the CDR card sorts), to explore the utility of card sorting and cluster analysis as a way to compare the average CDR and a CDR-domain knowledgeable geovisualization expert's mental models of crime tasks.

3.2.2 SUBJECTS

Initially, access to possible subjects was confined to LCC's research and information organisation part of the LCC Chief Executive's Department, consisting group of about 14 individuals divided into units of one to three in size. Later, access to teams outside the Chief Executive's Department - such as public libraries - became possible as mutual confidence with LCC grew, and the research and information team itself began to engage more with units within LCC as they developed into a local centre of research excellence and practice.

Within the research and information team, a mix of observation, interviews and studying documentation was employed to understand the work on the individual units in outline as a precursor to selecting a single unit to work with as a case. Contextual inquiry advocates a "master/apprentice" model as an effective way to collect data (Beyer and Holtzblatt, 1997) and this is how I approached the LCC people. In this phase I was looking to both establish an initial domain and subjects to work with, and also to evaluate the approaches used for doing this (see Figure 2.1 where the former represents the starting point for advancing towards the production of a final goevisualization application, and the latter represents an assessment of the extent to which HC approaches in a geovisualization context).

In work with US Census Bureau domain experts in the context of a future geovisualization application, Suchan (2002) analyses qualitative data from individual interviews and a group session under categories of types of data, tools applied now to analysis, type of analysis currently performed, and desired characteristics of future analysis tools. While an appropriate categorisation for experts in a complex, numerate domain, such an approach is not useful when learning about LCC subjects for the first time, where none are likely to have such data intensive roles as the Census Bureau employees. I developed criteria for assessing the LCC units' different potentials to gain benefits from a geovisualization (and hence as subjects for this research) as an evolving process as interviews and observation progressed. The scheme I adopted eventually considers three aspects to do with the essential character of geovisualization - the nature of data, spatiality and of exploration - and three aspects to do with the subjects and the team:

data – the availability and extent of subject data and whether it contained spatial and/or temporal as well as attribute aspects;

spatial skills – the ability of subjects to manipulate spatial data (e.g. use of a GIS), if used;

exploration - the extent to which subject tasks were about the exploration of data;

longevity – units which had an on-going role that was at least nominally "permanent" were preferred to units whose role had a time-limited 'project' orientation;

team size – larger units (with more subjects) were preferred to smaller ones;

enthusiasm – a conflation of a number of factors, expressing the *rapport* experienced with subjects (a pragmatic, "can we work together?", attribute); subjects' expressed *motivation* for a geovisualization approach to their work; and subjects' *aspiration* – the notion that the subjects see research as a way of making a step change in their delivery – better data, better tools or better presentation. (Although the research was seen by some subjects as a panacea for existing, unrelated issues, and wanting to shape the opportunity to their own ends).

The transcribed results are coded for 'geovisualization potential' (see Section 3.2.2) as follows:

Exploration: 0 = no exploratory role; 1 = basic exploratory role; 2 = moderate exploratory role; 3 = large exploratory role.

Data: 0 = no or little real data available; 1 = little data, or moderate data but lacking granular spatial component and/or accessibility; 2 = attribute and granular spatial data available, but limited in scope and/or accessibility; 3 = extensive, accessible, attribute, temporal and granular spatial data.

Spatial skills: 0 = No or minimal spatial skills; no GIS used; 1 = use maps in analysis but rely on others for GIS skills; 2 = basic GIS skills used for spatial analysis; 3 = advanced GIS skills for spatial analysis.

Team size: 1 = one person; 2 = two people; 3 = three people.

Longevity: 0 = Project based – ending within a year; 1 = Project based – ending greater than a year ahead; 2 = 'semi-permanent' task; 3 = long term 'permanent' task.
Enthusiasm: 0 = no enthusiasm for geovisualization research; 1 = low enthusiasm for geovis research; 2 = moderate enthusiasm for geovis research; 3 = strong enthusiasm for geovis research.

While the criteria above were my own, developed in response to the context within LCC, subsequent work by Valiati, Freitas and Pimenta (2008) is supportive of some of these aspects. They conduct multi-dimensional, in-depth, long-term case studies (MILC) and note that "in all case studies, the users had some common characteristics: all subjects had great motivation for analyzing their own data; all subjects were experienced computer users but with no previous experience with visualization tools; all subjects usually employed specific analysis tools and had different working practices for data analysis."

As reported below in Section 3.3, the result of weighting these different factors ranks the crime and disorder reduction (CDR) unit as the best choice for the research. Subsequently, public libraries was selected as a second, diverse, case (Seawright and Gerring, 2008). While the CDR unit has good access to rich data with spatial and temporal components that they explore regularly as part of their work, and possess good analytical tools and skills, the public libraries subjects have poor access to their data (which is, nevertheless, rich with temporal and spatial components), no tradition of exploring their data, and poor analytical tools and expertise. In the case of public libraries, no observation of the primary subjects was made as they did not engage in any exploration of their own data. Similarly, no card sorting was undertaken with them to understand their tasks (as it was with CDR subjects), as other methods of data gathering had indicated clearly the task they wished to focus on - namely clustering of their borrowing population for marketing purposes. Section 3.3 discusses this in detail.

Within the CDR and public libraries units are individuals who became subjects for the investigations carried out in this thesis. While there will be more on them subsequently, a brief introduction to them is in order at this point. They are all referred to by codes to preserve anonymity. C1 , C2 and C3 comprise the crime and disorder reduction unit with C2 and C3 reporting to C1; L1 is the public libraries marketing manager and L2 and L3 are staff from the management information unit of LCC Community Services (of which public libraries is a part) who report to L1. I conducted a one hour exploratory interview with L1 that followed the format used with the other LCC units to provide descriptions of people's skill and experience, aims and objections, inputs and outputs in order to consider the context of use for a possible geovisualization libraries application.

3.2.3 CASE STUDIES

This chapter contributes work that provides evidence related to Research Question 1: "How does the nature of geovisualization affect the selection of prospective users for a geovisualization application and the information we need to gather to understand them, their context and needs?"

The results (section 3.3) provide evidence to compare the use of interviews, observation, study of documents using contextual inquiry methods, and the use of card sorting to compare subjects' mental model of their task space.

For ease of reference, the overall case study approach for this chapter is reproduced below. Section 3.3 reports the results for case numbers 1 - 3.

Case No.	**ISO 13407 methods**	**Population**	**Sample**	**Units**	**Objective**	**Research Design**
1	**Context of use** (Ethnography, field studies and contextual inquiry using observation, interviews, study of documents and card sorting)	Prospective geovis application users in LCC Research and Planning department	Crime & Disorder reduction (CDR) Team	CDR team members	Understand CDR users' context of use; evaluate ISO13407 approaches	(b) Case Study II
2		Prospective geovis application users in LCC Libraries and Community Services ("Library") department	Library Team	Library team members	Understand Library users' context of use; evaluate ISO13407 approaches	
3		Leicestershire County Council (LCC) departments	Libraries and Research & Planning departments	Library and CDR teams	Compare CDR and Library users' contexts of use	(d) Cross-sectional

Table 2.2 extract: Context of Use case studies in the research (from Table 2.2)

3.3 RESULTS

3.3.1 RESULTS FROM INTERVIEWS

Interviews are conducted with LCC Research & Information team members in exploratory mode, with CDR unit and the public libraries marketing unit in detail.

3.3.1.1 EXPLORATORY INTERVIEWS WITH LCC TEAM MEMBERS

The results of the coding of the exploratory interviews with LCC Research team units to assess each unit's potential to benefit from geovisualization are in Table 3.1, along with a short description of each unit's role. Units are listed in order of cumulative score, a simple measure to help discriminate between them but that has some limitations. These include whether weights should be applied to criteria, and what they should be, and whether a particular score in some criteria (for example, exploration, or enthusiasm) represents a prerequisite for working with that team (meaning that a lower score can be used as a discriminator to eliminate some units from consideration). Considering the units with higher cumulative scores, **rural development** is focused primarily on intervention and policies to assist rural areas, has limited research content and only one person involved, albeit highly enthusiastic about the prospects for working with geovisualization; **economic development** use little or no spatiality in their work, and provide an information service with limited novelty of analysis. By contrast, the **crime and disorder reduction** unit, with three people, are operating in an environment where spatial information is being evaluated on an on-going basis to determine trends and possible causes, and to recommend outcomes. The unit has a sound grounding in data manipulation, statistics, criminology, and graphic presentation. For these reasons, the **domain chosen to proceed with in this research is crime and disorder reduction**.

In choosing a second case, I wished to select a 'diverse case' and also a team from outside the Research and Information unit in order to broaden the evidence base for the research. This depended on contacts that the unit had with other parts of LCC and their willingness to be involved in the research. The public libraries marketing team, agreed to cooperate, and the same information in Table 3.1 for their role is in Table 3.2. The coding is as for Table 3.1. Exploration is described as (0) as they are currently unable to explore their data adequately, but aspire to do so. Unit size is described as '1(3)' because although just one person is involved in public libraries marketing, two others, concerned with management information, report to the marketing manager and became involved in the later stages of the research at the marketing manager's request (see Chapter 6).

Unit	Description	Explor-ation	Data	Spatial skills	Long-evity	Unit size	Enthu-siasm	*Sum*
Crime & disorder reduction	Provides information on crime and disorder; produces performance statistics and single-theme exploratory crime-related reports to support local Community Safety Partnerships	2	3	3	3	3	3	*17*
Economic Development	Surveys local businesses twice-yearly to assess business situation - analysis is published for benefit of local business. Also conducts or commissions single-theme exploratory economic-related research	2	3	2	3	2	3	*15*
Rural Development	Coordinates funding for projects such as community development work aimed at protecting and enhancing rural Leicestershire by increasing voluntary and community sector engagement	1	1	1	3	1	3	*10*
Data4-Business	Manages detailed database of active businesses in Leicester. Leicestershire and Rutland for benefit of local businesses; major task is validating database	0	3	0	3	3	1	*10*
Land use & demography	Monitors availability and take up of residential & commercial land to ensure land supply in line with policy. Communicates land use changes to other LCC departments	1	1	2	3	2	1	*10*
Regional planning	Mediates between Leicestershire interests and the Regional Planning process; inputs to Regional Structure Plan/Regional Spatial Strategy	0	1	1	2	1	2	*7*
Economic Partnerships	Facilitates Regional Development budget dispensing to Economic Partnerships and capital programmes. manages Leicester-China link and miscellany of other development initiatives	0	1	1	2	1	1	*6*
Web portal (LSORA)	LSORA is a web portal providing access to data about Leicester and Leicestershire for local partnerships. Usage and response times were low.	0	2	1	1	1	0	*5*
European funding	Helps LCC and partners access European Social Fund funding and build project budgets when funds received. Passes on learning from Europe	0	0	0	2	1	1	*4*
Public Houses & Post Offices	Focuses on initiatives to help retain/expand use of (mainly rural) Public Houses and Post Offices with aim of maintaining rural community cohesion	0	1	0	0	1	2	*4*
Funding Toolkit	Manages a voluntary and community sector resource that increases success in bidding for funds by providing links to sources, contacts and best practice	0	0	0	0	1	1	*2*

Table 3.1: Work of LCC Research & Information units (at Jan 2006) showing criteria for 'geovisualization potential', ranked by sum

Unit	Exploration	Data	Spatial skills	Longevity	Unit size	Enthusiasm	*Sum*
Public libraries marketing	(0)	2	0	3	1 (3)	3	*9 (11)*

Table 3.2: LCC Public Libraries marketing showing criteria for 'geovisualization potential'

3.3.1.2 INTERVIEWS WITH CRIME AND DISORDER REDUCTION UNIT

The insights from CDR interviews are:

1 The LCC CDR unit is engaged in three main types of activity:

(a) ad hoc support to Crime and Disorder Reduction Partnerships (CDRPs). These are composite organisations comprising local Police, authorities, health trusts, fire and ambulance services, probation services and other agencies. CDRPs were created by the Crime and Disorder Act 1998, subsequently amended by the Police and Justice Act 2007. CDRPs were created to place "an unambiguous duty on local authorities and the police to work together to identify the pattern of crime and disorder in their area and implement strategies for tackling these problems" (Home Office, 2006). CDRPs and hence the LCC CDR unit only focus on 'community' crime and disorder, not dealing with business crime, fraud or sexual offences, for example.

(b) production of (mainly monthly) management statistics relating to CDR.

(c) exploration of data relating to specific themes in CDR and producing reports to guide CDRP policy in these areas.

C3 describes a typical task:

> *"I run queries out of Access to get data at various different geographical levels – output area, ward, district etc - by a particular time period for particular crime types say - and you'd tabulate them, produce thematic maps, produce cartograms perhaps. That's all very straightforward...The questions you get to answer are pretty ad-hoc"*

The cartogram reference shows an awareness of a geovisualization tool from prior exposure to the work of Attilakou (2005).

Figure 3.1 shows in diagrammatic form my understanding of the relationship between LCC's CDR unit, the local police, the local CDRPs, with flows of information and funds, based on interviews and an iterated email exchange with C1. There is a clear data exploration segment to the unit's work. C1 was asked to comment on the final version of Figure 3.1 and believed it to be "somewhat idealised" - the reality, in practice, being more complex.

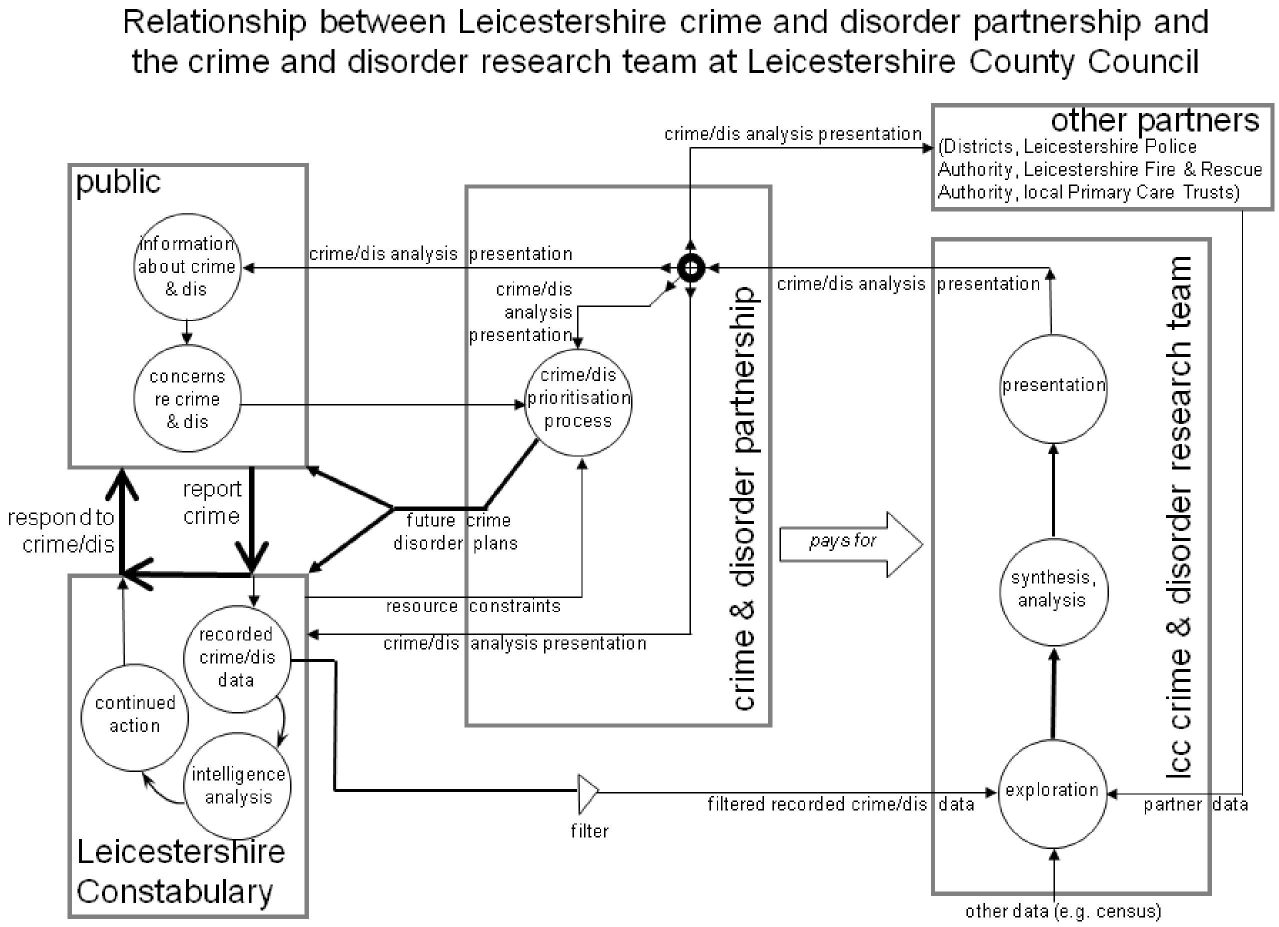


Figure 3.1: Context of LCC's Crime & Disorder Reduction unit, showing flows of information and funds, based on interviews with Subject C1

2 The LCC CDR unit is comprised of three people (initially: it reduced to two people in mid-2007) whose skill sets are centered on criminology (C1), statistics (C2), and GIS, databases and spreadsheets (C3). They occupy lower management grades within LCC; C2 and C3 report to C1. The tools used by the team are Microsoft Access, Excel, Word, PowerPoint and Publisher; the statistics package SPSS; and the GIS applications MapInfo and MapViewer.

3 The vast majority of the data used by the CDR unit comes from the local Police who, at the time of this study, aggregate the raw data. Crime attribute data is based on national standards and has a hierarchical taxonomy. For example, the major crime class 'violence against the person' contains a sub-class such as 'harassment' that contains a number of crimes, an example of which is 'breach of a restraining order'.

4 The CDR unit communicate with CDRP organisations at working level mainly by telephone and the production of material in the form of written reports. Communication with senior members of CDRPs is via their own management line within LCC (typically the manager two levels of management above C1).

Frequency counts and keyword-in-context

The corpus is analysed with concordance software (Hüning, 2003) using frequency analysis and then a keyword-in-context (KWIC) (Luhn, 1959) approach.

The highest word frequencies in the CDR corpus (excluding common and trivial) words (and limited to >12 mentions for manageability) are: data (112 mentions); crime (89); area/areas (63); police (57); partnership(s)/CDRPs (54); work (45); time (43); people (32); different (30); very (29); team (28); level (25); information (23); useful (21); local (20); research (19); rural (19); report (18); Access/access (17); SPSS (16); map (15); MapInfo (15); analysis (14); database (14); excel (14); questions (14); important (13); interesting (13); and performance (13). Note that this list not only contains nouns but also qualifiers such as 'different', 'useful', 'very', 'interesting' and 'important' that point towards what the subjects find particularly meaningful.

By itself, and limited and one-dimensional though this is, it indicates some interesting aspects of the CDR unit's work. Encouragingly for research that is predicated on exploring spatial data, the most common word is 'data' (112 mentions) with 'information' having 23 mentions. A spatial focus is indicated by area/areas (63) and map (15), and advanced tool use by Access/access (17), SPSS (16), MapInfo (15) and Excel (14). Care has to be taken aggregating occurrences of words like 'access' that can reference very different concepts (in this case, 4 instances of 'access' and 13 of 'Access'). Also note the need to aggregate plurals. When the frequency list is used as the basis for KWIC, another layer of meaning becomes apparent - the "why" to inform the "what". Figure 3.2 shows part of the text corpus based on the word 'police'. A set of statements within this relate to data *and* police and reveal issues and insights: inability of the CDR unit to access Police point data on crimes; the Police's aggregation of data before the CDR unit sees it to 100m squares for urban areas (but with full temporal detail) and to census output areas for rural areas (monthly totals only); and the way the CDR unit distinguishes itself from the Police. Supporting quotes from CDR subjects include: "Audience is Community Safety Partnerships and Police. CSPs are heavily dominated by Police."; "We work for LCC and not the police. The police have all the data and their own analysts."; "…thing that struck me was the noise – it's a working police station, the [Police] analysts are in this noisy environment."; "…police have data on crime themselves."; "…two sorts of data. From 1997 Police have supplied aggregated data…"; "Police aggregate to 100m for selected urban areas."; "Ask(ed) for point data from Police – couldn't get."; "Problem with access to Police data."

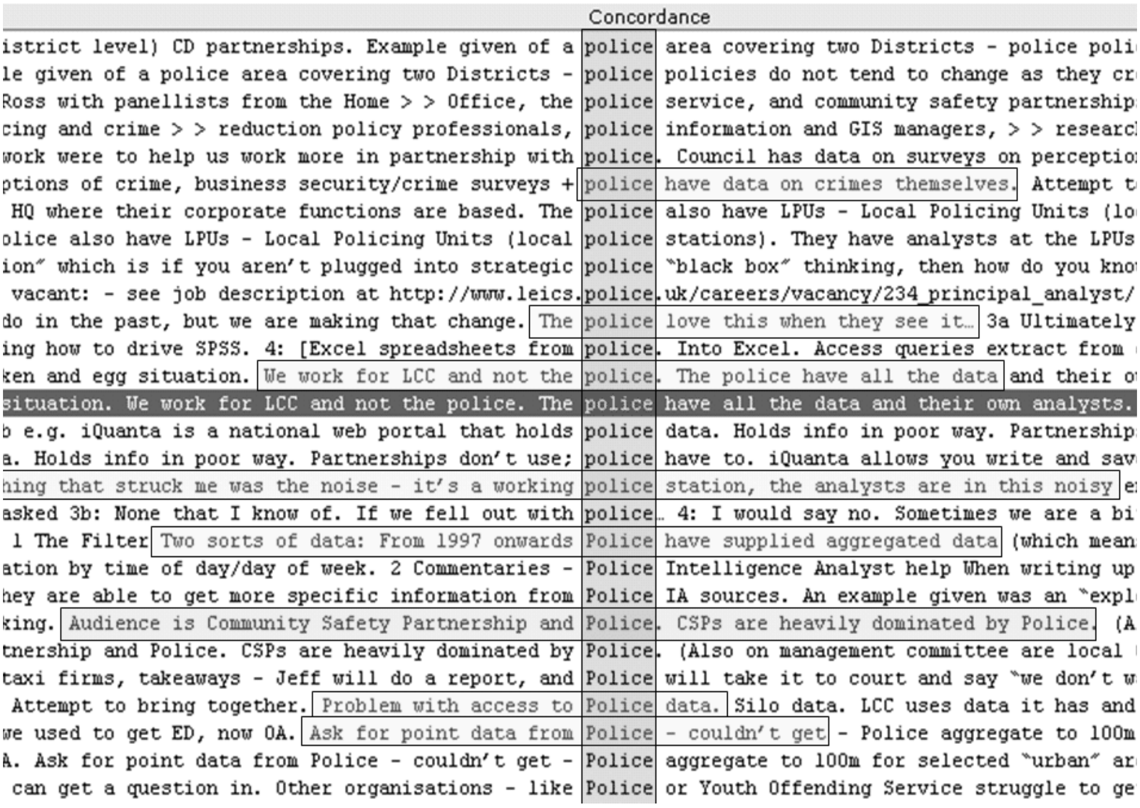


Figure 3.2: Keyword-in-context showing text corpus extracts centered on word 'police' (vertical highlighting). An example related themes ("data") is highlighted horizontally

By working through the frequent words and KWIC, deeper insights are obtained. The CDR unit receives almost all its working data from the Police, and the Police are one the most dominant partners in the CDRPs. The Police also have their own analysts. This places the LCC CDR unit in the position of having to constantly demonstrate the added value of their work. This manifests itself in a mindset of **differentiation**. The CDR unit place value in data, skills and tools that the Police do not have. Some supporting quotes reflecting this are:

> *"I think the Police have less analytical capacity than we have here, but they have much more and detailed data"*
> *"Council has data on surveys on perceptions of crime, business security/crime surveys and Police have data on crimes themselves. [We] attempt to bring together"*
> *"To succeed C1 needs to be able to go out and 'sell' it and add value to it"*
> *"It's quite difficult to approach the Police and present them their own information and start questioning it… You've got to make it look good and nice and earn yourself reputation and credibility...Small is beautiful. One concise table or chart with a couple of key facts or something clearly reinforcing something they perhaps already know"*
> *"Because we have the department's scanning software (SNAP) nearby, we tend to get involved in all kinds of other things…we can get a question in [to an LCC survey]. Other organisations – like Police or Youth Offending Service struggle to get data like that on perceptions of crime. C1 is interested in how to make better use of this data."*
> *"we have attempted to show what can be done – R and I gave a presentation to [Police] analysts a year or so back."*
> *"[SPSS] is useful. It adds value to data in a way that other organisations can't do. Police can't do it - don't have the capability; they don't know the Census; they don't do any statistical work. It's useful - a good plus point. In the past, presenting the Police their own data has been a bit like borrowing their watch to tell them the time."*

In line with "the tactic of getting feedback from informants" as advocated by Miles and Huberman (1994), the fact I had identified 'differentiation' as an underlying theme of the CDR unit's behaviour was fed back to C1 as manager of the CDR unit, whose response confirmed that it had evolved to be the case. Such an insight, while not contributing to the underlying research aims, nevertheless contributes to understanding subject context and what kind of result from a geovisualization application might find favour, that is, one the Police do not have.

3.3.1.3 INTERVIEWS WITH PUBLIC LIBRARIES UNIT

A single transcript of an interview with L1 was used as the corpus for content analysis with a frequency analysis and KWIC approach. The highest word frequencies in the public libraries marketing (PLM) corpus (excluding common and trivial) words (and limited to >7 mentions – a lower limit than the CDR one as the corpus was smaller) are: library/libraries (42 mentions); marketing (19); CS/community services (17); people (16); data (12); more (12); very (12); indicators (11); named (11); officer (11); system (11); years (11); services (9); team (9); organisation (8); performance (8); and work (8).

This frequency analysis offers less obvious direct insights into the work of the PLM unit than the technique does for the CDR unit. However the KWIC approach reveals richer insights. As an example, Figure 3.3 shows the corpus for the word "system". Quotations here include:

"data cleanliness is not high on the agenda of the system builders - there is no validation of fields"
"the people organising and running the system don't understand it completely"
"the system has been set up for another purpose"
"the system has evolved over time; has become complex"
"the people who manage the system internally do not understand the database structure"
"there is very little knowledge of how the system is structured"
"there is very little validation done on system"
"problems getting data out of the library TALIS system"

There are plainly issues here that point to possible data access and quality problems, and for what it will be possible to visualize.

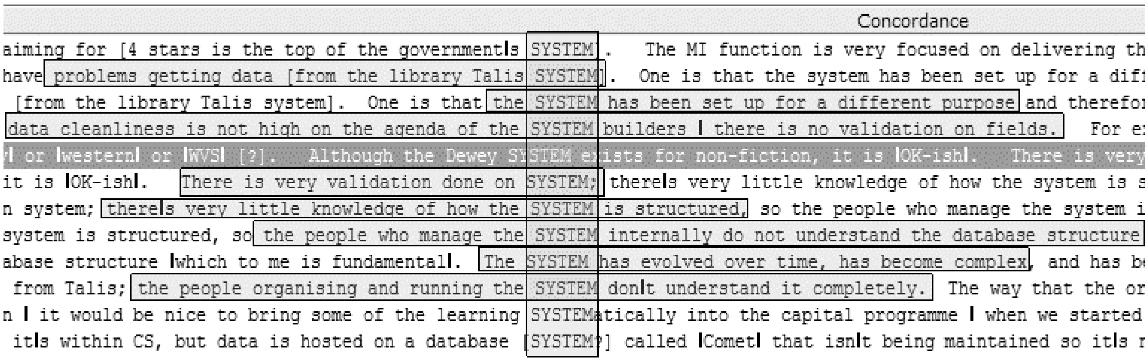


Figure 3.3: Keyword-in-context display showing text corpus extracts centered on the eleven instances of word 'system' (vertical highlighting).

Further KWIC analysis reveal a number of interconnected themes, shown in Figure 3.4 as a network diagram. It represents the overall network diagram created from the initial interview with public libraries subject L1, reflecting their context. The network evolved through a number of trial iterations.

The network in Figure 3.4 is read from lower left clockwise to lower right (words in **bold** are network nodes): an individual previously employed in the **private sector** runs the **marketing** function in public libraries, with an **ambitious** agenda to introduce modern marketing techniques. The marketing function is situated within LCC relative to the rest of the **organisation.** The ability of the individual to achieve progress is subject to **constraints** - such as lack of access to **data**, unskilled **personnel**, lack of **budget** and inappropriate **systems** - that

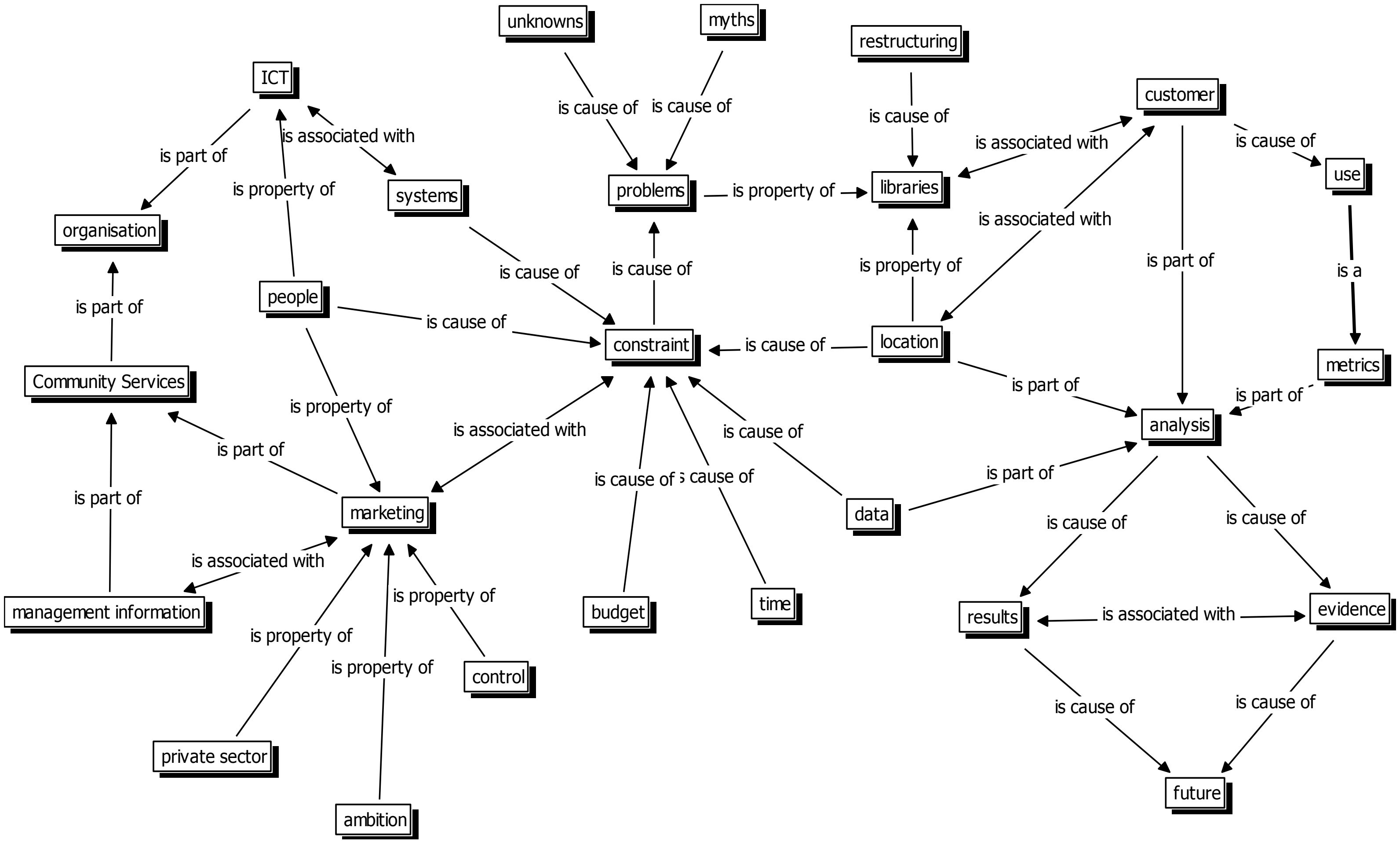


Figure 3.4: Network diagram of context of subject L1 from Leicestershire County Council's public libraries marketing

cause **problems**, compounded by **myths** and **unknowns**. The desire to market public libraries is situated in a context of **restructuring** of the service, **relocating** libraries, hence the need to understand **customers** and their borrowing **use**. Combining the right **data** and **metrics** about **customers** will permit **analysis** that gives **results** and **evidence** to direct the **future** of the public libraries service.

L1 summarises the aims of PLM at this stage as:

> *"to increase library issues and visits by understanding our customer data more intelligently…to look at the profile of the customers by their value…to have more segmentation of library customers by frequency and how recently they had had an issue of a library book; [to determine if] there is a model or pattern."*

A subsequent interview with L1 had the aims: to remind L1 of the earlier interview (considerable time had elapsed), to explain the role of my research and the work and benefits of the work already carried out with CDR, study documentation, obtain detailed PLM data, and to understand where best geovisualization can make a contribution. As a result, the focus was agreed mutually to be on the users of public library services and not on the libraries themselves or on the books and other material loaned. L1 is interested currently in a number of broad themes for exploration described by L1 as 'lapsed borrowers', 'loyal users', 'life stages', 'new members', and 'triggers'. These have a shared characteristic that reflect a desire on L1's part to consider the “trajectories” of different clusters of library users as they join or leave libraries or change their borrowing behaviour.

It is clear that the issue underlying these themes is **customer segmentation**. Subsequent conversation with L1 identified a strong desire to be able to identify customer segments, subsequently reinforced at a meeting with the LCC Head of Libraries and Head of Library Operations. L1 has ideas such as sending emails to customers with tailored messages designed to appeal to different segments. L1 believes clusters will have a spatial component.

Customer segmentation is a problem area that could be addressed in a number of ways - for example a statistical approach using factor analysis. It is also addressable by an exploration approach involving spatial, attribute and possibly temporal dimensions. That is, it could be considered a geovisualization problem. And if fashioned that way, it offers clear opportunities to advance this research as L1 interacts with and explores public libraries data in a geovisualization environment to determine customer segments.

Limited anonymised data that had been laboriously extracted from the Libraries TALIS system for another research purpose were made available. This contained the borrowing behaviour of the customers of four Leicestershire libraries – Oadby, Wigston, South Wigston and Great Glen for a two year span; about 800Mb of data in all - see section 3.3.5.2 for details of this data. This formed the basis for the library customer segmentation work.

3.3.2 RESULTS FROM OBSERVATION

Crime and disorder reduction unit

Within the CDR unit, a one-hour period of observation was scheduled with subject C1. Because this was timetabled in advance, I had no control over what C1 would be doing in that hour. In fact C1 decided - in a lull in the mainstream work - to tackle an in-tray that demanded attention. Much was routine, but one item sparked an insight. C1 opened a letter that had come from a Leicestershire district council. It attached a cheque representing that district's contribution to the CDR unit for the next quarter. What was surprising to me was the directness of the financial link between the CDR unit and a partner member of the CDRP. It illuminated what I had been told - in interviews - about one of the major tasks of the CDR team, "ad hoc support to Crime and Disorder Reduction Partnerships ". Important aspects of this task now became clearer – partners making a direct financial contribution could not fail to regard the CDR unit as a "paid for" service, from which a standard of customer service was expected. This affected the **balance** of the unit's work between exploration and analysis of crime data on one hand, and the information and sometimes 'hand-holding' support provided to partners. It was clear that ad-hoc support work would take precedence over exploration.

Another observation opportunity arose when invited to accompany the CDR unit and R to a regional crime event at Melton Mowbray. C1 and R gave a presentation that outlined their journey from presenting graphics in a less than adequate way, via the works of Edward Tufte (Tufte, 1986), to the current way of presenting graphics. This evangelising attitude to **presentation** and graphic excellence provided another facet to the earlier insight concerning the importance of **differentiation** of the CDR unit from the Police. Commenting on police ways of presenting information, one of the CDR subjects commented (my emphasis in bold):

> *"If you look at a piece of work produced by an analyst at the Police, they'll have a map with a big clunky star for each crime and it looks like a "beard of bees" - it's just a load of stars and you can't see anything. They should aggregate to 100m squares…but they …[show]… too much detail. They have point data but don't display it well. But the Police would probably deny that - and I don't see everything that's produced.* ***But we have attempted to show what can be done****."*

Public libraries

While the public library marketing unit subjects were not observed directly, some observations made are germane. I visited each of the four public libraries for which data were available - Oadby, Wigston, South Wigston and Great Glen – to gain a perspective of the **ground truth** as suggested by Veregin (1995): "Intimate knowledge of the world recedes into the background of 'ground truth' as the computer screen becomes the medium through which the geographer interacts with the world…Geographers need direct knowledge (knowledge of) as well as indirect knowledge (knowledge about)". Certainly, the reality did not disappoint.

An observation in one of the larger libraries was that the traditional library with rows of books, while far from superseded, is making way for other content (such as DVDs, audio CDs and talking books, internet access), and is employed for many other purposes than might be thought traditional. One librarian commented that the library was used by health visitors as a place to weigh babies, and that opportunity was taken by librarians to sign up mother, baby and any siblings as library members. I saw carrels full (at that time of day) of schoolchildren doing homework. Another smaller library had line-dancing taking place in a neighbouring room when I visited. These are snap shots – arriving at a different time of day, or speaking to another person, would undoubtedly have yielded very different impressions.

Another observation that may have a wider application for other researchers is that subject L1, although interested in proposals to visualize customer segments, was constrained by available resources**.** L1 was unwilling to commit to detailed work with me without approval from the Head of Libraries. I met this individual (with the Head of Library Operations and L1), and engaged in what can only be described as a 'pitch' for L1's involvement and time. Having an overview of L1's context from KWIC and the network diagram enabled me to tailor what might have been a perhaps rather dry academic message to the relevancies of continuing problems of data access, lack of appropriate tools, and past research already completed (but not delivering effective customer segmentation). Understanding context can make an effective contribution to gaining a subject's commitment. It can provide the basis for closer, perhaps more effective, work with the subject. Shneiderman and Plaisant (2006) go further and suggest: "HCI and information visualization researchers accept responsibility for...the achievement of users' goals within their domain of work. This is a substantial increase in expectations for researchers, which raises the responsibility of researchers for the successful work of their subjects/collaborators." There are clear dangers here - the research aims are paramount. But if L1 manages to segment library borrowers effectively, then this is a useful subsidiary aim.

3.3.3 RESULTS FROM STUDYING DOCUMENTS

This section considers both internal and external documentation in both the crime and disorder reduction and the public libraries contexts.

3.3.3.1 INTERNAL DOCUMENTATION

Crime and Disorder reduction internal documents

The Research and Information team describe their work and organisation in an LCC internal document (Leicestershire County Council, 2006). The corridor outside their offices had displays showing staff photographs and job responsibilities. These kinds of guides make orientation within a new organisation easier and might be sought out by researchers aiming to understand context.

Even a cursory glance at documents produced by the CDR unit reveals a highly sophisticated approach to the use of graphics influenced by the works of Edward Tufte, a mastery of mapping and of numerical data and an excellent sense of design and of **presentation**. This is a hallmark of the publications of the CDR unit that runs through their publications. Examples include: 'Loughborough CCTV crime report' (Hardy, 2005a); Understanding rural and urban crime' (Hardy, 2005b) and 'The frequency and intensity of the fear of crime in Leicestershire' (Adamson, 2006) - there any many more. In one document (a crime, disorder and drugs audit for an area of Leicestershire (Adamson, Hardy and Radburn, 2005), the crime summary of just five pages packs in a narrative, a sophisticated time series, small (spatial) multiples, sparklines (Tufte, 2006), bar charts with proportional widths, and box and whisker plots.

Figure 3.5 provides a concrete example of the variety of the CDR unit's handiwork. It shows a leaflet that C1 emailed me, with an accompanying note that contains confirmatory insights into the CDR unit's work, graphic and mapping skills and approach to presentation:

> *"Attached is something I put together as a handout for a presentation. Harborough Community Safety Partnership held an event with Parish Councils, Neighbourhood Watch Assns, etc and wanted an overview of crime/ASB [anti-social behaviour] in the area. The handout includes the usual 'Tufte-light' stuff. The only other thing I tried to include this time is in the centre pages at the top. This was to try and show the change over time (yr-on-yr) by LSOA [lower super output area] in a fairly concise way - i.e.the high(er) volume crime LSOAs and the big changes The idea is nicked, of course, from the 'bump chart' image which I've also attached here. This was used [by Tufte] to show the change over time of three rowing teams managed by the same person."* (C1)

Perceptions of crime and anti-social behaviour

The Leicestershire Local Area Agreement (LAA) is divided into a number of key themes. As part of the Economic Development block of the LAA a survey has been carried out in seventeen towns and villages across Leicestershire, including three in Harborough District. These were Broughton Astley, Lutterworth and Market Harborough. This survey included a number of questions on perceptions of crime and anti-social behaviour.

Generally it is low-level disorder and anti-social behaviour which concerns people, much more so than crime. People hanging around on the streets, rubbish and vandalism were considered to be the most problematic issues across all the areas surveyed (see Table 3, below). This pattern was generally reflected in the three areas of Harborough District, although street canvassers were also more of a problem in Market Harborough. Groups of people hanging around was thought to be a problem by more people in Lutterworth and Market Harborough (just over one-in-five) than the average for all areas surveyed, though this was much lower than average in Broughton Astley (one-in-ten). Rubbish was seen as more of a problem in Lutterworth, whilst a higher percentage of people in Market Harborough thought there was a problem with dirty pavements. Concern about road safety and speeding was higher in Lutterworth than the average for other areas surveyed and around twice as high as the other two areas in Harborough District.

Other questions in the survey included one around whether people worried about being assaulted or harassed while in the town/village centre. The proportion of respondents from Broughton Astley who worried was around one-in-ten (9%) and was comparable with the average figure for all areas (10%). In Market Harborough and Lutterworth around half as many people worried, one-in-twenty (4% and 5% respectively).

A separate question asked whether respondents agreed that their town/village centre could be described as 'safe'. Across all the areas surveyed, around two-thirds of respondents (69%) agreed the town/village was 'safe'. Again, the figure for Broughton Astley was very similar (65%). The corresponding figure for Market Harborough and Lutterworth was much higher at around nine-out-of-ten respondents (87% and 91% respectively). Only one other area out of the seventeen surveyed in the county had a higher figure.

Table 3 — Percentage of respondents who felt that the following factors were a 'very big' or 'big' problem in that town or village.

	Broughton Astley	Lutterworth	Market Harborough	all areas surveyed
Groups of people hanging round on the streets	10%	22%	23%	18%
Rubbish and litter lying around	15%	26%	16%	17%
Dirty pavements and chewing gum	6%	8%	17%	14%
Vandalism, graffiti and other deliberate damage to property or vehicles	9%	13%	13%	11%
People not treating each other with respect and consideration	3%	8%	7%	10%
People being drunk or rowdy in public spaces	3%	6%	7%	10%
Street canvassers	8%	1%	13%	10%
People using or dealing drugs	5%	9%	11%	9%
Verbal abuse or other aggressive behaviour	4%	1%	8%	8%
Road safety or speeding	5%	11%	4%	8%
Personal theft (pickpocketing)	5%	1%	8%	8%
Fly tipping	8%	9%	5%	8%
Property being stolen from a vehicle	3%	0%	6%	7%
Vehicles being stolen	4%	1%	5%	7%
Assaults and other violent crime (personal robbery, mugging)	8%	1%	6%	7%
Aggressive begging	3%	0%	1%	5%
Racial harassment	0%	1%	1%	5%

Source: Leicestershire Town and Village Centres Survey, Fieldwork took place over July and August 2006.

Produced by Research and Information Team, Leicestershire County Council. Data Source: Leicestershire Constabulary CIS (Performance Review Team). For further details contact Jon Adamson (0116 265 7419 or jadamson@leics.gov.uk).

Crime Summary for Harborough District, December 2006

Leicestershire County Council

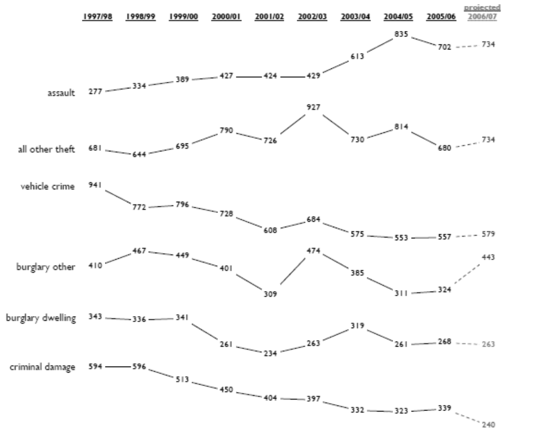
Harborough District is a low crime area. There have been large reductions in burglary, vehicle crime and criminal damage. There has been an increase in violent crime, partly due to changes in recording practices and consistent with a general increase elsewhere. Fewer people perceive there to be problems with crime and anti-social behaviour than in other areas and the towns and villages are generally thought to be safe places.

Table 1 (below) shows the trends for selected crime types in Harborough District over the last nine years (since April 1997). A figure for 'total crime' has not been included as it is very difficult to determine a consistent baseline over a long time period such as this. Also, it is the changes within different crime categories which is of more interest, and such changes are masked by an 'overall' figure.

The trend lines show that there have been substantial and sustained reductions in vehicle crime, burglary dwelling and criminal damage (also referred to as 'vandalism') over the last nine years. The figure for vehicle crime (which includes both theft of a vehicle and theft from a vehicle) for 2006/07 is projected to be down by almost 40% from the level recorded in 1997/98. Criminal damage is down almost two-thirds (60%) for the same period and burglary dwelling is down by around a quarter (23%).

There are slight increases in all other theft and burglary other (up by 8% over the nine years), both of which have fluctuated over this time period. The largest increase is in the category of assault, which has risen by around 165% over the nine years. However, some care must be taken in how this is interpreted as there have been two changes to crime recorded practices over this period (1998 and 2002) and the category of 'assault' covers a range of offences—such as harassment—which do not actually involve any physical injury or even any contact.

Chart 1 : Offences recorded by the police in each financial year since 1997/98 for selected major crime categories only.



Source : Leicestershire Constabulary, CIS.
Data has been extracted on a monthly basis from a live database. As crimes maybe re-coded, figures may differ slightly from those published elsewhere.

Police recorded crime in Harborough District by Lower Super Output Area

A Lower Super Output Area (LSOA) is an area of geography created by the 2001 Census. An LSOA is an area containing approximately 1,500 people and is the standard geography used to publish statistics.

Table 2 (right) shows the top fifteen LSOAs in Harborough in terms of all police recorded crime in the last twelve months (Dec'05 to Nov'06) and the corresponding figure for the previous twelve months. (The top fifteen LSOAs account for between a half and two-thirds of all crime recorded in the district.)

The lines show the movement—up or down—in the rankings. Those areas where crime fell between the two years and which dropped out of the highest fifteen LSOAs are highlighted in green. Those areas where crime increased and they went up into the top fifteen are highlighted with red lines.

Within the top five or six (high crime) areas there is not very much movement between the two years. The highest number of crimes was recorded in Market Harborough—Coventry Road LSOA. For 05/06 this was followed by Lutterworth Centre & East (up slightly on the previous year), Little Bowden South (down 76 offences on the previous year) and Ullesthorpe and Magna Park.

The three areas where crime increased and they moved into the highest crime fifteen were: Lutterworth South were all recorded crime increased from 74 offences between Dec'04 and Nov'05 to 117 offences between Dec'05 and Nov'06; Foxton, Saddington & Theddingworth, where crime increased from 60 offences to 112 offences; and, Wiston and Great Glen South, up from 58 offences to 117 offences.

The three areas which dropped out of the top fifteen were: Primethorpe—down from 116 offences to 94 offences; Peatling & Bruntingthorpe—down 35 offences; and Stoughton & Thurnby South.

Table 2—The top fifteen high crime Lower Super Output Areas (LSOAs) in Harborough District for all recorded crime.

04/05 rank	04/05 all crime	LSOA Name	LSOA code	LSOA code	LSOA Name	05/06 all crime	05/06 rank
1	299	Market Harborough -Coventry Road	801	801	Market Harborough -Coventry Road	338	1
2	292	Little Bowden South	798	792	Lutterworth Centre & East	310	2
3	277	Lutterworth Centre & East	792	798	Little Bowden South	216	3
4	160	Ullesthorpe & Magna Park	816	816	Ullesthorpe & Magna Park	164	4
5	159	Market Harborough Town Centre	795	793	Lutterworth North	135	5
6	154	Lutterworth North	793	806	Market Harborough - Welland Park	124	6
7	147	Market Harborough East - Welland Industrial Estate	796	795	Market Harborough Town Centre	122	7
8	131	Market Harborough - Welland Park	806	781	Wistow & Great Glen South	117	8
9	119	Fleckney Centre & South	778	791	Lutterworth South	117	9
10	116	Primethorpe	775	788	Foxton, Saddington & Theddingworth	112	10
11	111	Bosworth, Kilworth & Mowsley	771	796	Market Harborough East - Welland Industrial Estate	111	11
12	102	Scraptoft	811	808	Misterton, Gilmorton & Catthorpe	110	12
13	86	Misterton, Gilmorton & Catthorpe	808	811	Scraptoft	105	13
14	86	Peatling & Bruntingthorpe	810	778	Fleckney Centre & South	100	14
15	86	Stoughton & Thurnby South	812	771	Bosworth, Kilworth & Mowsley	97	15
16	74	Lutterworth South	791	775	Primethorpe	94	16
22	60	Foxton, Saddington & Theddingworth	788	812	Stoughton & Thurnby South	88	19
24	58	Wistow & Great Glen South	781	810	Peatling & Bruntingthorpe	51	32

Source: Leicestershire Constabulary, CIS. Figures refer to the period of the last twelve months (Dec'06 to Nov'06) and the previous twelve months (Dec'04 to Nov'05). The Lower Super Output Area (LSOA) codes for Harborough District all begin with "E01025" followed by three further digits. Only the last three digits are shown in the table here.

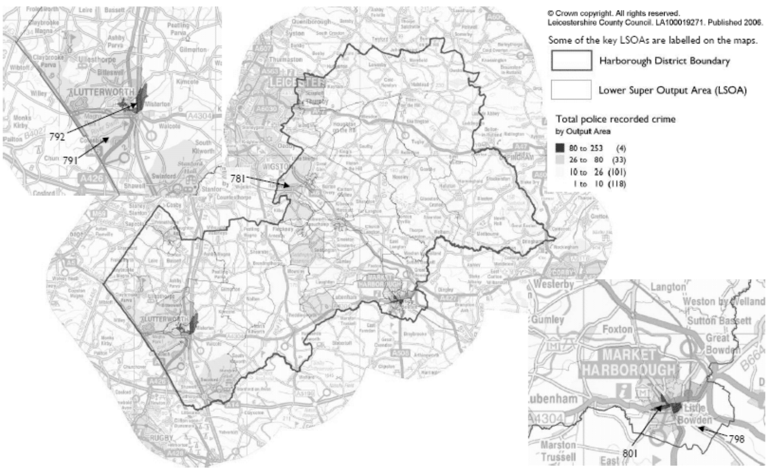


Figure 3.5: Handout (two sided) showing graphic, mapping and presentational sophistication and the influence of work of Edward Tufte

The attributes seen in the unit's documents adds confirmatory weight to the observations made at the regional crime event (see section 3.3.2) about the importance to this unit of their skills in graphic and spatial **presentation** as a **differentiating** factor.

Public Libraries internal documents

The internal documents about the PLM unit I studied were a mixture of: publicity material for library marketing initiatives; internal library reporting documents that enumerate stock or borrowing levels or report achievement against targets; the results of library borrower surveys produced by external companies; and the report of the Research and Information team work led by R on library borrowing recency and frequency. There are no examples of reports using advanced graphics or maps, with the exception of R's report.

Library publicity material include a 'Free Day' to promote free nature of public libraries and all-day Saturday opening; 'Borrow 6 books, get a free cd/dvd' and '3 for 2 offer on cds/dvds' to increase revenues; a 'Come back to us campaign'. These are aimed at a general audience. A typical external report is Barnes and Priest (2005). This employs a questionnaire to ask lapsed library customers about future borrowing intentions and collect their demographic information (n=1647; questionnaire mailed to 7000). The report presents results in a "top line" format only with no cross tabulation.

Radburn, Pye and Forster (2007) represents a collaboration between the Community Services Department (responsible for public libraries) and the Research and Information Unit to attempt to understand public library customers better. A significant effort was made to extract information suitable for analysis from the obsolescent libraries stock application TALIS and to represent customers spatially and by useful attributes such as their recency and frequency of visits. The process represented work in progress, and was reported to the wider Libraries community (Thomas et al., 2007).

The library documents viewed give two insights:

- The limited scope of the marketing material lends weight to the L1 interview analysis about the constraints of budget and to the lack of information to market to specific segments.
- The presence of simple analysis and lack of graphic or spatial analysis is indicative of either limited tools, or skill limitations, or both. However, the(Radburn, Pye and

Forster (Radburn, Pye and Forster, 2007) report represents a turning point for PLM as it points to new possibilities by tapping into the skills, expertise and tools of R.

3.3.3.2 EXTERNAL DOCUMENTATION

Geovisualization application design is predominantly the domain of academics at the current time, and searching external documentation is a well-developed skill for this community. It is proposed as a pragmatic suggestion for a source of contextual information. Clearly studying external documentation is not a replacement for studying internal documents or for field studies of domain experts in general. The most likely value of such information from external documentation is provide corroboration (or otherwise) of insights obtained from subjects – to contrast their context to the generality of similarly situated individuals or teams.

Crime and disorder reduction external documents

External documents in the field of crime and disorder reduction fall into a number of themes: the background to recent crime reduction initiatives in the UK, particularly evidence-based policing; the background to the creation of CDRPs and their role and functioning; and - of particular interest to geovisualization researchers - the use of spatial tools in CDR.

Background to crime in UK – evidence based policing

In parallel to the establishment of CDRPs was the introduction of an evidence-based approach to crime reduction (Tilley and Laycock, 2000, 2002), paralleling similar developments in the USA (Sherman, 1998; Sherman et al., 1999). Sherman (1998) describes evidence-based policing as "use of the best available research on the outcomes of police work to implement guidelines and evaluate agencies, units, and officers." Cabinet Office (1999) emphasise the importance of good quality policy making on:

> "high quality information, derived from a variety of sources - expert knowledge; existing domestic and international research; existing statistics; stakeholder consultation; evaluation of previous policies; new research, if appropriate; or secondary sources, including the internet. Evidence can also include analysis of the outcome of consultation, costings of policy options and the results of economic or statistical modelling."

According to Bullock, Mountford and Stanley (2001), a policy maker adopting an evidence based approach "reviews existing research, commissions new research, consults relevant experts and/or used internal and external consultants, and considers a range of properly costed and appraised options." Tilley and Laycock (2000) caution "evidence-based policy in relation to crime…looks like plain common sense. Yet getting good evidence to policy and policy to good evidence faces an uphill struggle... evidence-based policy calls for a more policy-literate research community, and a more research-literate policy community."

Background to CDRPs and their role

In the UK, the Crime and Disorder Act 1998 (Home Office, 1998) established local crime reduction partnerships (CDRPs), reviewed (Home Office, 2006) as a result of the White Paper, 'Building Communities, Beating Crime' (Home Office, 2004). CDRPs bring together local partners such as the police, local authorities, health authorities, probation services and other bodies to provide comprehensive solutions to crime and disorder issues. The 1998 Act requires CDRPs to produce strategic crime reduction plans on a rolling three-year basis. Support teams were created to support CDRPs in their work preparing and monitoring such plans, and in Leicestershire, the CDR unit was created within the local county council.

Hope (2005) provides an overall review of the government's reforms and policies of crime prevention and community safety in England and Wales since 1997. Home Office (2007) sets out the main lessons learnt over the past ten years in crime and disorder reduction and the key areas for future focus. The National Audit Office (Gibby, Mason and Murphie, 2004) review how well Home Office Crime Reduction initiatives such as CDRPs reduce crime and concluded they "contributed to the continuing reduction in crime reported by the British Crime Survey."

However there are a number of articles that consider the workings of CDRPs critically. Read and Tilley (2000) find: "Amongst the police, however, other agencies were most often valued for their participation in implementing or funding the implementation of measures to address the problem. They were rarely seen to be central to the whole problem-solving process." and "Partnership involvement in deciding what to do was seen to sometimes lead to fudging schemes, as partnerships lose focus accommodating the varying interests, and ideologies of partners are satisfied at the expense of clear thinking and targeted action. There is a risk that partnership in all things is fetishised as an end in itself." Organ (2005) finds "idiosyncratic differences of coterminosity, data, procedure and culture between police forces, local authorities, CDRPs and other government bodies...". Skinns (2006) reviews the practices and politics of three community safety partnerships (CSPs) and finds organisational weaknesses. "CSPs resemble a collection of loosely affiliated agencies… [more] a flotilla rather than an armada." Loveday (2006) considers the impact of "the failure to establish coterminous boundaries between police force areas and local authorities and…the problematic nature surrounding the delivery of crime reduction strategies within non-metropolitan counties." Further critiques are made by Hughes (2002).

Use of spatial tools in crime and disorder reduction

Government bodies have been active in promoting resources and mapping solutions to combat crime for a decade, led by the USA (Boba, 2000; Harries, 1999). As well as being a good general introduction to the basics of map use in the crime and disorder domain, Harries provides an example of an attempt to communicate a complex application domain (GIS in this case) to an audience of prospective general users.

There has been academic interest in researching the creation of geovisualization tools and applications for tactical law enforcement. These include the COPLINK Spatio Temporal Visualizer (STV) (Buetow et al., 2003; Chen et al., 2005). Bowers, Johnson and Pease (2004) aim to develop predictive crime mapping tools and describe a mapping procedure that "seeks to produce 'prospective' hot-spot maps", while Ashby (2005) discusses "the value of geodemographic neighbourhood typologies, spatial analysis and geographical expertise in the evaluation of policing performance and the refinement of local service delivery." Commercial products have been created that extend established GIS systems to provide crime reduction-related spatial and temporal tools such as Crime Mapper (ESRI (UK) Ltd, 2007).

Academic and UK government interest has focused on delivery and use of spatial tools for crime reduction. Wastell (2005) evaluates the potential of geographical information systems to support strategic decision making in the context of local CDRPs. Weir and Bangs (2007) aggregate information about the use of GIS by crime analysts, and although their sampling methodology has weaknesses, some common themes do emerge. GIS is used predominantly for presentation rather than analysis; both data and training are poor; skill levels vary.

A fair number of these insights from external documents echo results drawn from interviewing, observing and studying internal documents of LCC CDR unit members. For example, difficulties accessing police data; difficulties of partnership working, especially the difference in culture between partners; the tendency to elevate presentation at the expense of analysis; the need to disseminate good practice. This lends weight to the notion that the experiences of the LCC CDR unit are not unique, are rooted in the generality of their situation and thus learning from this one unit may be more widely applicable.

Public Libraries external documents

Relevant external documents in the field of public libraries cover the history of public library use and their general decline; and the marketing and branding of public libraries.

Public library use and decline

Smith (1999) compares data from a large public library with significant studies of public library use from the last 50 years, examining the social and demographic factors influencing use and found that "aspects of public library use have remained constant over at least the last 50 years, and across geographical boundaries." These aspects are

> "a small minority of adults regularly use public libraries; a small number of library users are responsible for most library borrowing; library use is determined by education; library users buy more books than non-users; most people do not use the library as a source of information; libraries are used for leisure, not to pursue enlightenment; library users have wider social and community interests than those who do not use libraries; most demand is for recently published material...and for pop music”

Hawkins, Morris and Sumsion (2001) identify library use and value related to a person's age, and finds that "while book borrowing is spread fairly evenly across the population, information seeking is much less so, with those in most need of information least likely to seek it from a public library." Grindlay and Morris (2004) review possible reasons for the decline in annual adult book issues from UK public libraries since 1980 as "cuts in book funds in real terms; reduced accessibility of libraries through library closures and reduced opening hours; increased real households' disposable income; the widespread use of home computers and the Internet."

The Library and Information Statistics Unit at Loughborough University conducts a periodic survey of libraries and information services in the UK and provides the most recent figures available on expenditure, stock and staffing. The most recent report (White, 2008) reveals that while expenditure on UK public libraries has generally increased between 1998 and 2006, arresting a long term decline, in 2007/8 there was no growth and an expected 1.4% decrease in 2008/9. Book expenditure fell by 1% in 2007/8 with a further 0.5% decrease forecast for 2008/9; audio-visual expenditure increased 4.2% in 2007/8 with a forecast decrease of 6.6% in 2008/9. Total staff fell by 1.2% for the third year running in 2007/8, with professional staff decreasing 6.2% in 2007/8. Creaser, Maynard and White (2006) provide detailed statistics on many aspects of public libraries and chart the decline of public library book borrowing - a 40%

decline in books issued per capita from 1990 to 2005 in spite of actual and per capita increases in public library expenditure.

Public library marketing and branding

Hood and Henderson (2005) provide an overview of branding activity in the UK public library service. Barlow and Morris (2007) examine libraries from the perspective of new users and highlighted a number of best practices to aid future library design looking at the impact of new versus old buildings and comparing public libraries to bookshops.

The last Audit Commission report into LCC Libraries (Audit Commission, 2002) assessed LCC in 2002 as "providing a 'good', two star service that has uncertain prospects for improvement." The subsequent appointment of L1 from the private sector can be seen as a response to issues within what is clearly a Cinderella service in long-term decline. But the external literature makes clear the extent of the challenge facing L1 too - the constraints L1 reports in interview - skills issues, data access issues, tools issues, budget issues - are deep and ingrained in the UK public libraries service. There is a consonance with the wider domain, and I can be more confident that the issues addressed are not just confined to LCC.

As in CDR, consulting the external documentation on public libraries sets L1's situation in a more general context and provides the prospect that progress in LCC public libraries using new approaches – like the use of geovisualization to visually segment library borrowers – may have wider applicability.

3.3.4 RESULTS FROM CARD SORTING

Card sorting is intended to give an insight into the conceptual world of CDR tasks from the CDR unit and geovisualization expert perspectives. Figure 3.6 shows the crime task sort in progress by a CDR subject. Table 3.3 gives a list of the 35 crime tasks and their categorisation under freely chosen headings by CDR subjects C1, C2 and C3 and by a geovisualization expert (D). Asterisks show the task considered 'most representative' of each category as determined by the CDR subjects. The freely chosen headings need to be coded and categorised in order to gain traction on the data. Following the approach of Lewins and Silver (2007) outlined in section 2.1.4, a categorisation was generated inductively from "the salient aspects identified in the data". Clearly 'spatial-related' – a key focus of the research - needs to be a category. Other categories are "temporal-related" and "attribute-related"; a "spatio-temporal-related"

Figure 3.6: Crime task card sort in progress by a CDR subject

category is needed as one subject used this specifically. The small number of remaining headings are assigned to an "other" category.

Figure 3.7 shows the 35 crime tasks aggregated according to the category heading given by subjects based on this coding. It shows that aggregated headings differ between CDR unit members – C1 in particular categorises tasks predominantly by attribute and **never by space**. C2 categorises tasks predominantly by space; C3 is midway between the two. Geovisualization expert D's results are similar to C3's. C3 is the unit GIS expert and might be more aware of the spatial aspects of the crime tasks. Certainly, the difference in the nature of the header descriptions would indicate that such headings, chosen freely in a card sort, did not 'converge' to a narrow set of terms typical of the unit. This has implications for understanding context of use in that interviews with, and observations of, a single individual might reflect a partial view of the totality of the context. In the case of C1, **a view that might exclude or minimise spatial aspects. Asking subjects to complete a task card sort and analysing the headings may give an indication of this kind of issue so that its consequences could be anticipated**.

CRIME TASK	C1	C2	C3	D
Arson in schools	ASB, low level crime, fear of crime	Place related	Location specific crime	Geographic focus
Bicycle theft	Specific thematic research	Low level crime	Theme – crime topic	General reports
Car park crime	Specific thematic research	Place related	*Location specific crime	Geographic focus
Cars set alight	ASB, low level crime, fear of crime	Place related	Theme – crime topic	General reports
CCTV effectiveness	*Specific thematic research	Place related	*Comparison of geography	General reports
Crime affecting the Islamic community in the county.	Crime affecting specific communities	*Hate crime	Theme – less about the numbers	*Conditioned by attribute
Crime on Leicestershire's borders with other counties	Implausible	Geography comparison	Comparison of geography	Geography essential
Crime taking place at annual festivals or sporting events	Seasonal crime	Time and space	Location specific crime	Geographic focus
Crimes affecting pensioners living alone	*Crime affecting specific communities	Place related	Theme – less about the numbers	Conditioned by attribute
Crimes associated with places that sell alcohol	Alcohol; night-time economy	Place related	Location specific crime	Geography essential
Crimes associated with, and/or affecting, recent migrants	Crime affecting specific communities	Hate crime	Theme – less about the numbers	Conditioned by attribute
Crimes occurring outside school premises after school	ASB, low level crime, fear of crime	*Place related	Location specific crime	Geographic focus
Crimes taking place near pubs at or about closing time	*Alcohol; night-time economy	*Time and space	Time comparison	Geography essential
Domestic crime	*Domestic crime	Hate crime	Theme – more people specific	*General reports
Drug related crime	ASB, low level crime, fear of crime	Place related	Theme – crime topic	General reports
Fear of crime and how it relates to the reality	*ASB, low level crime, fear of crime	*Perception	*Theme – less about the numbers	Relationships/ comparison
Friday and Saturday night crime	Alcohol; night-time economy	*Time related	*Time comparison	Time constrained
Graffiti	ASB, low level crime, fear of crime	Low level crime	Theme – crime topic	General reports
Housebreaking	Specific thematic research	Place related	Theme – crime topic	General reports

CRIME TASK	C1	C2	C3	D
How crime varies across neighbourhoods	*Neighbourhood focus crime	*Geography comparison	Comparison of geography	*Geography essential
Illegal dumping	ASB, low level crime, fear of crime	Low level crime	Theme – crime topic	General reports
Linking where police activity v 'before' and 'after' crime	Performance management	Place related	Time comparison	*Relationships/ comparison
Low level harassment (e.g. bad neighbours)	ASB, low level crime, fear of crime	Low level crime	Theme – more people specific	Conditioned by attribute
M1 Service station(s) crime	Specific thematic research	Place related	Location specific crime	Geographic focus
Predicting actual end of year crime against target	Performance management	*Predictive and seasonality	*Statistical, forecasting & management information	*Time comparison
Racial crime	Crime affecting specific communities	*Hate crime	*Theme – more people specific	General reports
Seasonal crime	*Seasonal crime	Predictive and seasonality	Time comparison	*Time constrained
Setting targets for crime categories for the year ahead	Performance management	Predictive and seasonality	Statistical, forecasting & management information	Time comparison
Shoplifting in the major town centres	Specific thematic research	Geography comparison	Location specific crime	*Geographic focus
The big increases in crime in the last month	*Performance management	Data integrity	Statistical, forecasting & management information	Time comparison
Top 10 crimes this month by impact on the community	Performance management	Data integrity	Time comparison	Time comparison
Travel to punchup [distance travelled to commit assault]	Alcohol; night-time economy	Time and space	*Journey - distance related	Geography essential
Uncertainty in the county's crime data	Implausible	*Data integrity	*Housekeeping/ Data issues	Relationships/ comparison
Vandalism	ASB, low level crime, fear of crime	*Low level crime	*Theme – crime topic	General reports
Weekend crime	Seasonal crime	Time related	Time comparison	Time constrained

Table 3.3: Card sort crime tasks and categorisation by CDR subjects C1, C2 and C3 and geovisualization expert (D). Asterisks show task considered by each subject to be most representative in each category. [ASB is anti-social behaviour]

	C1	C2	C3	D
Bicycle theft	1	1	1	1
Crime affecting the Islamic community in the county	1	1	1	1
Crimes associated with, and/or affecting, recent migrants	1	1	1	1
Domestic crime	1	1	1	1
Graffiti	1	1	1	1
Illegal dumping	1	1	1	1
Low level harassment (e.g. bad neighbours)	1	1	1	1
Racial crime	1	1	1	1
Vandalism	1	1	1	1
Cars set alight	1	2	1	1
Crimes affecting pensioners living alone	1	2	1	1
Drug related crime	1	2	1	1
Housebreaking	1	2	1	1
CCTV effectiveness	1	2	2	1
Arson in schools	1	2	2	2
Car park crime	1	2	2	2
Crimes associated with places that sell alcohol	1	2	2	2
Crimes occurring outside school premises after school	1	2	2	2
How crime varies across neighbourhoods	1	2	2	2
M1 Service station(s) crime	1	2	2	2
Shoplifting in the major town centres in the county	1	2	2	2
Friday and Saturday night crime	1	3	3	3
Travel to punchup	1	4	2	2
Crimes taking place near pubs at or about closing time	1	4	3	2
Fear of crime and how it relates to the reality	1	5	1	5
Seasonal crime	3	3	3	3
Weekend crime	3	3	3	3
Crime taking place at annual festivals or sporting events	3	4	2	2
Crime on Leicestershire's borders with other counties	5	2	2	2
Linking where police activity v 'before' and 'after' crime	5	2	3	5
Predicting actual end of year crime against target	5	3	5	3
Setting targets for crime categories for the year ahead	5	3	5	3
Top 10 crimes this month by impact on the community	5	5	3	3
The big increases in crime in the last month	5	5	5	3
Uncertainty in the county's crime data	5	5	5	5

Figure 3.7: Crime tasks aggregated according to the category heading given by subjects (1=attribute related; 2=spatial; 3=temporal; 4=spatio-temporal; 5=other)

Another way of analysing this data is to set aside the freely attributed heading names headings and use a cluster analysis that relies only on which crime tasks are stacked together (and not what a subject calls them). Figure 3.8 shows the tree diagram from a hierarchical cluster analysis resulting from a 'pair-group average' clustering for subjects C1, C2 and C3."This method is…very efficient when the objects form natural distinct "clumps," however, it performs equally well with elongated, "chain" type clusters" (Hill and Lewicki, 2006). The EZCalc application (Dong, Martin and Waldo, 2001) is used for the calculations and output.

The tree in Figure 3.8 results in a clustering that makes subjective 'sense'. Crimes like vandalism, graffiti and illegal dumping; or crime affecting the Islamic community and crime affecting migrants are linked together at the lowest level. At the intermediate level there are eight clusters (shaded alternately in Figure 3.8) that relate (subjectively) to 'meta-crime' questions; management reporting of crime; the 'night-time economy'; seasonal crime; crimes affecting specific communities; crimes occurring in the community; fear of crime; and minor crime. Cluster member numbers range from 1 (for fear of crime) to 8 (for minor crime). From the clustering it is possible to see that certain crime tasks are regarded as very different from others by the CDR unit, for example the 'meta-crime' questions (dealing with crime data uncertainties, crime variance and crimes close to LCC's borders) and 'fear of crime'. **For a geovisualization application to be of most use to the CDR unit, the clustering of crime tasks provides an indication of where it would have most breadth of coverage**. Note that the relative 'value' of these crime task clusters to the subjects cannot be determined from card sorting.

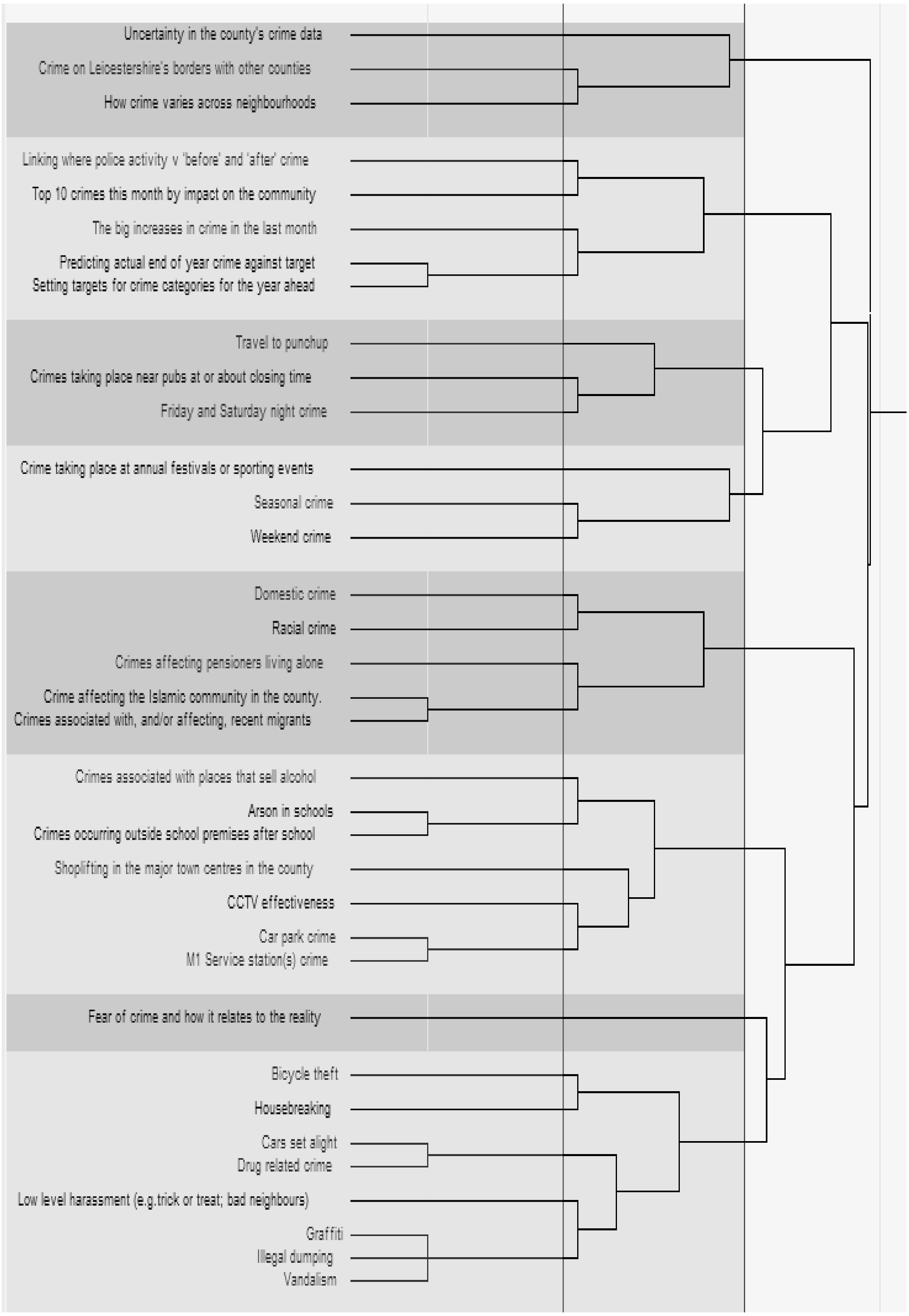


Figure 3.8: Tree diagram showing the averaged clustering of crime tasks for C1, C2 and C3 Different shading indicates different degrees of clustering.

The clustering application allows a quantitative overview of how a subject's or groups of subjects' clustering behaviour differs. The method generates a **distance matrix** that expresses how far each crime task is relatively from every other in the final tree. Subtracting the normalised values in one distance matrix (say for the geovisualization expert (D)) from the averaged distance matrix of C1+C2+C3) yields a **difference distance matrix** that shows the disparity (it is an analogous process to map algebra (Tomlin, 1990)). By calculating the variance of each crime task, those with the greatest spread of differences can be highlighted visually. Figure 3.9 shows the difference distance matrix for D minus the average of C1+C2+C3 as an example. Similar displays could be produced for differences between geovisualization expert D and an individual CDR subject. In this case, CCTV effectiveness, domestic crime and racial crime are the crime tasks clustered most differently by D compared to C123. However there is strong agreement on seasonal crime, weekend crime, setting targets for crime categories for the year ahead, crime affecting the Islamic community, and crimes associated with, and/or affecting, recent migrants. **The difference distance matrix provides an objective way of seeing which tasks are clustered most differently by different subjects and provide assistance in assessing different subject's context**. Figure 3.10 shows the C1+C2+C3 averaged tree diagram with the addition of geovisualization expert D's headings and heading clusters. This provides a visual check for the notion that there is more that unites the CDR subjects and the geovisualization expert than divides them.

In summary, card sorting is useful in a geovisualization situation for exploring context of use. It enables the researcher to mix together tasks that are spatial and non-spatial or partly spatial and examine how the subjects categorise them. It can discover who regards spatiality as a key organising factor, and such information can inform any future design and analysis. The method provides quantitative data rather than qualitative, differentiating it from information acquired via interviews, observation and studying documents and providing another window into the context problem. It can be used compare different subjects' conceptual views of tasks using the difference distance matrix and thus highlight different clustering of tasks within the subject's domain. The technique can also be used in reverse, to test subject's understanding of the geovisualization domain, and this useful approach is employed in Chapter 4.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	var
Arson in schools	1	0.0	0.0	0.3	-0.7	-0.3	0.0	0.0	0.7	-0.3	-0.7	0.0	0.0	0.0	0.0	-0.7	-0.3	0.0	-0.3	-0.3	0.0	-0.3	-0.3	-0.3	0.3	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	-0.3	0.0	0.09
Bicycle theft	2	0.0	0.0	-0.3	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.7	0.0	0.0	0.3	0.3	0.0	0.3	0.0	-0.3	-0.3	0.0	1.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.11
Car park crime	3	0.3	-0.3	0.0	-0.3	-0.7	0.0	0.0	0.7	-0.3	-0.7	0.0	0.3	0.0	0.0	-0.3	0.0	0.0	0.0	-0.7	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.08
Cars set alight	4	-0.7	0.7	-0.3	0.0	0.7	0.0	0.0	0.0	-0.3	-0.3	0.0	-0.7	0.0	1.0	0.0	-0.3	0.0	0.3	0.3	0.0	0.3	-0.3	-0.3	-0.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.15
CCTV effectiveness	5	-0.3	0.7	-0.7	0.7	0.0	0.0	-0.3	0.0	-0.3	-0.3	0.0	-0.3	0.0	1.0	0.7	0.0	0.0	1.0	0.3	-0.3	1.0	-0.3	0.0	-0.7	0.0	1.0	0.0	0.0	-0.3	0.0	0.0	0.0	-0.2	1.0	0.0	0.23
Crime affecting the Islamic community in the county	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	-0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05
Crime on Leicestershire's borders with other counties	7	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	1.0	-0.5	0.0	0.0	0.10
Crime taking place at annual festivals or sporting events	8	0.7	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.7	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	-0.3	0.0	0.7	0.0	0.0	-0.3	0.0	0.0	-0.3	0.08
Crimes affecting pensioners living alone	9	-0.3	0.0	-0.3	-0.3	-0.3	0.3	0.0	0.0	0.0	-0.3	0.3	-0.3	0.0	0.0	-0.3	-0.3	0.0	0.0	-0.3	0.0	0.0	-0.3	1.0	-0.3	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.07
Crimes associated with places that sell alcohol	10	-0.7	0.0	-0.7	-0.3	-0.3	0.0	1.0	-0.3	-0.3	0.0	0.0	-0.7	0.7	0.0	-0.3	0.0	-0.3	0.0	-0.3	1.0	0.0	-0.3	0.0	-0.7	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.7	0.0	0.0	0.0	0.16
Crimes associated with, and/or affecting, recent migrants	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	-0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05
Crimes occurring outside school premises after school	12	0.0	0.0	0.3	-0.7	-0.3	0.0	0.0	0.7	-0.3	-0.7	0.0	0.0	0.0	0.0	-0.7	-0.3	0.0	-0.3	-0.3	0.0	-0.3	-0.3	-0.3	0.3	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	-0.3	0.0	0.09
Crimes taking place near pubs at or about closing time	13	0.0	0.0	0.0	0.0	0.0	0.0	1.0	-0.3	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	-0.7	0.0	0.0	1.0	0.0	-0.3	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	-0.3	0.3	0.0	0.0	-0.3	0.10
Domestic crime	14	0.0	1.0	0.0	1.0	1.0	-0.3	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	1.0	0.0	-0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.20
Drug related crime	15	-0.7	0.7	-0.3	0.0	0.7	0.0	0.0	0.0	-0.3	-0.3	0.0	-0.7	0.0	1.0	0.0	-0.3	0.0	0.3	0.3	0.0	0.3	-0.3	-0.3	-0.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.15
Fear of crime and how it relates to the reality	16	-0.3	0.0	0.0	-0.3	0.0	-0.3	0.0	0.0	-0.3	0.0	-0.3	-0.3	0.0	0.0	-0.3	0.0	0.0	-0.3	0.0	0.0	-0.3	1.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	-0.3	0.0	0.09
Friday and Saturday night crime	17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	-0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	-0.3	-0.3	0.0	0.0	0.3	0.04
Graffiti	18	-0.3	0.3	0.0	0.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	1.0	0.3	-0.3	0.0	0.0	0.7	0.0	0.0	0.0	-0.7	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.13
Housebreaking	19	-0.3	0.3	-0.7	0.3	0.3	0.0	0.0	0.0	-0.3	-0.3	0.0	-0.3	0.0	1.0	0.3	0.0	0.0	0.7	0.0	0.0	0.7	-0.3	0.0	-0.7	0.0	1.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.7	0.0	0.15
How crime varies across neighbourhoods	20	0.0	0.0	0.0	0.0	-0.3	0.0	0.3	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	1.0	-0.2	0.0	0.0	0.09
Illegal dumping	21	-0.3	0.3	0.0	0.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	1.0	0.3	-0.3	0.0	0.0	0.7	0.0	0.0	0.0	-0.7	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.13
Linking where police activity v 'before' and 'after' crime	22	-0.3	0.0	-0.3	-0.3	-0.3	0.0	0.0	0.0	-0.3	-0.3	0.0	-0.3	-0.3	0.0	-0.3	1.0	-0.3	0.0	-0.3	0.0	0.0	0.0	0.0	-0.3	-0.3	0.0	-0.3	-0.3	0.0	-0.3	-0.7	0.0	1.0	0.0	-0.3	0.11
Low level harassment (e.g.trick or treat; bad neighbours)	23	-0.3	-0.3	0.0	-0.3	0.0	1.0	0.0	0.0	1.0	0.0	1.0	-0.3	0.0	-0.3	-0.3	-0.3	0.0	-0.7	0.0	0.0	-0.7	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.7	0.0	0.15
M1 Service station(s) crime	24	0.3	-0.3	0.0	-0.3	-0.7	0.0	0.0	0.7	-0.3	-0.7	0.0	0.3	0.0	0.0	-0.3	0.0	0.0	0.0	-0.7	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.08
Predicting actual end of year crime against target	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.3	0.7	0.0	0.0	0.0	0.0	0.02
Racial crime	26	0.0	1.0	0.0	1.0	1.0	-0.7	0.0	0.0	-0.3	0.0	-0.7	0.0	0.0	0.3	1.0	0.0	0.0	1.0	1.0	0.0	1.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.24
Seasonal crime	27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	-0.3	0.0	0.0	-0.3	0.0	0.0	-0.3	0.0	0.0	0.0	0.3	0.03
Setting targets for crime categories for the year ahead	28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.3	0.7	0.0	0.0	0.0	0.0	0.02
Shoplifting in the major town centres in the county	29	0.7	-0.3	0.3	0.0	-0.3	0.0	-0.3	0.7	0.0	-0.3	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	-0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06
The big increases in crime in the last month	30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.3	0.0	-0.3	0.0	0.0	0.02
Top 10 crimes this month by impact on the community	31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	-0.7	0.0	0.0	0.7	0.0	-0.3	0.7	0.0	0.3	0.0	0.0	-0.3	0.0	-0.3	0.06
Travel to punchup	32	0.0	0.0	0.0	0.0	0.0	0.0	1.0	-0.3	0.0	0.7	0.0	0.0	0.3	0.0	0.0	0.0	-0.3	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.08
Uncertainty in the county's crime data	33	0.0	0.0	0.0	0.0	-0.2	0.0	-0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	-0.2	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	-0.3	0.0	0.0	0.0	0.0	0.07
Vandalism	34	-0.3	0.3	0.0	0.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	1.0	0.3	-0.3	0.0	0.0	0.7	0.0	0.0	0.0	-0.7	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.13
Weekend crime	35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.02

Figure 3.9: Difference distance matrix showing the normalised geovisualization expert (D) distance matrix minus the averaged C1, C2 and C3 combined distance matrix (red-white-blue bivariate colouring). The final column shows the variances of each row (darker the colour hue = greater the variance) as a rough indicator of agreement between D and the averaged C1, C2 and C3 categorisation. The matrix is symmetrical along the leading diagonal.

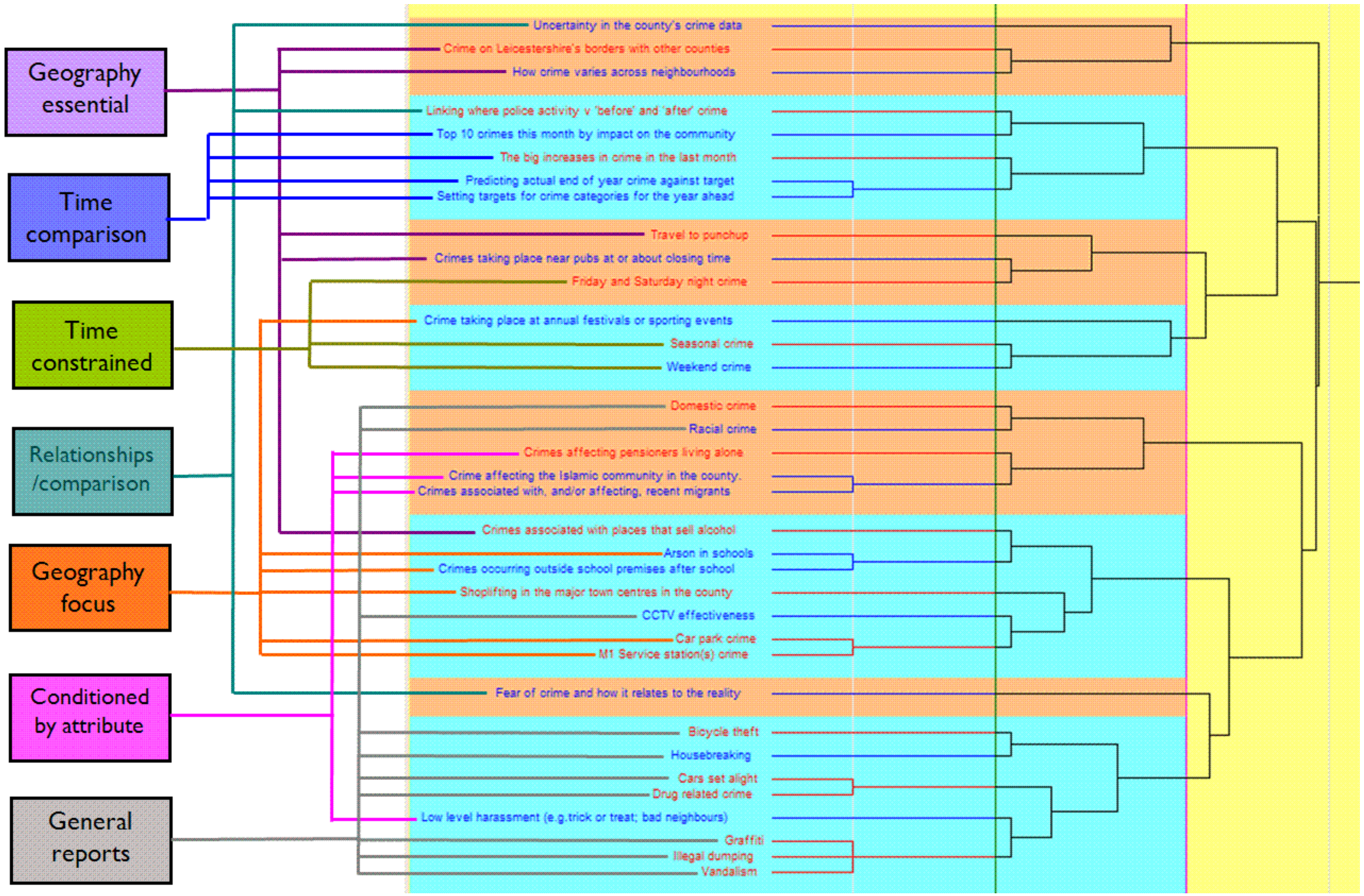


Figure 3.10: Crime task categories (left hand side) as determined by geovisualization expert (D) related to the average tree cluster for C1, C2 and C3 combined

A cautionary note needs to be made about the choice of crime tasks. There is a paradox here - the tasks written on the cards have to be compiled by the researcher, and the researcher has an imperfect knowledge of the subject's domain. And this is done in order to obtain an understanding of the subject's domain. Without an informed intermediary to validate the tasks (as was done by R in this case – see section 3.2.1), there is no guarantee that a particular task list will cover the full range of possible tasks, that it contains only plausible tasks, or that it does not unreasonably over-sample or under-sample certain tasks. Clearly, a process of understanding subjects' context via interviews, observation and/or studying documentation needs to precede card sorting.

3.3.5 'DATA IN CONTEXT'

So far, this chapter considers different context of use approaches – interviews, observation, studying documentation and card sorting – and teases out results from LCC subjects that have implications for geovisualization. But in attempting to understand the context of use of the subjects, an important aspect of applications designed for exploration (such as geovisualization applications) is not made explicit in ISO13407 - to understand and acquire subjects' data - not merely metadata for data (as might be the case for non-exploration applications), but the data itself.

Clearly the way to do that involves some of the approaches already discussed (specifically interviews and studying documentation). What is different is that the focus is not on the subjects and their context of use, but rather on their **data** and its **context in use**. This is something that distinguishes the production of applications that aim to explore data from other kinds of application. Geovisualization's particular uniqueness is that the researcher needs to acquire and understand not just domain attribute data but the associated spatial data (and perhaps temporal data as well). Clearly, an understanding of the context of both subjects *and* their data is needed.

In the majority of cases (the exceptions being domain experts working with publicly available data), the domain experts will be custodians of, or at least gatekeepers to, their data. For a designer planning to work with domain experts to create a geovisualization application, it is implicit from the outset that at some point the designer will need to acquire the domain expert's data or a significant sample of it.

This need for the data demands something different from seeking merely to understand subjects' context of use, and many issues arise as a consequence. As a result of working with LCC subjects, I determine the following to be relevant:

- A basis for trust has to be established and maintained with the subjects sufficient for them to be willing to part with data. This is greatly in excess of the trust needed to ask subjects about their context of use. In the case of the CDR team, the release of data happened gradually rather than immediately. In the case of Libraries data, this was forthcoming once I had explained the purpose of the research to the Head of Libraries.
- understanding data in detail needs subject time and effort; metadata needs to be collected, understood and documented. This was true in both CDR and Libraries cases. In addition, the time taken for the CDR data and the Libraries data to be data cleansed and placed in a form it could be manipulated was several weeks in each case.
- Confidentiality of data may be a concern and anonymisation a condition of releasing it. This may have implications for design – for example dictating a polygon approach to aggregated spatial crime data that could otherwise be handled as point data.
- Intellectual property rights inherent in spatial data that subjects do not own themselves (for example Ordnance Survey data) might be difficult to access and involve third parties who are custodians of such data within an organisation. This will always be an issue for geovisualization applications that by their nature include geographic data.

My LCC experiences show that a number of secondary issues arise:

- Data contributed by subjects to the researcher diverges from its original source as it is manipulated in different ways – to clean the data, remove outliers, make transformations, aggregate and filter and so on. This is a concern to subjects who cannot control the integrity of this data and seek to understand the full details of any transformation processes the data have undergone.
- If getting data from subjects is difficult, there are also problems reintroducing it to the subjects in the form of prototype applications. Firewalls, prohibition on connecting computers from outside the organisation to the internal network, and prohibition on loading unapproved applications or plug-ins (even such tools as an SVG plug-in for a browser) onto the organisation's computers, create practical problems that impede interaction between subjects and application designers.

- As a consequence, the researcher's laptop often becomes the mechanism for showing prototypes of applications in the field, and thus subjects are not situated within their own desktop environment. This is ameliorated by 'borrowing' a local external monitor on occasions (often along with the room they were in) or by 'importing' one to overcome the constraints of small screen size. Laptop processing power can also be a limitation when attempting to run both a geovisualization application and monitoring programmes. For example, while laptop audio recording is usually possible at the same time as running a geovisualization application, I found using screen capture software was not. The finding for HC approaches applied in a geovisualization context is that the demands of calculating and displaying geovisualizations makes demands on the computer available in the field (choice of which might be limited) and that certain HC techniques of monitoring (such as screen capture applications) may not be possible as a consequence.

A brief introduction to the details of CDR and public libraries data is useful to indicate the particular characteristics and complexities of the data. This detail is essential because it constrains geovisualization possibilities in as tangible a way as does subjects' context of use. This information comes from open-ended interviews (and follow up email exchanges) with subjects to capture information about data and metadata *and* from my own interaction with the data. Indeed, many of the deeper and more subtle insights about the data – and hence constraints to geovisualization design - come solely from studying and working with the data myself. This process of **'studying data'** is akin to the process of 'studying documentation' – an off-line process, disconnected from subjects, who nevertheless provide the raw data (documents or domain data).

3.3.5.1 CRIME DATA

The crime and disorder data possessed by the LCC CDR team comes overwhelmingly from police sources. The data provided to me covered over half a million crimes over a five year period. My insights about it from interviews are:

- At the time of this research, point data on crimes is not made available to the CDR unit. Detailed crime and temporal data for are provided for urban areas, but aggregated to the nearest 100m square by the police. For other, rural, areas, the detailed crime attributes data are made available aggregated to census output area and aggregated by month. As this research was concluding, the LCC CDR unit are receiving point data for all areas from the police. Figures 3.11 to 3.13 show samples of this data with relevant metadata.

- Crime data has three temporal attribute associated with each record - the time the crime is reported, the earliest time the offence could have been committed, and the latest time it could have been committed. This uncertainty over offence time results in aoristic crime data (Ratcliffe and McCullagh, 1998) and complicates analysis. Different crimes can have very different uncertainties – if you are robbed you know with some certainty when that was; however returning from a two week holiday to find you have been burgled is another matter.
- As well as temporal uncertainty, crime data is also subject to uncertainty in attribute (actions leading to arrest can be classified in a number of ways depending on the judgement of the arresting officer); and in space (some crimes can occur in 'fuzzy' places – for example theft of a purse in a shopping centre).
- Crime is strongly spatially correlated (the same crimes occur in the same places) and temporally correlated (the same crimes occur at the same times, either hour of day or day of the week). Hence the popularity of 'hot spot' mapping with crime analysts. "*What is a tranquil town centre during daytime is very different at night.*" (Subject C3)
- The police's geographical base at its lowest level (police beats) does not align to any other boundary system (such as output areas), thus any differences in policing between beats cannot examined using OA or 100m square aggregated data.

There are large differences in the types of crime and the number of offences per crime type in a unit time. Apparently similar crimes can have complex and very different causes or motivations. CDR analysts find some crimes 'more interesting' than others (see section 3.2.2) The variation in different types of crime makes the use of any one scaling denominator impossible. While 'households' might be an appropriate denominator for domestic burglary, it would not be for assault, car theft, or shoplifting. Such denominators are often not available for particular crimes at the resolution of the crime data and have different uncertainties. This complicates the task of providing a geovisualization application with wide applicability – for example constraining the deployment of meaningful cartograms.

There is more than one classification system for crimes and different partners within the CDRP use these differently - care is needed to ensure like is compared to like. Crime definitions have also changed over time.

Insights about the crime data from studying the data itself are:

- Crime data contains artefacts that have nothing to do with actual crime at their point of reporting. For example, the vast majority of drug offences in Loughborough are concentrated in two 100m squares centered on Loughborough police station. This is undoubtedly a reflection of police searching persons brought to the police station, perhaps for unrelated offences, and discovering illegal drugs as a result.
- Limitations of the classification system mean that crimes with particular characteristics ('knife crime' comes to mind) cannot easily be extracted (until the Home Office introduces specific offences that relate to the carrying or use of knives). This places limits on the tasks to which a geovisualization application might be applied.
- Crime patterns are scale dependent and can look very different at various spatial resolutions.
- Crime patterns at, say, a 1km square resolution can change significantly when the data at 100m squares is rebased on a 1km square 100m to the left (or right) of a previous square.

All the above show the ecological reality of **data in context**, a limited amount of which might be revealed simply by focusing on context of use. Many of these have consequences for a geovisualization designer looking to construct an application for the CDR unit.

HOclass	Description	ReportedDate	ReportedTime	OffenceDate1	OffenceTime1	OffenceDate2	OffenceTime2	Easting	Northing	CDRPName	WardName	Month	Year
806	ABH SEC 47	01/04/2001	16:29:00			01/04/2001	14:15:00	454250	319550	Charnwood	Loughborough Hastings	4	2001
2803	BURGLARY DWELLING	01/04/2001	14:00:00	31/03/2001	21:30:00	01/04/2001	02:00:00	452450	319750	Charnwood	Loughborough Storer	4	2001
2803	BURGLARY DWELLING	01/04/2001	14:30:00	31/03/2001	23:30:00	01/04/2001	00:05:00	454350	319150	Charnwood	Loughborough Hastings	4	2001
2803	BURGLARY DWELLING	01/04/2001	14:34:00	31/03/2001	19:30:00	01/04/2001		452750	318550	Charnwood	Loughborough Outwoods	4	2001
2803	BURGLARY DWELLING	01/04/2001	22:50:00	31/03/2001	13:00:00	01/04/2001	21:00:00	451950	320350	Charnwood	Loughborough Storer	4	2001
3002	BURGLARY OTHER THAN DWELLING	01/04/2001	15:00:00	01/04/2001	12:30:00	02/04/2001	12:30:00	451250	318850	Charnwood	Loughborough Ashby	4	2001
3002	BURGLARY OTHER THAN DWELLING	01/04/2001	12:56:00	30/03/2001		30/03/2001	21:30:00	451250	319850	Charnwood	Loughborough Garendon	3	2001
5865	CRIMINAL DAMAGE TO DWELLING	01/04/2001	23:20:00	01/04/2001	21:45:00	01/04/2001	22:15:00	453950	317850	Charnwood	Loughborough Shelthorpe	4	2001
5864	CRIMINAL DAMAGE TO MOTOR VEHICLES	01/04/2001	10:08:00	31/03/2001	21:00:00	01/04/2001	07:00:00	451450	320550	Charnwood	Loughborough Dishley and Hathern	4	2001
5351	OBTAIN PROPERTY BY CHEQUE CREDIT CARD FRAUD	01/04/2001	13:00:00	11/02/2001		11/02/2001	23:59:00	454250	318950	Charnwood	Loughborough Hastings	2	2001
4910	OFFENCES UNDER THEFT ACTS NOT CLASSIFIED ELSEWHERE	01/04/2001	11:26:04	01/04/2001	10:30:00	01/04/2001	10:45:00	453250	320650	Charnwood	Loughborough Lemyngton	4	2001
4510	THEFT FROM MOTOR VEHICLE	01/04/2001	16:25:00	01/04/2001	08:00:00	01/04/2001	16:15:00	453550	319650	Charnwood	Loughborough Southfields	4	2001
4510	THEFT FROM MOTOR VEHICLE	01/04/2001	14:50:00	01/04/2001	12:00:00	01/04/2001	14:30:00	453350	319250	Charnwood	Loughborough Southfields	4	2001
4510	THEFT FROM MOTOR VEHICLE	01/04/2001	13:41:00	31/03/2001	19:00:00	01/04/2001	13:15:00	452750	319950	Charnwood	Loughborough Storer	4	2001
4600	THEFT FROM SHOPS/STALLS (SHOPLIFTING)	01/04/2001	13:30:00	10/04/2001	13:15:00	10/04/2001	13:50:00	453750	319650	Charnwood	Loughborough Southfields	4	2001
301	THREATS TO KILL	01/04/2001	16:00:00	28/03/2001		31/03/2001	16:00:00	451150	318850	Charnwood	Loughborough Ashby	3	2001
301	THREATS TO KILL	01/04/2001	16:00:00			28/03/2001		450950	318750	Charnwood	Loughborough Ashby	3	2001
301	THREATS TO KILL	01/04/2001	16:00:00	28/03/2001		31/03/2001		450950	318750	Charnwood	Loughborough Ashby	3	2001
4802	UNAUTHORISED TAKING OF MOTOR VEHICLE (TWOC)	01/04/2001	16:55:00	31/03/2001	18:00:00	01/04/2001	11:30:00	451950	318750	Charnwood	Loughborough Nanpantan	4	2001
12600	VEHICLE INTERFERENCE	01/04/2001	11:45:00	31/03/2001	19:30:00	01/04/2001	09:45:00	453050	319450	Charnwood	Loughborough Southfields	4	2001
12600	VEHICLE INTERFERENCE	01/04/2001	17:05:00	01/04/2001	16:00:00	01/04/2001	17:00:00	453550	319750	Charnwood	Loughborough Southfields	4	2001
12512	"HARASSMENT, ALARM OR DISTRESS"	02/04/2001	21:45:00			02/04/2001	21:45:00	454050	320550	Charnwood	Loughborough Lemyngton	4	2001
12512	"HARASSMENT, ALARM OR DISTRESS"	02/04/2001	09:45:00	29/03/2001	11:40:00	31/03/2001	10:00:00	453050	320850	Charnwood	Loughborough Lemyngton	3	2001
806	ABH SEC 47	02/04/2001	22:50:00			02/04/2001	20:00:00	454250	319850	Charnwood	Loughborough Hastings	4	2001
806	ABH SEC 47	02/04/2001	11:00:00			02/04/2001	09:00:00	454250	320450	Charnwood	Loughborough Lemyngton	4	2001
806	ABH SEC 47	02/04/2001	17:00:00			02/04/2001	14:30:00	451350	319050	Charnwood	Loughborough Ashby	4	2001
3002	BURGLARY OTHER THAN DWELLING	02/04/2001	16:20:00	01/04/2001	08:00:00	01/04/2001	12:00:00	453150	320850	Charnwood	Loughborough Lemyngton	4	2001
5865	CRIMINAL DAMAGE TO DWELLING	02/04/2001	22:35:00	02/04/2001	22:25:00	02/04/2001	22:30:00	454050	317650	Charnwood	Loughborough Shelthorpe	4	2001
5865	CRIMINAL DAMAGE TO DWELLING	02/04/2001	12:25:00	29/03/2001	12:00:00	29/03/2001	17:00:00	451250	319050	Charnwood	Loughborough Ashby	3	2001
5864	CRIMINAL DAMAGE TO MOTOR VEHICLES	02/04/2001	11:39:00	31/01/2001	23:00:00	01/04/2001	02:30:00	453550	319250	Charnwood	Loughborough Southfields	4	2001
5325	MAKING OFF WITHOUT PAYMENT (BILKING)	02/04/2001	16:34:00			02/04/2001	16:20:00	453850	320450	Charnwood	Loughborough Lemyngton	4	2001
5352	OBTAIN MONEY BY CHEQUE/CREDIT CARD FRAUD	02/04/2001	09:43:00	27/03/2001	20:00:00	29/03/2001	18:00:00	453450	319650	Charnwood	Loughborough Southfields	3	2001
4910	OFFENCES UNDER THEFT ACTS NOT CLASSIFIED ELSEWHERE	02/04/2001	13:13:00	30/03/2001	18:00:00	01/04/2001	12:00:00	453050	318350	Charnwood	Loughborough Outwoods	4	2001
4910	OFFENCES UNDER THEFT ACTS NOT CLASSIFIED ELSEWHERE	02/04/2001	17:11:22	02/04/2001	16:50:00	02/04/2001	17:30:00	453350	319250	Charnwood	Loughborough Southfields	4	2001
4910	OFFENCES UNDER THEFT ACTS NOT CLASSIFIED ELSEWHERE	02/04/2001	16:45:00	30/03/2001	13:00:00	30/03/2001	14:00:00	453550	320650	Charnwood	Loughborough Lemyngton	3	2001
5870	OTHER CRIMINAL DAMAGE	02/04/2001	11:21:00	01/04/2001	09:00:00	01/04/2001	16:00:00	453550	319750	Charnwood	Loughborough Southfields	4	2001
4510	THEFT FROM MOTOR VEHICLE	02/04/2001	23:55:00	02/04/2001	10:30:00	02/04/2001	23:45:00	453650	319850	Charnwood	Loughborough Lemyngton	4	2001
4510	THEFT FROM MOTOR VEHICLE	02/04/2001	19:45:00	02/04/2001	12:10:00	02/04/2001	19:00:00	453550	320650	Charnwood	Loughborough Lemyngton	4	2001
4510	THEFT FROM MOTOR VEHICLE	02/04/2001	10:30:00	01/04/2001	18:00:00	02/04/2001	08:45:00	453850	320150	Charnwood	Loughborough Lemyngton	4	2001
4400	THEFT OF PEDAL CYCLES	02/04/2001	12:20:00	27/03/2001	20:00:00	28/03/2001	08:45:00	453050	320250	Charnwood	Loughborough Lemyngton	3	2001
4400	THEFT OF PEDAL CYCLES	02/04/2001	18:46:00	02/04/2001	11:00:00	02/04/2001	11:50:00	452750	319650	Charnwood	Loughborough Southfields	4	2001
4802	UNAUTHORISED TAKING OF MOTOR VEHICLE (TWOC)	02/04/2001	07:00:00	30/03/2001	13:30:00	02/04/2001	05:50:00	451750	320350	Charnwood	Loughborough Garendon	4	2001
12600	VEHICLE INTERFERENCE	02/04/2001	14:30:00	01/04/2001	17:30:00	02/04/2001	14:15:00	453150	320150	Charnwood	Loughborough Storer	4	2001

Figure 3.11: Sample LCC urban crime data aggregated to 100m squares with full temporal information

METADATA

ID	A simple identification code to identify each record
Beat	Police beat - a defined geographical area
OffenceCode	A high level classification system for crime types. ASH=assault; BDW=Burglary of a dwelling; TOV=Theft of motor vehicle; TFV: Theft from motor vehicle etc.
HOclass	Detailed numeric/alpha UK Home Office classification system. Nests within OffenceCode
Description	Lowest level description of crime
ReportedDate	Date the crime was reported
ReportedTime	Time the crime was reported
OffenceDate1	Earliest date the crime occured
OffenceTime1	Earliest time the crime occured
OffenceDate2	Latest date the crime occured
OffenceTime2	Latest time the crime occured
Easting	UK Ordance Survey Grid easting coordinate
Northing	UK Ordance Survey Grid northing coordinate
CDRPName	Name of Crime and Disorder Reduction Partnership within which crime occurred
WardName	Local administrative area in which crime occurs
Month	Month crime occurred (1=Jan; 12=Dec)
Year	Year crime occurred

List of crime categories showing Offence code, Home Office class and "OffClass" - a description of the Home Office class.
(note that for "Indecency" the details of "Description" have been omitted as some may find them disturbing)

HOclass	OffenceCode	OffClass	Description
101	Assault	Murder	Murder
102	Assault	Murder	Murder Under 1 Yr
200	Assault	Attempted Murder	Attempt Murder
301	Assault	Threat of Conspiracy to Murder	Threats To Kill
302	Assault	Threat of Conspiracy to Murder	Conspiracy To Murder
303	Assault	Threat of Conspiracy to Murder	Assist Offender Murder
401	Assault	Manslaughter	Manslaughter
402	Assault	Infanticide	Infanticide
403	Assault	Child Destruction	Child Destruction
404	Assault	Causing Death by Dangerous Driving	Death By Dangerous Driving
405	Assault	Causing Death by Dangerous Driving	Diminished Responsibility
406	Assault	Causing Death by Dangerous Driving	Death By Careless Driving Under Influence Drink Or Drugs
407	Assault	Manslaughter	Cause Or Allow The Death Of A Child Or Vulnerable Person
501	Assault	Wounding or Other Act Endangering Life	G.B.H. With Intent Sec. 18
502	Assault	Wounding or Other Act Endangering Life	Shooting Naval Revenue Vessels
504	Assault	Wounding or Other Act Endangering Life	Choke Suffocate With Intent
505	Assault	Wounding or Other Act Endangering Life	Using Chloroform Etc. To Commit Offence
506	Assault	Wounding or Other Act Endangering Life	Burning Maiming Etc By Explosion
507	Assault	Wounding or Other Act Endangering Life	Causing Explosions Or Casting Corrosive Fluids With Intent To Cause G.B.H.
508	Assault	Wounding or Other Act Endangering Life	Placing Explosives In/Near Ships Or Buildings With Intent To Cause Bodily Harm
509	Assault	Wounding or Other Act Endangering Life	Place Explosives In/Nr Ships/Bldgs With Intent To Cause Bodily Harm
510	Assault	Wounding or Other Act Endangering Life	Endangering Life/Causing Harm By Administering Poison.
511	Assault	Wounding or Other Act Endangering Life	Cause Danger To Anything On A Road Which Interferes With A Vehicle Or Traffic Eq
513	Assault	Wounding or Other Act Endangering Life	Possess Explosive With Intent To Endanger Life
514	Assault	Wounding or Other Act Endangering Life	Possess Firearm With Intent To Endanger Life Or Damage Property (Group One)
515	Assault	Wounding or Other Act Endangering Life	Possess Firearm With Intent To Endanger Life Or Damage Property (Group Two)
516	Assault	Wounding or Other Act Endangering Life	Possess Firearm W1Th Intent To Endanger Life Of Damage Property (Group Three)
517	Assault	Wounding or Other Act Endangering Life	Using Firearm / Imitation With Intent To Resist Arrest (Group One)
518	Assault	Wounding or Other Act Endangering Life	Using Firearm / Imitation With Intent To Resist Arrest (-Group Two)
519	Assault	Wounding or Other Act Endangering Life	Using Firearm/Imitation With Intent To Resist Arrest (Group Three)
520	Assault	Wounding or Other Act Endangering Life	Contravene Use Etc Of Chemical Weapons
521	Assault	Wounding or Other Act Endangering Life	Making Chemical Weapons
522	Assault	Wounding or Other Act Endangering Life	Use Of Nuclear Weapons (Anti-Terrorism Act)
523	Assault	Wounding or Other Act Endangering Life	Overseas Weapon Related Acts (Anti-Terrorism Act)
524	Assault	Wounding or Other Act Endangering Life	Use Of Noxious Substancesto Harm Or Intimidate (Anti-Terrorism Act)
525	Assault	Wounding or Other Act Endangering Life	Piloting Aircraft Under The Influence Of Drugs Or Alcohol
527	Assault	Wounding or Other Act Endangering Life	Torture
600	Assault	Endangering Railway Passengers	Endangering Life On The Railway

Figure 3.12: Metadata for Figure 3.11 describing data and an extract from the crime classification hierarchy

OA	Totals	00301	00404	00501	00511	00801	00806	00811	00821	00823	00826	00827
31UBFY0001	4						2					
31UBFY0002	2						1					
31UBFY0003	1											
31UBFY0004	1											
31UBFY0005	1						1					
31UBFY0007	5			1								
31UBFY0010	1											
31UBFY0012	2						1					
31UBFY0013	6						3					
31UBFY0015	2											
31UBFZ0001	2											
31UBFZ0002	2											
31UBFZ0005	3											
31UBFZ0007	1											

Figure 3.13: An extract from LCC rural crime data aggregated to census output areas (OA); numbers represent number of crimes for each detailed crime category (Home Office classification description) committed in a particular month. Note the low total crime per OA in the month and hence the sparseness of the matrix. The full matrix is 81 columns by 1993 rows.

3.3.5.2 PUBLIC LIBRARIES DATA

The libraries data is the result of a tortuous extraction process from the public libraries TALIS system. The data covers borrowing from four libraries (Oadby, Wigston, South Wigston and Great Glen) to the south of LCC over a two year period with data aggregated by week. The data provided to me covered 54,785 borrowers that when 'cleaned' yielded only 16,932 complete records of active borrowers with one of the four libraries as their 'home library'. The largest category of borrowers removed from the initial sample is people who had not borrowed during the two year period. The key aspects of the data obtained from interviews are:

- Borrowing of physical media such as books, films and music CDs is the most dominant aspect of library use. Other uses of the library, for example use of library internet terminals, means that an individual may be an intensive library user without being an intensive borrower. Borrowing behaviour is only one aspect of library use.
- Attribute data about borrowers is limited to their age, gender and which of the four libraries they originally joined (their 'home library'). Borrower data is anonymised so it is not possible - from the data available - to identify families or households.
- Spatial data is limited to borrowers' full postcodes; addresses are not provided (but are available to LCC).
- The four libraries in the sample range in size and facilities. The number of issues during the two year period, by library, is Oadby (367,000), Wigston (331,000), South Wigston (33,000) and Great Glen (27,000).

Insights from studying the data are:

- Aggregated borrowing over time is very stable, apart from periods such as the Christmas/New Year period. The temporal aspect of borrowing is unlikely to be as important as attributes associated with borrowers, their borrowing itself, and their spatial distribution.
- Attribute data about user borrowing is extensive for books, and absent for other categories. Books are classified under adult fiction (13 genre categories of which the most widely borrowed are 'general', crime, sagas and adventure); adult non-fiction (48 main categories based on Dewey ranges (Dewey, 2003), of which biography/autobiography, geography/travel and domestic life are the most widely borrowed categories); junior fiction (13 categories); junior non-fiction (23 categories) and ethnic language books (five categories, based on language). The distribution is adult fiction: 47%; adult non-fiction: 22%; junior fiction: 24%; junior non-fiction: 5%; ethnic: 1%. Borrower reservation requests and renewals data is also available, plus the name of the library the borrowing was made from (borrowers are not confined to borrowing from their home library).
- Borrowing is dominated by books (88 % of all issues); film (not available in all four libraries) is 6%; sound 3% and talking books 3%.
- Total borrowing follows a strong log-log distribution (Figure 3.14), especially if those borrowing a very small number of items (less than one item every six months) are excluded. Just 191 borrowers (out of 16,932) account for 10% of issues; 486 for 20%; 1,924 for 50%; 3,664 for 70%; 7,540 for 90%.

Figure 3.15 summaries the structure of the available public library data. As with the crime data, many of these aspects (for instance, the dominance of book borrowing; the richness of the book genre data; the absence of non-book details; the granularity of postcodes that fail to provide a unique geographic reference for each borrower) have consequences for a geovisualization designer looking to construct an application for the public libraries unit.

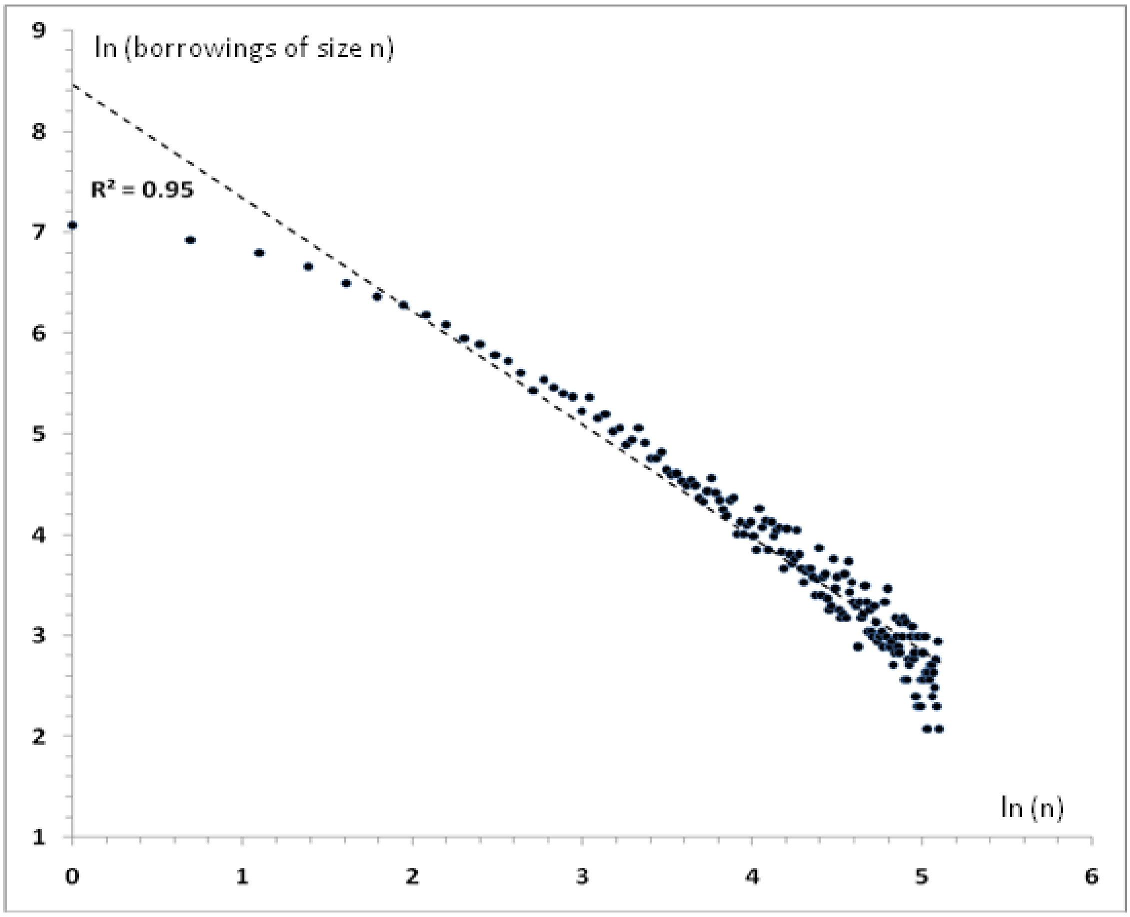


Figure 3.14: Log-log plot: ln(no. of total borrowings of size n) v ln(n) with linear trend line,for Great Glen, Oadby, South Wigston and Wigston libraries (Two years data; number of borrowers=16,932, cut off at 95% of cumulative borrowing)

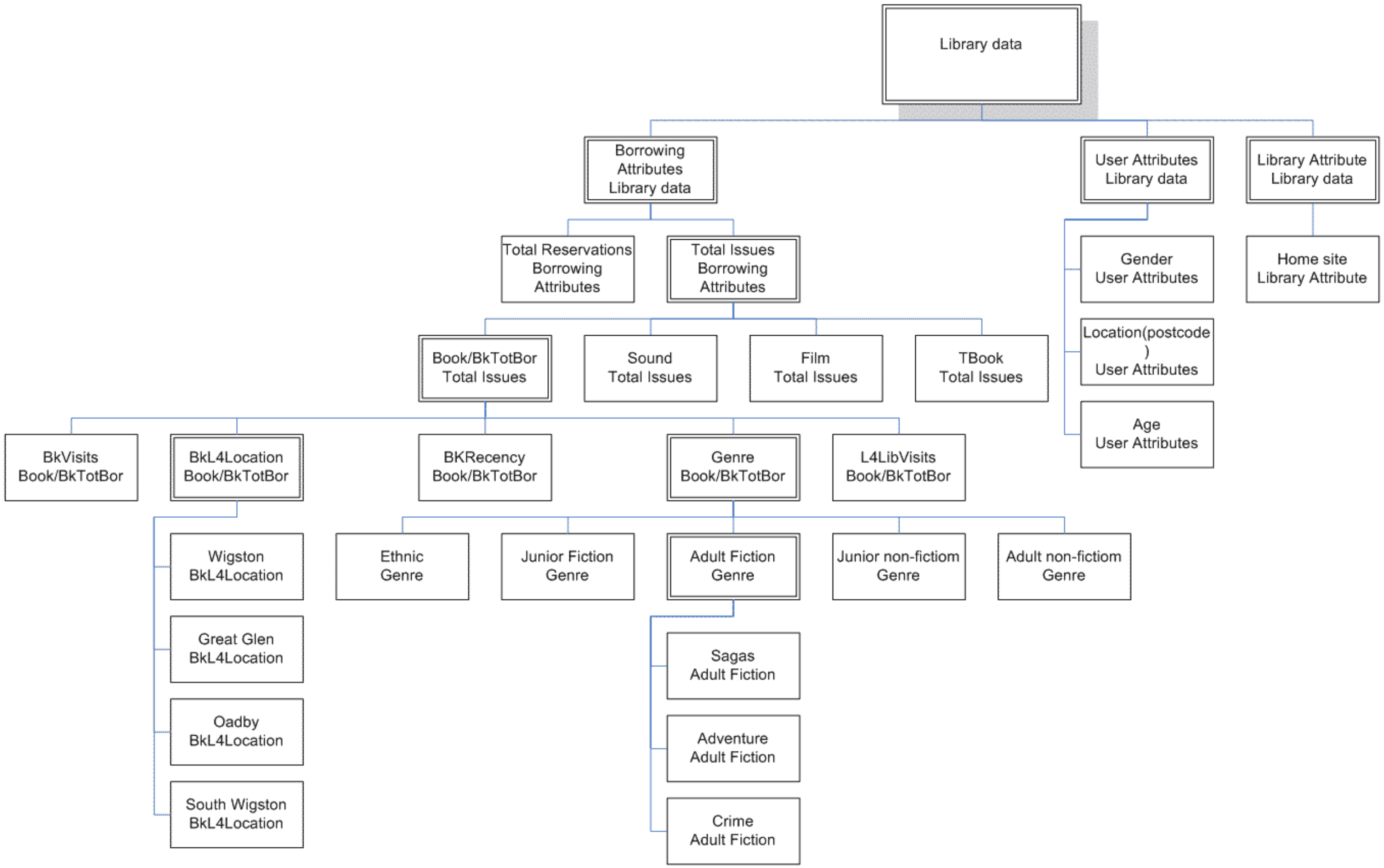


Figure 3.15: Structure of available public library data

3.4 CONCLUSIONS

Research Question 1 asks: **How well do human-centered approaches concerned with establishing context of use work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of establishing context of use from prospective users?**

RQ1.1 How well do human-centered approaches concerned with establishing context of use of prospective users of a geovisualization application work in an applied geovisualization context?
The Contextual Inquiry master/apprentice model works well in practice and the roles are easily assumed in both **interviewing** and **observation** (section 3.3.1 and 3.3.2). **I commend** this approach to geovisualization researchers.

There is **good evidence** from both CDR (section 3.3.1.2) and Library (see section 3.3.1.3) subjects that **interviews** provide useful insights from subjects on skills, experience, tools, aims, inputs and outputs that would be of use to a geovisualization designer in understanding their context of use. (See section 2.1.4 for outline of how the strength of evidence is classified)

There is **good evidence** from analysis of both CDR (section 3.3.1.2) and Library (see section 3.3.1.3) subject interviews that **word frequency counts** from interview transcriptions yield useful quantitative information about subjects context in use, highlighting key concepts.

There is **good evidence** from analysis of both CDR (section 3.3.1.2) and Library (see section 3.3.1.3) subject interviews that **keyword-in-context analysis** is a particularly rich and valuable approach as it provides greater insight into subjects' motivations.

I commend both the **word frequency count** and **in particular the keyword-in-context approach** as offering the potential for significant insight into subject context for geovisualization researchers.

There is **good evidence** from one observation session of a CDR subject, and one with Libraries senior managers, that **observation** provides a less systematic approach to gathering contextual information, and a smaller coverage, than interviews. But it can lead to avenues of inquiry and to important insights that it is hard to imagine surfacing in an interview, and it can lead additional weight to evidence uncovered in interviews (section 3.3.2).

There is **good evidence** from considering both CDR and Libraries (section 3.3.3.1) that **studying internal documents** is an effective way of learning about a subjects' context without taking up their time. As well as explicit information about the work, it can provide insights into approach, presentation, data use, analysis methods and the breadth of insight subjects achieve, and can confirm information from other methods such as interviews and observation. **I commend** this approach to geovisualization researchers.

There is **good evidence** from considering both CDR and Libraries (section 3.3.3.2) that **studying external documentation** can provide corroboration (or otherwise) of insights obtained from subjects, and contrast their context to the generality of similarly situated individuals or teams. **I recommend** the study of external documentation to supplement internal documentation and provide a context for generalisation.

RQ1.2 How might human-centered approaches concerned with establishing context of use of prospective users of a geovisualization application be changed?
ISO13407 on human-centred approaches to context in use refers only to "users, tasks and the organizational and physical environment." An important aspect of applications designed for exploration (such as geovisualization applications) is to **understand and acquire subjects' data and their relationship with it** (section 3.3.5). This has significant implications for the relationship with subjects and **requires a focus on data in context** (section 3.3.5) as well as subject context in use. However data in context is not a substitute for context of use. Subject data needs to be studied explicitly in a process akin to the process of 'studying documentation' - an off-line process, disconnected from subjects, who provide the raw data (section 3.3.5).

I strongly recommend other researchers concerned with exploratory application development (such as information visualization and geovisualisation designers) to recognise explicitly their need to collect information about data and metadata from prospective users, and to engage with, and study, subject data themselves.

Card sorting is typically employed is to determine the optimal way of including items in a series of drop-down menus . It also offers a quantitative way of gaining access to subjects' conceptual worlds to assess their categorisation of tasks. I find that:

- It enables tasks that include spatiality (that are important to geovisualization) to be set alongside other tasks.
- a geovisualization expert can perform the same card sort as subjects and thus permit comparisons between subjects' and a geovisualization expert's conceptual views of subject tasks (section 3.3.4).
- there is **some evidence** card sorting reveals differences and similarities when category headings given by subjects to their sorted cards are compared. One subject categorises tasks without reference to spatiality, whereas colleagues have extensive spatial categorisation. Such an individual might reflect their aspatial view of tasks in other approaches such as interviews (section 3.3.4).
- clustering analysis of card sorting (that takes no heed of subject headings) produces subjectively sensible task tree diagrams. The clustering of tasks provides an indication of where a geovisualization application would have most coverage and therefore be of most use to prospective users (section 3.3.4). The cluster analysis of the CDR subjects' card sort, for example, shows a cluster comprising domestic crime, racial crime, crime affecting persons living alone, crimes affecting the Islamic community and crime associated with, and/or committed by, recent migrants.
- a card sorting difference distance matrix highlights differences between the way that different users cluster tasks and therefore provides both a check of consistency with a group of subjects, and also a comparison between subjects and a geovisualization expert. This enables a quantitative assessment the similarity between such a geovisualization expert's concept of the subjects' task domain and that of the subjects themselves (section 3.3.4).

I commend card sorting as a useful quantitative technique for geovisualization application designers to explore the conceptual worlds of the prospective users and their own understanding of prospective user domains.

RQ1.3 How does the nature of geovisualization affect the process of establishing context of use from prospective users?

Prospective users who have access to and work with spatial data, have skills in its manipulation, and/or whose tasks involve data exploration, clearly represent better prospective users of a geovisualization application. I develop a set of criteria to differentiate the groups within LCC in order to assess their potential to benefit from geovisualization. These relate to aspects of geovisualization's character - concern with data availability and scope, groups' spatial skills and the extent to which data exploration is part of groups' work. These criteria are obvious and, 'spatial skills' excepted, would be as applicable to information visualization or even exploratory data analysis. A less obvious, human-centered, criterion is the 'enthusiasm' of subjects, which I see as a conflation of rapport, motivation and aspiration (section 3.2.2).

3.5 DISCUSSION

I have used a series of HC approaches concerned with understanding context of use with local government subjects based on the proposition that these were prospective users of an as-yet unbuilt geovisualization application. The purpose has been to see what, if anything, about HC context of use approaches needs to change because of the nature of geovisualization. As the application is unspecified, finding aspects of HC approaches that need to be modified because of the geovisualization nature of the final application is a challenging endeavour. A great deal of interviewing, observation, studying of documentation and card sorting has taken place to produce a mass of raw material from which to tease out these small strands.

In the context of geovisualization, there is little, if anything, to say about basic techniques such as interviewing, observation and studying documentation. It would have been surprising if it were otherwise. I have some recommendations about the particular strengths of keyword-in-context analysis and the use of external documentation, but these do not touch on the main research question. The results from CDR and public library domains support each other as to the efficacy of keyword-in context and use of external documentation, lending weight to their wider application.

In the very beginning of a relationship with a number of potential subjects, it is useful to have a filtering mechanism with criteria and scoring to assess who might benefit most from a geovisualization approach. For a geovisualization application, criteria around data, spatial and exploration, along with subject enthusiasm is a useful starting point.

One HC approach where I have found the nature of geovisualisation makes a difference is card sorting. This approach is used widely to understand subjects' conceptual worlds - the canonical example being selecting items to be included in drop-down menus. Using it to understand how subjects group plausible tasks enables a researcher to include spatial tasks next to other tasks and see how they are categorised. The quantitative nature of analysing card sorts through cluster analysis and the production of distance matrices makes comparing different subjects possible. The inclusion of a geovisualization designer in a card sort enables a quantitative comparison against the categorisations of the subjects using a difference distance matrix, which can be visualized with bivariate colouring. This gives a check on the geovisualization designer's conceptual thinking of the subjects' domain early on in the process, before subjects requirements are explored, before designs are produced and before any code is cut. This is useful as it can identify disconnections between the subjects' view of their domain and that of the geovisualization designer.

The key finding from this chapter is that geovisualization researchers working with subjects to understand their context of use (as opposed, say, to employing 'real' users to test the design of an already-developed application), need to recognise explicitly that they must understand both the context of prospective users *and* their data in context. With the data in context but without the context of use lies the problems confronted by Slocum et al (2003) and Andrienko et al (2006); with context of use but without the data in context, it is not possible to proceed meaningfully to construct a geovisualization design or application. Both are needed.

To understand data in context requires researchers to ask subjects about their data, take that data away and study it in detail. In planning work with domain experts in the field, geovisualization researchers need to factor the extent of their involvement with 'subjects' and the trust such 'subjects' will need to place in researchers whose explicit aims include removing their data. As indicated by the quote marks, the notion of 'subjects' is a poor description for one party in a relationship necessitating this kind of commitment. To refer to them as 'partners' or 'collaborators' threatens academic objectivity, but in truth these are the kinds of description that are more realistic. Indeed, by the end of the process, 'co-discovers' or 'colleagues' might be more appropriate terms.

Given the focus on data, researchers would do well to have a prior notion of the data characteristics they should be looking seeking from domain experts. This should include as much metadata as possible, how, if at all, data has been filtered, aggregated, normalised or otherwise manipulated, the attributes of the data – dimensionality, continuous or discrete, nominal, ordinal, interval or real, univariate or bivariate, and so forth, as well as specific details relating to spatial data.

This concludes Chapter 3 on context of use. Building on my acquired understanding of the crime and disorder reduction and public libraries marketing domains, the next chapter begins by looking at HC approaches to **establishing requirements** from prospective users of as-yet unspecified geovisualization applications.

GEOVISUALIZATION
EXPERTS
SCENARIO
TOOLS
INTERACTIONS
SUBJECTS
APPLICATION
data
CDR
USE
crime
information
might
way
one
work
particular
CONTEXT
DOMAIN
TEMPLATE
RESEARCH
RESULTS
USEFUL
REQUIREMENTS
Table
think
need
like
time
using
C1
team
APPLICATIONS
able
PROCESS
different
things
subject
EXPERT
maps
tasks
QUESTIONS
RESPONSES
VOLERE
LECTURE
SUGGESTIONS
sketches
spatial
see
mentions
CARD
RECALL
kind
get
want
two
C3
C2
P1
P2
APPROACH
techniques
INTERVIEW
ANALYSIS
people
users

4 REQUIREMENTS

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ABSTRACT

Armed with an understanding of prospective users from studying their context of use, the context in use of their data, and their desire to be able to better explore their crime data (see Chapter 3), I now consider the second section of ISO 13407 dealing with requirements. I explore the use of a **requirements template** - asking subjects what their requirements are for a prospective geovisualization application using a pre-prepared guide.

Results show that subjects are able to provide little in response to the template questions to assist in the design of a geovisualization application. To overcome this inability of subjects to establish requirements via the template, I carry out further, indirect, ways in an attempt to establish requirements or otherwise provide an input to the design of a geovisualization application. In the first, I communicate the subject's context to geovisualization experts; and in the second, I communicate geovisualization tools and interactions to the CDR subjects.

I construct a **scenario** of the CDR subjects' context in use, focusing on exploratory tasks. Using this with extracts from subjects' data, I ask nine geovisualization experts individually what suggestions they would make for geovisualization tools and interactions that might be incorporated in an application for the situation described in the scenario.

The CDR subjects receive a lecture on geovisualization tools and interactions delivered by a geovisualization expert to communicate geovisualization to them, and from that attempt to establish requirements. The subjects assessed the potential usefulness of these in their exploratory tasks through a **card sorting** exercise conducted immediately after the lecture. The subjects were asked individually after two weeks which tools and interactions they recalled as being potentially useful to them. Subjects produced rough **sketches** of application designs for exploring their most important crimes tasks, illustrated with geovisualization tools and interactions.

Repeating the template questions after 18 months when subjects have had far more geovisualization practice also fails to establish requirements. Geovisualization experts agree that the scenario plus supplemental information in the form of sample data and metadata, maps and a 'crib sheet' of geovisualization tools and interactions, is an effective way to communicate the subjects' context in use. They largely agree on the 'most mentioned' tools and interactions, and provide a degree of convergence in their advice that would enable a

designer to create a geovisualization application, tailored to the CDR subjects' context of use. CDR subject card sorts indicate that they have difficulty differentiating between geovisualization tools/interactions, and that communicating geovisualization to them via a lecture is largely ineffective as a means of eliciting information that would meet their (unstated) requirements. Recall of geovisualization tools and techniques after two weeks show limited recall. Their sketches give an insight into their understanding of the geovisualization tools and interactions, but provide limited information to inform the geovisualization design process.

4.1 INTRODUCTION

RQ2: **How does the nature of geovisualization affect the process of establishing requirements from prospective users? How well do human-centered approaches concerned with establishing requirements work in an applied geovisualization context; how might they be changed and which work best and which work differently?**

The context of use phase has established a desire for tools to assist the CDR subjects in the general exploration of crime to assist their goal of providing strategic level support to crime and disorder partners to establish priorities. The crime data available to them is heterogeneous with complex attribute, spatial and temporal qualities.

Preece, Rogers and Sharp (2002) define a requirement as "a statement about an intended product that specifies what it should do and how it should perform". The public library subjects are clear about their requirement – established during context in use investigation (see 3.3.1.3) - a strong desire to be able to identify customer segments, to market to customer with tailored messages. Their requirement is clear and demands no further elicitation. This chapter therefore focuses on establishing requirements from and for the LCC CDR team.

Section 2.2.2 outlines the HC approaches to establishing requirements. Firstly, the use of a requirements template (the Volere template); secondly methods of communication - consulting experts with a scenario, and bridging the gap between visualization researchers and domain experts by "(educating) domain experts to define visualizations themselves" (van Wijk, 2006).

Superficially, the simplest way to establish requirements would appear to be to ask prospective users (the CDR team) what they want from an application. However, such an approach may be problematic, given the complex nature of geovisualization. Nevertheless such an methodology should be attempted to determine if this is so. A systematic way of approaching this is to use one of a number of 'template' approaches that offer the advantages of being pre-prepared, completeness (in the sense of covering areas that might not be immediately apparent) and the potential for swift administration.

RQ3: **How does the nature of geovisualization affect the process of mediation between the geovisualization domain and prospective users? How well do human-centered approaches concerned with mediating between the geovisualization domain and prospective users work in an applied geovisualization context; how might they be changed and which work best and which work differently?**

Another approach for a field such as geovisualization with its many complexities is to encapsulate the subjects' context to experts who have prior experience of constructing geovisualization applications to explore complex, spatial data. The HC domain suggests the use of a scenario (Carroll, 2000) in such situations, and a CDR scenario is created, along with supplemental information on subject data and geography and a 'geovisualization crib sheet' based on the tools and interactions in Table 1.1, with which to approach geovisualization experts for their advice on which tools and interactions might be appropriate for the CDR subjects' context of use.

van Wijk (2006) suggests mediation between domain experts and visualization experts could occur by using visualization experts to "educate domain experts to define visualizations themselves". So another approach is to communicate geovisualization tools and interactions to the CDR team members using a lecture format. I assess the perceived usefulness of these tools and interactions to the CDR subjects' context using card sorting (Nielsen and Sano, 1995) and sketching (Tohidi et al., 2006), and by interviewing (Kahn and Cannell, 1957) them after two weeks to determine what tools and interactions they recalled and that they now felt, on reflection, would be of use to them. Alexander, Kulikowich and Schulze (1994) link recall and interest with experiments that position "knowledge, recall, and interest within a model that acknowledges three stages of domain learning - acclimation, competency, and proficiency."

4.2 METHODS

Case No.	ISO 13407 methods	Population	Sample	Units	Objective	Research Design	Research Question
4	**Requirements** (Establishing requirements with a template; communicating geovisualization to subjects with a lecture; consulting geovisualization experts with a scenario, using observation, interviews, card sorting, sketching and questionnaires)	Prospective geovis application users in LCC Research and Planning department	Crime & Disorder reduction (CDR) Team	CDR team members	Establishing requirements with Volere template sections; evaluate templating approach	(c) Case Study III	**RQ2**
5		Geovisualization experts	Nine geovis experts	Individual geovis experts	Response to CDR scenario; geovis tools, and interactions suggested; evaluate scenarios approach	(b) Case Study II	**RQ3**
6		Prospective geovis application users in LCC Research and Planning department	Crime & Disorder reduction (CDR) Team	CDR team members	Communicating geovis to CDR subjects via lecture to elicit requirements; evaluate this approach		

Extract from Table 2.2: Requirements (Research Questions 2 and 3) - the sections of this research showing case study details by type according to Gerring (2004).

The case study schema reproduced above outlines the framework for the research in this chapter.

4.2.1 REQUIREMENTS TEMPLATE

A number of 'templates' (set of questions), for establishing requirements are available, among them the widely used **Volere Requirements Specification Template** (Robertson and Robertson, 2006a). The template defines five main themes containing 27 sections:

- **project drivers** (product purpose; client, customer, stakeholders; users of the product),
- **project constraints** (mandated constraints ; naming conventions and definitions; relevant facts and assumptions),
- **functional requirements** (scope of the work and product; functional and data reqs),
- **non-functional requirements** (look and feel; usability and humanity; performance; operational; maintainability and support; security; cultural and political; legal), and
- **project issues** (open issues, off-the-shelf solutions; new problems; tasks; migration to the new product; risks, costs; user documentation; 'waiting room'; ideas for solution).

Figure 4.1 gives an extract from one of the template's sections.

1 The Purpose of the Product
1a. The user problem or background to the project effort.
Content A short description of the work context and the situation that triggered the development effort. It should also describe the work that the user wants to do with the delivered product.
Motivation Without this statement, the project lacks justification and direction.
Considerations You should consider whether or not the user problem is serious, and whether and why it needs to be solved.
1b. Goals of the product.
Content This boils down to one, or at most a few, sentences that say "*What do we want this product for*?" In other words, the real reason that the product is being developed.
Motivation There is a real danger of this purpose getting lost along the way. As the development effort heats up, and the customer and developers discover more and more what is possible, it may well be that the system as it is being constructed wanders away from the original goals. This is a bad thing unless there is some deliberate act by the client to change the goals. It may be necessary to appoint a person to be "custodian of the goals", but it is probably sufficient to make the goals public, and periodically remind the developers of it. It should be mandatory to acknowledge the goals at every review session.
Examples
"*We want to give immediate and complete response to customers ordering our goods over the telephone*."
"*We want to be able to forecast the weather*."

Figure 4.1: Example section from the Volere template (Robertson and Robertson, 2006a)

Robertson and Robertson (2006b) state that small projects may not use any formal process for requirements, gaining feedback in an iterative way from users: "the fastest way to learn your customer's…requirements is not at the keyboard but at the whiteboard". But Robertson and Robertson (2006b) also say that "such feedback should not be used to find out what stakeholders wanted in the first place". This is a caution to those researchers who advocate cooperative, collaborative or participatory approach to prospective user engagement. The CDR subjects C1, C2 and C3 were questioned independently using the Volere template as the basis for the questions. Questions were omitted where the subject matter was inappropriate to the scale of the proposed application, where it was inappropriate to the subjects because of their position within the CDR team, or where answers to earlier questions indicated that follow-up Volere questions were likely to be inappropriate. Responses from subjects were audio recorded (with their consent) to encourage more complete responses than might be the case if they had been given the Volere template in the form of a questionnaire to complete. Eighteen months after asking the CDR subjects the Volere questions, the process was repeated in order to see how responses differed given the additional exposure the subjects had had to geovisualization over the period. At this time subject C1 had left LCC and C2 was unable to attend the interview, so only C3's later results are available. All audio recordings were transcribed and coded for analysis using an emergent coding scheme.

4.2.2 SCENARIO/GEOVISUALIZATION EXPERTS APPROACH

4.2.2.1 SCENARIO

Scenarios "support reasoning about situations of use, even before those situations are actually created. Scenarios are stories. They are stories about people and their activities" (Carroll, 2000). They are a method of communicating the context of users to others (such as geovisualization experts or designers) outside the particular work situation. This approach is inspired by Robertson (2004) who indicates "There are a number of situations when scenarios are the best tool for requirements discovery: when you do not know where to start, when you have difficulty involving a stakeholder, when you want to encourage innovation and creativity…" The last of these attributes is valuable in the context of geovisualization, where its exploratory nature may be novel to prospective users, as well as its varied tools and their combined, interactive character. Dumas and Redish (1999) consider what makes a good scenario - "short, in the user's words, not the product's; unambiguous; enough information to do the task; directly linked to your task and concerns".

Following this advice, I wrote a scenario (through a number of iterations) that incorporated the key elements learned from context of use work with the CDR subjects (see Chapter 3) embracing subject goals, expertise, experience of geovisualization, existing tools, end-customers, tasks and data range and type. Written as an informal, first person narrative, it represents a composite of all three CDR subjects, and was intended as a probe to extract information about techniques, tools and interactions that might be useful to the CDR team in the context of their exploratory work. The final scenario was shown to CDR subject C1 (the CDR team leader) before it was used. C1 felt it fairly represented the exploration portion of the CDR team role. The final scenario is at Figure 4.2. The scenario was supplemented with simple examples of CDR crime data and the list of geovisualization techniques, tools and interactions in Table 1.1.

"I work as part of the Crime and Disorder Reduction (CDR) team in the County Council. Today I am starting a specific piece of research. This is more enjoyable than my other task of producing the month update report and graphics of how well we are doing against our CDR targets. We do original research from time to time, and it's an opportunity to focus in depth on either a particular part of the county, a particular crime category, or the impact of a particular crime reduction initiative. In the past we've looked at the differences between urban and rural crime; violent crime; and how crime has changed in an area covered by CCTV cameras.

I usually start by looking at the literature to see what's been done before on the topic - not just results but good ways to present them and good analysis techniques. We have become quite expert at presenting results to our customers over the last few years. We try to show just what is important with clear graphics and text - not putting all the data into tables the way we used to. We've been heavily influenced by Edward Tufte's work in this. But the process of creating great presentations from the raw data is very loosely coupled and takes a great deal of time.

After searching the literature, I pull out data by querying our Access database to populate spreadsheets. I'm extracting the relevant crime data and whichever spatial area I'm interested in, along with any potentially useful attribute data. There isn't a systematic way I choose the particular attribute data – it goes on experience and "gut feel". We have a lot of detailed Census data plus local data from the council and from the surveys it carries out. We don't subscribe to demographic data from ACORN or Experian. Crime data is hierarchical in nature - the many hundreds of different crimes are aggregated into broader categories such as "Assault" or "Theft". The data comes from the local police, and there are limitations to what we can get. For town centres we can get complete data – all the various crimes by day and time for 100 metre square tiles. For the rest of the County we receive only monthly aggregated data for Output Areas.

Analysis is sometimes repeated for different areas or different time periods. We use a GIS to map thematically and can produce "hot spot" maps where that's useful. We have recently started to use cartograms in different ways to give an alternative perspective.   Sometime the patterns in the data are clear, sometimes not. The tools we have - a GIS and spreadsheet plus some use of a statistics package - can be limited. We have seen an example of geovisualization work that link maps to parallel coordinate plots and these seem to add something new - once you get used to what they are showing!

After we have gathered as many insights as we can, we pull together the appropriate information in Microsoft Publisher and produce a pdf paper report (also posted on our website) for our customers. They are a partnership of senior people in the Council, the Police, the Fire & Rescue Service and so on, and they use our work to set priorities for crime and disorder reduction in the County. They are busy people and have come to trust our integrity and skills in presenting them with relevant information in a clear ad concise way. And they appreciate it when we suggest causes for things we see in the data."

Figure 4.2: Scenario based on the work of the Crime and Disorder Reduction team at Leicestershire County Council given to geovisualization experts

4.2.2.2 CONSULTING EXPERTS

Consulting experts is a widely studied field given the need to elicit information from experts in domains such as giving evidence in legal proceedings and the construction of expert systems. There is literature on consulting experts that suggests that many experts are better than one. Mittal and Dym (1985) advocate consulting multiple experts and counsel that selected experts are "practicing experts in the selected task" - this advice influenced the choice of experts consulted in this research. McGraw and Seale (1988) assert that "...using more than one expert allows developers to study different problem-solving approaches, cognitive-mapping strategies and applications of the same body of knowledge." Richardson and Domingos (2003) point to the difficulties of accessing high-quality expert knowledge and advocate the use of combining multiple weak expert sources into a strong collective knowledge base. (Winkler and Clemen (2004) find that "adding experts and adding methods can both improve accuracy, with diminishing returns to extra experts or methods. The gains are generally much greater from adding experts than from adding methods." In a geovisualization context Bhowmick et al (2008) evaluate a new cancer atlas using distributed users including cartographic and information visualization experts to assess its utility for public health professionals.

Three geovisualization researchers (P1, P2 & P3) ("geovisualization experts") at the giCentre at City University London, all of whom had published papers on geovisualization and had built geovisualization applications, were interviewed to:

- elicit geovisualisation techniques, tools and interactions that might be useful to the CDR subjects based on the scenario,
- ask specific questions focusing on the tools, techniques and interactions suggested by the scenario,
- probe to elicit more information and for follow-up clarification.

Each expert made suggestions and comments, thinking aloud, while I audio recorded them, with their consent, for later transcription, coding and analysis. I intervened to explain that supplemental information on data, geography and geovisualization techniques, tools and interactions was available that they could access if they wished, and to keep the interview on track when necessary. I administered a short, summative questionnaire that asked about:

- geovisualization experts' research interests;
- how they well they agree or disagree that the scenario by itself gives them a good understanding of the particular task that was being undertaken;
- … of the range of data available;

- …of the <u>type</u> of data available;
- …of the <u>goals</u> of the CDR subjects;
- … of the <u>end customers</u> for their work;
- …of the <u>tools</u> available to the CDR subjects;
- …of their <u>expertise</u>;
- whether the scenario, <u>by itself</u>, contains enough information to enable the geovisualization expert to provide further information that would be of use in constructing a geovisualization application;
- whether the <u>scenario plus interview process</u> succeeds in eliciting information from the geovisualization expert that would be of use in constructing a geovisualization application.
- which supplemental material has been consulted;
- the conduct of the interview
- whether the purpose of the interview has been conveyed adequately.

These "tick box" questions were supplemented by opportunities to contribute more detail, if appropriate.

As a result of pilot feedback, and to better reflect the importance of "data in context" (section 3.3.5), a supplemental sheet of information about CDR data was prepared giving examples of both kinds of CDR data (100m squares for town centres with complete temporal crime information, and monthly aggregated crime by census output area for rural areas) and associated metadata - see Figures 3.10 - 3.12. This was available for the geovisualization experts to consult if they wished. In addition - again, available to the experts if desired - was a list of geovisualization techniques, tools and interactions (see Table 1.1) and a page of maps that described visually the administrative geography of Leicestershire. A check was kept of which supplemental material was consulted by which geovisualization expert by asking for this information on a questionnaire administered after the experts had given their individual advice. The scenario was also slightly amended, post-pilot, for clarity, as was the summative questionnaire.

After the pilot interviews at my home institution, additional geovisualization experts with practical application building experience were sought from other universities, as they were likely to be uninfluenced by any specifically local approaches to geovisualization design. A second UK university yielded two further experts. Further geovisualization researchers from

Holland, Finland, Switzerland, Ireland and Germany were approached, and based on their willingness and accessibility from the UK, two researchers were selected for interview from each of the last two countries. Of the six non-pilot experts, half were male and half female. With one exception, all interviews were conducted face-to-face in English at the home institutes or universities of the experts. One pilot interview was carried out using Adobe Acrobat Connect software to see whether the system would be a viable alternative to face-to-face. This worked only adequately. There were problems when two people were speaking closely (in time) with each other when words were lost, and the expert concerned found it difficult to share drawings in a fluid way - holding sketches up to a web camera works, but is not ideal. In addition, Adobe Acrobat Connect has inadequate playback control tools.

Interviews lasted 50 minutes with 10 minutes allocated to filling in the post-interview questionnaire. Experts' comments are anonymised and the experts themselves referred to as P1, P2…P9 in the analysis. Expert P1 had additional knowledge of the LCC CDR team and had met with them in advance, therefore P1's results must be treated with caution (although P1's contribution to the number of mentions of interactions and tools is low compared to the other experts).

4.2.2.3 CODING AND ANALYSIS

The initial coding scheme for this data was built from the geovisualization techniques, tools and interactions list (see Table 1.1) - that is, a deductive scheme, constructed "according to predefined areas of interest" (Lewins and Silver, 2007). The pilot revealed that this approach was likely to prove inadequate as geovisualization experts contributed ideas and suggestions beyond the rather narrow confines of Table 1.1. As Robinson (2007) - in a geovisualization context - remarks: "It is…common to allow schemes to emerge after an initial pass through the data", and so it proved here, as an inductive scheme evolved iteratively from successive expert transcriptions. The final scheme gathered codes under the headings of techniques, tool, and interactions but also data-related, layout-related, and references to existing (visualization) applications. Comments on the process were also identified and coded to provide additional evidence to supplement the questionnaire results (the former not being reflective in nature, and therefore particularly valuable).

4.2.3 COMMUNICATING GEOVISUALIZATION TO SUBJECTS WITH A LECTURE

Nielsen (1993) states that "users are not designers" and they "have a hard time predicting how they will interact with potential future systems with which they have no experience." One way to overcome this and gain input from subjects is by providing them with an understanding of the possibilities of geovisualization and then elicit from them which tools and interactions they engage with in their context of use. This builds on a HC tradition of user involvement through participatory, collaborative and/or cooperative engagement with users. In the visualization domain, Winter and Keen (2005) propose educating aviators in the visualization of weather, while van Wijk (2006) examines the ways the gap between visualization researchers and domain experts can be bridged and suggests that "the domain experts could make steps to cross the bridge" by using visualization experts to "educate domain experts to define visualizations themselves".

Providing some limited experience of geovisualization to the CDR subjects is an approach worth attempting where there is the prospect of building a bridge to establish "undreamed of requirements" (Robertson, 2001). There is limited literature on teaching information visualization (including geovisualization) to students. Kerren, Stasko and Dykes (2008) describe the process as "a challenge because it is a new and growing field". Its review of taught visualization courses finds that 17 out of 19 are at graduate level. Clearly it is a daunting prospect to attempt to "communicate geovisualization" to the CDR team with a lecture over an hour or so. But here the aims are strictly limited to describing geovisualization tools and interactions, in the expectation that the subjects will at least be able to decide which do and which do not have any promise to assist them in their context of use.

A particular inspiration for this approach is the 'Tech Box' by the design company IDEO, described in Hargadon (2003):

> "IDEO has made a science of accumulating junk. Many designers put plastic parts, toys, prototypes, drawings, and sketches on display in their offices. Building on such collections, IDEO designers have amassed a shared collection of over 400 materials and products in what they call the Tech Box, a set of filing cabinets…that houses many of the cool mechanical and electrical gizmos, ideas, artifacts, and materials that designers run across in their projects: When a problem comes up in a new project, designers can grab what looks related from the Tech Box and try to find a useful connection."

There seems to be a parallel between IDEO's Tech Box and the miscellany of the various tools, interactions and techniques of geovisualization, accumulated over time from the fields of cartography, graphics, various visualization disciplines and other sources. Providing a lecture on tools and interactions to CDR subjects is analogous to providing a window into geovisualization's own 'Tech Box'.

The activities in this section took place over a day where the CDR team members were away from their normal place of work at a nearby conference centre to ensure the activities were uninterrupted by work-related matters. The team members were together throughout but undertook the various tasks individually. However it was possible for adjacent subjects to see each other's work, and it was not possible to enforce a ban on communication while tasks were taking place. Subjects were asked to work individually, but when questions were asked or comments made by one subject, they would have been audible to other team members. Subjects were not encouraged to collaborate or assist each other.

4.2.3.1 GEOVISUALIZATION LECTURE

I prepared the geovisualization lecture based on the list of tools and interactions in Table 1.1, with the number of interactions reduced and all the "techniques" excluded. This was for reasons of limited presentation time, a desire not to overstretch the CDR subjects, and to concentrate on those geovisualization elements most likely to be of use (the tools and interactions themselves). The lecture material was in the form of PowerPoint slides, with a notional one slide per tool, although explaining some complex tools took more than one slide. Interactions were illustrated using videos of the interaction in use in a geovisualization application. Graphics were mainly sourced from screenshots of existing information visualization and geovisualization applications. The emphasis throughout was to show the tool or interaction in use, if possible with crime data (although it was not possible to show CDR crime data). The presentation was themed as an exploration through space, time and data, contained 45 slides plus four animations of simple interactions, and was delivered by a geovisualization expert.

4.2.3.2 CARD SORTING

After the lecture, a card sort (Figure 4.3) was used to determine which tools/interactions were thought to be most helpful to the team's exploratory tasks. The CDR subjects were given a stack of 29 cards containing the names of the 29 major tools and interactions taught in the lecture, and provided with a paper handout of the slides for their reference. The subjects were asked to go through the cards and divide them into four piles as follows:

- tools/interactions they believed would be most helpful to their in-depth research into single issues to include in a prototype geovisualization application ('tick')
- tools/interactions believe to be least helpful or unhelpful… ('cross')
- tools/interactions that were 'intermediate'... ('dash')
- tools/interactions about which they were unsure or didn't know... ('question mark')

The information was recorded, and a feedback session scheduled to reach a consensus, through discussion between subjects, on the results, anticipating there would be be divergence between the individuals' results. In the event (section 4.5.1) this was not the case.

Figure 4.3: Free card-sorting of geovisualization tools and interactions by a subject

4.2.3.3 INTERVIEW

In order to triangulate the evidence from the card sort, subjects were interviewed, individually, two weeks after the card sorting exercise. They were asked which geovisualization tools and interactions - after the passage of time and on reflection - they recalled as being potentially useful to them. No prompting was given, although subjects who recalled a tool and were able to describe it, but were unable to remember its name, were assisted.

4.2.3.4 SKETCHING

From the results of the card sort conducted on crime tasks (see section 3.3.4), three major crime tasks were selected. These were chosen by going through the stacks, beginning with those with the most cards, and using the given stack titles and the subjects' selection of task considered most representative in each stack. This process was carried out in front of the subjects so they could see the derivation of the three major tasks and agreed with their selection. The three major crime tasks were 'night-time economy' (meaning alcohol-related assault, damage and disorder); 'fear of crime'; and 'racial crime'.

Subjects were provided with flip chart paper and pens and asked to produce a rough design for an application - to include geovisualization components – that they would consider would best help them gain an insight into each crime research task. Subjects worked individually, and completed two or three sketches in the time available (30 minutes) – see Figure 4.4. Each sketch was examined subsequently to see what could be elicited about how the subjects' had made use of the geovisualization tools and interactions, and what, if anything, it contributed to eliciting their requirements. By making a numerical count of the components within each sketch, it was possible to derive quantitative information. Tools/interactions that appear frequently or on sketches from more than one subject indicate both recall of these geovisualization components and a perceived utility to the task in hand.

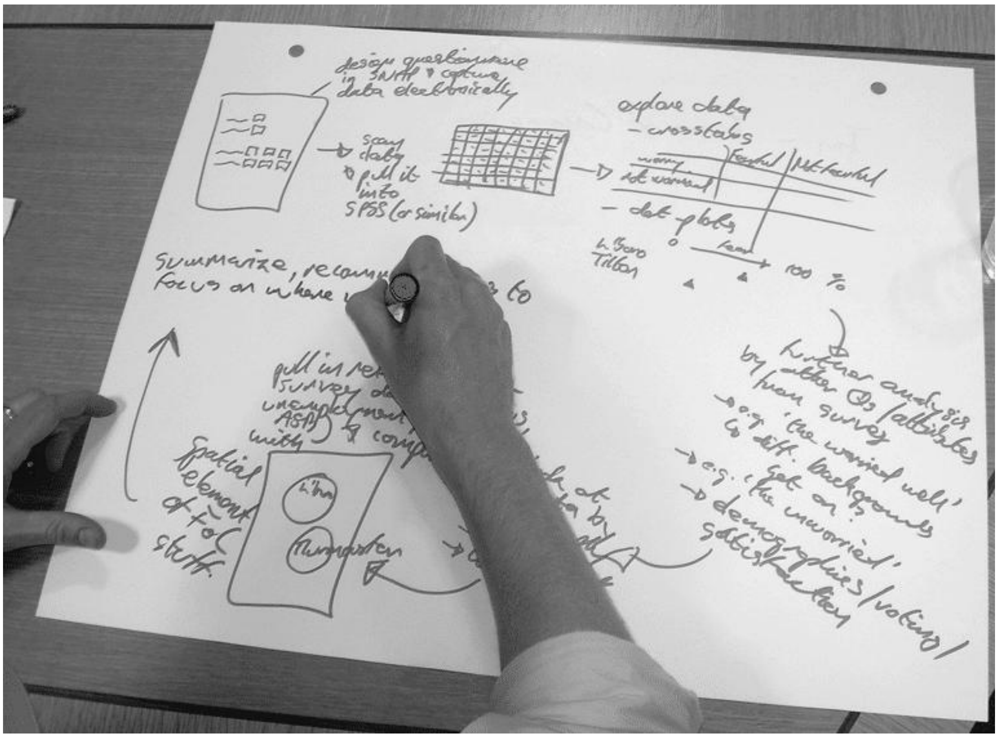


Figure 4.4: Subject in course of sketching a “fear of crime” application

4.3 RESULTS – REQUIREMENTS TEMPLATE

These results correspond to case number 4 on Table 2.2 (an extract of which is at the start of this chapter).

4.3.1 SUBJECTS' RESPONSES TO VOLERE TEMPLATE QUESTIONS

The CDR subjects' responses to questions prompted by the Volere template are coded with an emergent scheme that focuses on how the users were able to **envisage** the application they wanted; the **ideas from other applications** that might be useful to such an application; and specifics about **tools and interactions**. **Learning** observed by subject C3 between sessions and after exposure to geovisualization is noted (the abbreviation 'C3+18' is used to denote C3's responses after 18 months). The Volere template also elicits facts about the subjects' domain, and contributes to information about the subjects' **context of use**.

4.3.1.1 ENVISAGING THE APPLICATION

This topic is at the heart of whether the Volere template can supply meaningful requirements to enable a geovisualization application to be built. All three subjects, and subject C3 on both occasions, indicate an inability to imagine an "undreamed of" geovisualization applications, as these quotes demonstrate:

1a What are the key things that make you want me to produce a spatially-related application for you?

C2: "It sounds very good to be able analyse space, time, and situate it at a geographical level, but I can't get picture of how it's going to work."
C3: "I haven't got a clue what the final product will look like…"

1b What do you want this product for? You want it to do….what?
Aspects:

C1: "I don't have a clear view of what it looks like"
C3+18: "I can't think off the top of my head…I can't think."

27 Have you got any particular ideas for solutions?

C1 :"I would need to think about this."

4.3.1.2 IDEAS FROM OTHER APPLICATIONS

The Volere template explicitly seeks information by encouraging subjects to think about aspects of other applications that might be useful in an application:

19c Is there something you have seen in an existing system (either a Crime based one or a geovisualization one) that we could copy?

C1: "www.historyshots.com – particularly like visual displays. The website zoom in/zoom out. Would be useful to be able to do the zoom in/zoom out for CDR. Like brushing in the geovisualization prototype we have seen, but didn't get the tri-colour thing." [Later suggested liked http://www.nytimes.com/ref/elections/2006/House.html*]*

C3: "The whole interactivity thing – the fact that you can multiple representations of the same place and they are all highlighted at the same – that's really good…[but] you don't know where to look unless you're told. Knowing geographically where somewhere is, and knowing the attributes about that place and linking the two together. Being able to drill in and out of places as well…geographically, time and all the other ways… at different levels of geography, for instance, output area, super output area, a district."

www.historyshots.com is a site that produces posters of historical events in a number of styles by different graphic designers. Some are influenced by Minard's graphic of Napoleon's 1812 invasion of Russia, that appears in Tufte (1986); others by the Themeriver application (Havre et al., 2002); some feature timelines. The emphasis is on presentation of historical facts in an attractive way.

www.nytimes.com/ref/elections/2006/House.html reports 2006 USA mid-term election information through thematic colouring of geographic and cartogram maps, and permits some 'detail-on-demand' and selective filtering by state. It is a true geovisualization application, but its scope is limited to anything other than the simplest exploration, and its main purpose appears to be presentation.

The 'tri-colour thing' is a reference to a three-colour thematic colouring scheme used in the geovisualization prototype produced by Attilakou (2005) and may indicate a lack of understanding of it or a general desire for less complex visual representations.

4.3.1.3 TOOLS AND INTERACTIONS

Another indirect way that the subjects might use to describe aspects of the future geovisualization requirement is their response to Volere questions about particular tools and interactions:

1a What are the key things that make you want me to produce a spatially-related application for you?

C2: "analyse a given crime problem, using time, using spatial analysis and be able to be able to deliver that at the level of a CDRP"
C3: "I'd like a method or tool to ask it sensible questions and receive sensible replies. Simple, database questions… if I had those tools in one place, in a standard way, it would simplify the task immensely - my [current] tools aren't packaged together to be reused."
C3+18: "The ability to respond to questions in a more analytical way...flexibility to drill into the data…to allow you to spend more time looking at the information"

1b What do you want this product for? You want it to do….what?

C1: "I use MapInfo… Excel, Publisher, trends over time; perhaps survey results. Combining these things it's difficult to put it then down on paper. You want to be able to visualize better"

19c Is there something you have seen in an existing system (either a Crime based one or a geovisualization one) that we could copy?

C2: "I've gone through the data, I've found an interesting correlation between X and Y, I want to be able to visually and data-wise pull that data out and ideally I'd like it to be in a presentable form and prettify everything up and pull apart to put it back together again just to be able to present it."

Additional things (raised by subjects):

C2: "Will this all be able to be pulled out and put into a reporting format rather than us having to do it manually and put it into Publisher? Will I be able to go back to an insight I had 5 minutes ago?"

There are a number of strands here. One is that subjects are situated in the context of their current environment, and see matters through the inadequacies of their present tools. The second is the focus on eventual presentation, identified in earlier context of use work. The third is the desire to combine temporal, spatial and attribute data in a flexible way to visualize their tasks better. Finally, user C2 has a specific requirement for the functionality to return at a later stage of the application to an earlier insight.

4.3.1.4 LEARNING

Only subject C3 was asked to repeat some Volere template questions 18 months after the first session, results that reflect the passage of time and increased exposure to geovisualization are necessarily limited:

10a Have you got any feel, or preferences, for what the final application's "look and feel" will be? Things like style, colours etc?

C3+18: " No, I don't think they are necessarily the things that [matter]…I might have said they were really important before, but I think I would be more bothered about the things like the flexibility with the scale, and being able to see the actual values, and making it usable. The kind of "prettiness" - it is important to a degree, but I am far more hung up on making sure that it is showing you what you think it is showing you. The big lesson I have learned is that when you portray any of this information to your audience, it has got to be crystal clear and really simple."

19c Is there something you have seen in an existing system (either a Crime based one or a geovisualization one) that we could copy?

C3+18: "I suppose that I am now aware that we spend a lot of our time looking at offences. Whereas, there's a lot of information out there involving victims, and the offenders, and where people live, and the routes people travel, and all of that kind of information, which is completely unrelated to [the current prototype]…"

C3 is thinking less about presentation and "prettiness", albeit being more concerned than ever about the simplicity, detail and clarity of the final message and about the nature of the available data and how it could meet C3's goals. C3's experience of being able to explore scale differences easily and flexibly in the preceding 18 months has been significant.

4.3.1.5 CONTEXT OF USE

The Volere process – entailing as it does a dialogue with subjects about aspect of the work – inevitably gathers a great deal of information that, in an ISO13407 sense, belongs to understanding context of use.

4.3.1.5.1 CDRP FOCUS

All the quotes here are from C1, who, as team leader, has the principal role for interfacing with CDRPs. The most revealing comment is made in response to Volere question 11b that circumscribes very clearly the degree to which the CDR team must tailor their output to their end customers:

1a What are the key things that make you want me to produce a spatially-related application for you?

C1 "CDRPs would benefit from getting information to them in a useful way and getting them to do their job better"
C1: "I want to produce something that CDRPs OR Community Safety people can use."
C2: "analyse a given crime problem, using time, using spatial analysis and be able to be able to deliver that at the level of a CDRP"

2c Who are other stakeholders (apart from this team)?

C1 provides an extensive list of stakeholders in LCC, police and CDRPs

3 Who do you see as being the users of the application? Within LCC? Any outside LCC? Who are the key users?

C1: "8 CRDPs inc Rutland; Police; LCC: research team + community safety team. Youth Offending service; Fire and rescue: Probation; Primary Health Care Trusts: Youth crime prevention"

11b How easy to LEARN does the application have to be? (e.g. CDR team will be able to use it effectively after n weeks training")

C1: "It has to be easy to use for stakeholders. Essentially we're talking about policymakers – not at desks at all, not IT literate. Some of them can't use Excel well at all. Needs to be really really straightforward. We don't send material out as Excel, but as a pdf without the data behind it. One page only. So they can't break it; can't get confused. I go out and do a presentation - simple, but it has a big impact. Invest time in explaining it. On balance I think we should go for something highly interactive (rather than static or paper as a means of presentation)."

12d What reliability and availability does the application need to have?

C1: "It's 'off-line' [away from customers] so if it 'crashes', it happens, but not when it's in 'presentation mode' to CRDPs."

4.3.1.5.2 CDR PROFESSIONALISM

In responses to a number of questions, an overall sense of the CDR team's professionalism come through – the sensitivity with which they handle information which might place one of their customers in a bad light; their integrity; their confidence within their domain of expertise; and their openness to change:

2c Who are other stakeholders (apart from this team)?

C2: I think there's a danger of understanding what the tools do, to interpret them correctly and to put data into a novice's hands … is very dangerous. There's a high level of integrity in [the LCC] Research [unit] to doing it properly."

4a-1 What constraints are there on application I produce? e.g. computers, operating system, screen size, resolution?

C1: "We can do what we want and argue the case"

11a How easy to USE does the application have to be? (Is it going to be for experts? Will parts of it be used by non-experts etc.?)

C1: "For CDR team…We need to be able to work with it at an advanced level. We're prepared to put in time. For non experts: Depends what we produce; how much we do before they see it. [My] view about stakeholders is they explicitly do NOT get to play with the data."

16 Are there any special factors about the product that would make it unacceptable for some political reason?

C2: "I would say no. Sometimes we are a bit tentative about the reports we put out in case it shows a CDRP in a poor light., e.g. a performance issue. But no."

C3: "Yes and no…if the information is correct and represented corrected and telling you the full story or at least there are notes that are telling you that (or caveats), then I have no qualms."

20a What problems could the new system cause in the current environment? Would it radically alter what people do, or could do, say?

C1: None. Everyone's excited"

C2: "Don't feel threatened ; always want to learn."

C3: "Doesn't upset me; it's an opportunity to look at technology and techniques.

C3+18: " No,it is really beneficial. I think we are at a real turning point… because you have got something tangible here now [digital prototype] that can demonstrate the benefits. I don't really care about the responsibilities and who does what work, and whether it changes the work that we do. If it changes the work we do, it changes the work we do. And that can't be a bad thing – [we] should not be static; we shouldn't just roll out more reports, week in week out, month in month out. If it questions things, then so be it."

4.3.1.5.3 SUPPORT FOR THE APPLICATION

The Volere template specifically asks about maintainability, support and documentation for applications. The individual reactions of the CDR team to these topics shows a common desire to be able to support the application themselves through their own learning:

12d What reliability and availability does the application need to have?

C3+18: "It depends on the ability of the individual to fix it…things [can] fall over and we need to be in a position to maintain it and understand it, to a level that we can keep it going"

14a How easy must it be to maintain this application – especially after I leave? Specifically how long should maintenance take?

C1: " I think it's best long term if we develop the skills to maintain within the team rather have IT maintain (and recharge us)."

20a What problems could the new system cause in the current environment? Would it radically alter what people do, or could do, say?

C3: "With final product, we need to make sure that there's some kind of support to continue it. Will the system you build going to be flexible enough to cope with future change?"

25 What kind of user documentation are you expecting or would need?

C3+18: I don't think that's important at all. As long as the knowledge shared out amongst a few people they can pass it on. If the software is intuitive enough, you'll find your way around it." Being aware more of how it's put together, so that if it goes wrong for any reason, or needs maintaining, you've got the capability to do that."

4.3.1.6 FACTS

A number of Volere questions simply reveal factual information, which is useful for context, but does not contribute to establishing a geovisualization application:

4a-1 What constraints are there on application I produce? e.g. computers, operating system, screen size, resolution?

C1: "My setup is a fairly regular Windows desktop -with a large monitor"
C2: "All "power user" types with Windows XP"
C3: "Win XP on my desktop with 17" flat screen. Partners are unlikely to be running anything strange like Macs or Linux"

4c What apps are you using that my app might have to feed into or take data from – what extent of interface with these?

C1: "MapInfo, Access, Excel, Word, Publisher, Snap, SPSS
C2: "Excel, Access, MapInfo, Publisher , SPSS, Snap, Vertical Mapper "
C3: "Vertical Mapper, SPSS"

4f Timescale for this project is about 3 years, are there any other milestones? Any windows of opportunity? Timings that have to be achieved?

C1: "You can be relaxed about timescales. However once you've spoken to stakeholders, expectations are raised"
C3: "I wouldn't let the research get drawn into other people's timescales, if I were you."

6a Are there any external factors that impact this project? Changes in organizational structures within LCC, or within local govt, or in CDRPs ?

C1: "Partnership working is here to stay; structures may change but the audience is the same. Police force mergers not happening currently. The [proposed] local government reorganisation has gone away."

7b Can you take me through the key activities that you (and others) carry out around your processes?

C3: "The questions you get to answer are pretty ad-hoc; we use the same techniques over and over. I run queries in Access to get data at various different geographical levels by a particular time period for particular crime types, say – and you'd tabulate them, produce thematic maps, cartograms perhaps. It's a very manual process to get data out of non-spatial database into a spatial form you can map."

10a Have you got any feel, or preferences, for what the final application's "look and feel" will be? Things like style, colours etc?

C1: " In a word, 'no'."
C2: "No."
C3: " Don't know. Look at the style of our work – we use same font style (Gill Sans) Our schemes are all ColorBrewer. LCC has its own Pantone colours for its logo etc.- I wouldn't say you were bound by this though – chose your own."

10b Is there anything in the style I need to take into account given the audience?

C1: " No. Well thought through only. No corporate style."

C2: "I like the style that C1 tends to chose – quite minimalist, Gill sans… "

11b How easy to LEARN does the application have to be? (e.g. CDR team will be able to use it effectively after n weeks training")

C2: "If I'm taught piecemeal, I'm probably going to find it hard; if there's a logical, well-set out set of instructions and a bit of teaching behind it, I think I'd find it fine."
C3+18: "From a work of perspective, then you want to be able to learn it quite quickly, in order to be able to get on with those day-to-day tasks that you need to do. But from my personal perspective, then there is also that fear that you plateau really quickly."

12a How fast will the application have to perform? (e.g. How long a gap in seconds between user selecting a "new screen" and it appearing?)

C1: "I can wait 2 seconds or five seconds. If it's good, we can wait."
C2: "It totally depends on expectations. If it's been built and we know it's going to be a bit longer then that's OK. I can cope with a second or two"
C3: "5 seconds [wait] would drive me mad in all honesty."
C3+18: " I think it does need to be fast. It couldn't go slower than [the digital interactive prototype developed and described in Chapter 6] is…otherwise you would just sit there in frustration. As soon as you get negative feelings about a tool delivering what you need it to do, then you don't do it."

12c What precision does the application need? (e.g. numbers should be shown to n dec places or y sig figures; boundary maps should nest; maps not be generalised beyond z)

C1: " CDRP level is reported in words - "2/3 of people think this" is more memorable than '63.5%'. I don't go to greater than one dec place. Boundary maps should nest- yes. Level of detail: what customers want to see."

12e What capacity does the application need to have? i.e what volumes of data must be processed in what sort of timescales?

C1: "Don't think large datasets would be needed. Our crime offences database is huge but it is filtered before we use it. The range is potentially huge - any crime type over 7 years at OA level etc. but the application shouldn't have to cope with this. I can't see us even having tens of datasets."
C3+18: "It comes down to being able to filter certain areas. And the fact that it is all relative to the areas that you work in."

13a What environment will the application need to work in?

13b What's the spec of the machines this application will run on?

13c What other applications (if any) MUST my application interface with?

C1: (13a): Standard office environment.
C2: (13a): "Just our desktops [in the office]. But sometimes we take data home and play with it on laptops."
C1: (13b): "Standard Microsoft Office XP PC"
C1: (13c): "none"

15a Are there any specific security requirements for the application (for example should it hold crime data in a secure way, or have some kind of access system?)

15b Are there any specific data integrity issues that need to be borne in mind?

15c Are LCC's auditors likely to get involved in any way with this application? If so, how?

C1: (15a): "No password protection [needed]"
C1: (15b): "No"
C1: (15c): "No"

16 Are there any special factors about the product that would make it unacceptable for some political reason?

C1: "None that I know of. If we fell out with police…"
C2: "I would say 'No'."

17a Does the proposed system fall under the jurisdiction of any law?

17b Are there any standards with which I must comply?

C1: (17a & 17b): "No"

19a Do you know of any commercial systems that do what this application intends to do?

C1: "No. Existing stuff is very 'tactical'" – it's at a very different level."
C3+18: "There's quite a few different applications out there that do hot spotting, but then at the end of the day, I don't think they really answer the questions that people want."

20b Will the new development affect any currently installed system?

20c Will any existing users be adversely affected by the new development? If so, how?

20d Are there any limitations you can think of where the application will be used that may inhibit the new system?

C1 (all): "No"

There are quite a few questions where the subjects provide almost monosyllabic responses – for example, 15a, 15b, 15c, 16, 17a, 17b, 20b, 20c, 20d. These sections clearly do not engage relevantly with the subjects for reasons that are more likely to do with the small scale of the application that anything to do with the nature of geovisualization.

4.3.2 ANALYSIS OF VOLERE RESPONSES

The responses to the Volere questions provide from the three CDR subjects reveal to what extent it is a suitable method for establishing requirements for a geovisualization application.

Asked directly about the key things that motivate their desire for a geovisualization application, what its purpose would be and what it would include, the responses of the CDR subjects are unambiguous and consistent.

C1: "I don't have a clear view of what it looks like"
C2: "I can't get picture of how it's going to work."
C3: "I haven't got a clue what the final product will look like…"

These responses indicate an inability to imagine "undreamed of" geovisualization applications and that 'head on' questioning of the subjects in this way is not going to establish meaningful requirements.

A different, more tangential, approach is inherent in the Volere template when it asks about what other applications, known to the subject, contain aspects of use in an eventual application (this echoes the guidance in IS13407 to engage in competitor analysis). C1 produces examples of existing systems with components and enumerate the aspects liked, which are both interactions – zooming and brushing. C3 does not reference a particular existing system, but talks in more general terms with a focus on interactions that permit linking between multiple representations, and drilling down to get details both spatially and temporally. This tangential approach is more successful in establishing *a little* information on subject requirements than one that is more 'head on', when the application is so removed from the subjects' everyday experience. Showing geovisualization examples in use - another tangential approach - might act as an effective way to communicate geovisualization to these subjects.

Another indirect way that the subjects use to describe aspects that might be useful in a future geovisualization requirement is their response to Volere questions about particular tools and interactions. A number of strands emerge here. One is that subjects are situated in the context of their current environment, and see matters through the inadequacies of their present tools. The second is the focus on eventual presentation, identified in earlier context of use work. The third is the desire to combine temporal, spatial and attribute data in a flexible way to visualize their tasks better. Finally, user C2 has a specific requirement for the functionality to return to an earlier insight at a later stage in a visualization. Once again, while some information is elicited, it fails to establish firm requirements.

From reflective comments made by C3 to Volere questions repeated eighteen months after the first Volere session, there is evidence that C3's thinking has broadened somewhat, and that C3 is now considering how different data might be visualized in novel ways to better meet the goals of the CDR team. But C3's response to a 'head on' Volere question about the purpose of a geovisualization application that C3 might now want, eighteen months later, is the same as it was before:

C3+18: "I can't think off the top of my head…I can't think."

The Volere template is a conversation with subjects about their work, and has the attendant benefit of gathering much information that aids the understanding of the subjects' context of use. Three particular strands are prominent: a focus on CDRPs, the CDR team's professionalism, and the support needed for an eventual application.

4.3.3 VOLERE TEMPLATE RESPONSES DISCUSSION AND RECOMMENDATIONS

The Volere template has not been a successful HC approach to establishing the requirements of the CDR team for a geovisualization application. Subjects are unable to contribute answers to 'frontal' questions about the content or the motivation for such an application. Where Volere questions that are more 'tangential' are asked using the template, for example asking about ideas from other applications, or when giving subjects the opportunity to extrapolate from their existing tools, then some, limited, insight is obtained. But nothing like enough to inform a geovisualization designer. The results are similar across all three CDR team members suggesting that the limited outcome is not down to any one individual but a combination of some or all of: the CDR domain, the approach employed by the template, or the nature of geovisualization. Because the Volere template is well used in a number of different domains, evidenced by the list of 100 diverse international companies and organisations on the Volere website (Atlantic Systems Guild Ltd., 2010), it seems unlikely the Volere template itself is at fault. Given that the CDR domain has been the focus for previous academic (Buetow et al., 2003; Chung et al., 2005) and commercial (ESRI (UK) Ltd, 2007) geovisualization applications, it is most likely that the limited outcome is down to geovisualization. However, it is unclear which aspects of geovisualization – its spatiality, exploratory nature, inclusion of multiple components, interactivity, or its overall novelty and complexity - contribute to this. The inability of subjects to envisage a geovisualization application (section 4.3.1.1) implies that this is a case of "undreamed of" requirements. It is particularly telling that Volere cannot elicit requirements about content from C3 by means of 'frontal' questions asked after 18 months of learning about geovisualization, and experience with geovisualization wireframes and prototypes.

The Volere questions supply part of the body of evidence that contributes to an understanding of context of use – useful in constructing the scenario (see sections 4.2.2 and 4.4) but this is a by-product and not its main function. Many of the later sections of the template dealing with matters such as security, auditing, 'politics', law, standards and other developments appear to be irrelevant to the CDR subjects. This may be down to the small scale, limited, nature of the project, even though Volere is recommended by its authors for all scales of project including simple, 'agile' ones.

As in Chapter 3, a piece of the jigsaw that appears to be missing from the Volere template process is any clear thrust towards asking in sufficient detail about subject data, and by extension, using it as a way to get subjects to talk about the ways to visualize it. The template mentions "a specification of the essential subject matter, business objects, entities, and classes that are germane to the product. It might take the form of a first-cut class model, an object model, or a domain model" (Robertson and Robertson, 2006), but this does not address asking subjects about the details of the data itself. The fact that the 'end product' is an application that transforms and displays subjects' data, rather than a system that incorporates such data to support a broader purpose, may be the problem. It suggests that processes such as exploratory data analysis and information visualization would encounter similar problems with Volere and that the spatial aspect of geovisualization is unlikely to be crucial.

An interesting detail is the way in which information about a topic can emerge from different subjects as replies to different questions (for example, 14a for C1 and 12d for C3+18; another is C2's reply to Q19c which is an answer to Q1b). In this respect, the Volere template appears to act sometimes as an opportunity for researcher-domain expert dialogue, where the CDR subjects are able to surface the ideas, concerns and aspirations that they consider important.

I recommend that geovisualization researchers avoid the Volere template approach to establishing requirements from subjects. There is good evidence (section 4.3.1.1) that the proposition of a geovisualization application does not elicit requirements from subjects, whose responses indicate its "undreamed of" nature. Nevertheless, the Volere template might help researchers by providing a long 'check list' of issues, and yielding additional context of use information. The kind of information a designer needs to build a geovisualization application depends on an understanding of the characteristics of subject s' data and associated metadata – spatial and attribute (and possibly temporal). This is not implicit in the Volere template and needs to be gathered as a separate exercise.

4.4 RESULTS – CONSULTING GEOVISUALIZATION EXPERTS WITH A SCENARIO

These results correspond to case number 5 on Table 2.2.

The Volere template does not assist in establishing detailed requirements for constructing a geovisualization application for the CDR subjects. Another approach is to write a scenario based on the context of use of exploratory crime analysis by the CDR crime subjects. Geovisualization experts consider the scenario of CDR subjects' work, and are questioned about which geovisualization tools and interactions would be useful to incorporate in an application to meet the needs of the people in the scenario.

This approach gives results in the form of:

- counts of the tools, interactions and references to geovisualization applications that might be of use to the CDR team mentioned during the interview,
- responses to a questionnaire administered after the interview, covering expert's research areas, qualitative and quantitative comment on the use of the scenario, and the conduct of the process,
- comments made about the scenario/expert process made during the interview, transcribed and coded according to an emergent scheme.

4.4.1 EXPERT SUGGESTIONS: GEOVISUALIZATION INTERACTIONS, TOOLS & APPLICATIONS

Interviews with geovisualization experts on the scenario yield many suggestions for tools and interactions, but few if any for any 'techniques' such as those set out in Table 1.1. This is not surprising given that the focus of geovisualization is not on pre-processing data. Where experts mention tools and interactions in the context of the scenario, these instances are coded in the analysis. The transcripts were coded on sections of text representing natural conversation blocks, typically ending when the topic changed or there was a change of speaker. Geovisualization experts also reference a number of existing visualization applications as exemplars of a particular approach of use to the CDR team. Care was taken that expert's references to tools and interactions directed towards the scenario and the CDR team were coded, and that coding of mentions of tools and interactions that were more general in nature were minimised.

The counts of the tools, interactions and references to geovisualization applications that might be of use to the CDR team are given, by individual geovisualization expert, in Tables 4.1, 4.2 and 4.6, respectively. Repetition of a term within a single block of coded text is treated as a single incidence. Results are listed first in order of the total number of experts mentioning a particular tool, interaction or visualization application, and then by the total number of mentions.

4.4.1.1 INTERACTION SUGGESTIONS

Table 4.1 shows that the geovisualization experts mention 31 possible **interactions**. The top eight interactions - that account for 60% of the 187 mentions in total – are considered here.

One expert (P8) mentions some interactions significantly more frequently than other experts - 'filtering' (13 out of 22), 'zooming' (5 out of 11) and 'comparing' (8 out of 17). P8 is the sole expert mentioning 'dragging' (7 out of 7) and 'saving/history/recall/favourites' (6 out of 6). The only other expert who mentions an interaction on anything like the same scale is P3, who mentions 'linking' 6 times out of 13. On reviewing the transcripts, these frequencies appear to be more to do with the placement of the segment blocks during coding and P8's style of speaking (repetition at different points in the interview for emphasis or recapping, for example) than anything more significant for the interactions being described. P8's mentions do not significantly affect the overall rankings.

The most mentioned interaction is '**aggregating**', 23 times in all by eight of the nine experts. Experts appear to see this interaction as particularly important to address the hierarchical nature of the data and to uncover detail hidden in an extensive hierarchy. The ability of aggregation to embrace spatial, temporal and attributes makes it a particularly widely scoped interaction. Some characteristic quotes on 'aggregating' are:

> *"It seems to me we have a hierarchy here, so we need something that allows us to aggregate through this hierarchy and symbolise the levels and different categories in this hierarchy with our points." (P1)*
>
> *"…that suggests you would want a system that allows you to explore the effects of aggregation. That might be particularly useful in that the decision-makers…are used to edited, aggregated data that are a product of a lot of transformations that are going to lose a lot of the detail." (P2)*
>
> *"…you would be able to explore the effect of these different representations if you could interactively change the level of aggregation. Basically all this comes down to is distinguishing between genuine patterns in the data and artefacts of the representation process." (P2)*
>
> *"…taking the individual data, because we can always re-aggregate the individual data back up to different levels of space and time." (P9)*

'**Zooming**', mentioned eleven times by six experts, is another widely scoped, navigational interaction:

> *"It should be possible to zoom in on geographical scale; it should be possible to zoom in on temporal dimension; it should be possible to zoom by qualitative or quantitative statistics." (P7)*

Although 'zooming' is highly ranked, 'panning' is not. "Zooming and so on" or "zooming etc." is sometimes used as a shorthand by some experts for the totality of the user/computer navigation interaction, and only rarely is panning mentioned:

> *"they need to have interactive maps, with all the basic functions like zooming, panning and so on" (P6)*

The second highest number of mentions (22) is for '**filtering**', by five of the experts, however 13 of those are from one expert, P8. This is an interaction with a wide scope, embracing spatial, temporal and attribute and the corollary to 'aggregating', so it is perhaps unsurprising to find it highly ranked:

> *"First of all, you need to have tools for filtering."(P7).*

'**Clustering**' is a process with a wide general applicability, and is mentioned 15 times by five experts:

> *"for this purpose, may be some kind of multi-attribute clustering would be useful" (P6)*

'**Linking**' provides the simultaneous binding for multiple tools and is a fundamental interaction to all but the simplest geovisualization applications, and is mentioned 13 times by five experts, although six times by P3:

> *"We are clearing looking at some sort of linking as an appropriate way to go forward between their spreadsheet of crime statistics <u>and</u> Acorn and other socio-economic data <u>and</u> maps, because that's the crucial linkage as I see it. Probably with some sort of dynamic linking to the crime hierarchy." (P3)*
> *"If you are looking at interaction tools, you definitely need the interlinked windows, brushing, so you can see where things correlate between different views." (P4)*
> *"I believe that they need something integrated, where all the tools are linked, so that they don't need to use different systems." (P6)*
> *"In terms of visualization, I suppose one of the first things I'm thinking of here is some kind of map linked with a table." (P8)*

'**Comparing**', like 'clustering', is a process with a wide general applicability. There is some suggestion that like "zooming and so on" it stands for a wider set of interaction processes – "compare and contrast" comes to mind. Indeed two of the three instances for 'comparing' are references to "compare and contrast"

> *"you show the dynamics by a line [on a time graph]. If you have several attributes of several areas, then you overlay several lines, and you can compare all the dynamics of different attributes or the dynamic of the same attributes in different areas." (P6)*
> *"you get a small multiple type view of it there, and you could compare and contrast - is it that assaults that involve muggings were all in one part of the city centre and other kinds were in another part, and so forth. The other thing that you might want to do is compare its patterns to other types of crime. So car theft - do you get a lot of car thefts in the places you get assaults?" (P7)*

P1 and P8 account for 9 out of 11 mentions of '**symbolising**'. This is a less of an interaction than an aspect of the 'look and feel', although some experts see a creative aspect:

> *"I would just play with the symbolism, and I would do it on photo-realistic Google Earth for starters because of…taxi ranks and very specific features that you might be able to see on the ground" (P1)*
> *"you would do colouring by type of event, or if there are some numeric attributes, like how many people are involved, or what is the total damage. Then I would try to use graduated symbols for seeing places…" (P7)*

'**Classifying**' receives six mentions from four experts, three mentions from one expert, P4, whose emphasis is on the flexibility the CDR team will need to reclassify during exploration:

> *"Where you have top level hierarchies there are things that may link into different areas – obscene publications come into 'miscellaneous' which links to incidences of 'indecency'. 'Other firearms offences' to 'Assault' or even some of those sort of cross-links." (P4)*
> *"It is useful to have the pre-processing, but at the same time if they start to feel they have found a lead within something, and they need to change the classification they need to be able to do that fairly quickly." (P4)*

Interactions with a wide scope appear more frequently than those with less wide a scope, raising the possibility that it is the wider applicability of such interactions, rather than their particular fit for the needs of the CDR team expressed in the scenario, that might be the reason for their high ranking.

Another issue is the identification of geovisualization interactions within the coding scheme. I built the coding scheme starting with the list at Table 1 .1 (in chapter 1)and added other "interaction" terms that emerged from the expert transcripts. It is no coincidence that the vast majority of the interactions in Table 4.1 are expressed as verbs. According to the taxonomy chosen (see section 1.1.2), what may be regarded as an interaction will differ. It may be that 'brushing' should be regarded as more fundamental to geovisualization than 'aggregating', and 'aggregating' more fundamental than 'symbolizing', for example.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	Total
aggregating	4	6	2	1	0	1	3	4	2	**23**
zooming	1	0	1	1	0	1	2	5	0	**11**
filtering	0	1	0	5	1	0	2	13	0	**22**
clustering	0	0	0	0	5	2	3	4	1	**15**
linking	0	0	6	2	0	1	0	1	3	**13**
comparing	0	0	0	1	0	3	5	8	0	**17**
symbolising	4	1	0	0	0	0	1	5	0	**11**
classifying	0	0	1	3	1	0	1	0	0	**6**
correlating	0	1	1	2	0	2	0	0	0	**6**
transforming	0	3	0	0	0	2	0	0	1	**6**
reordering	0	1	1	0	0	2	0	0	0	**4**
toggling	2	0	0	0	0	0	0	4	0	**6**
slicing	2	0	0	0	0	0	0	0	2	**4**
grouping	0	0	2	0	1	0	0	0	0	**3**
brushing	0	0	0	1	0	1	0	0	0	**2**
detail-on-demand	0	0	0	0	0	1	0	1	0	**2**
panning	0	0	0	1	0	1	0	0	0	**2**
spatial correlating	0	1	0	0	0	1	0	0	0	**2**
summarising	1	0	0	0	0	1	0	0	0	**2**
dragging	0	0	0	0	0	0	0	7	0	**7**
saving/history/recall/favourites	0	0	0	0	0	0	0	6	0	**6**
contrasting	0	0	0	0	0	0	0	3	0	**3**
splitting	0	0	0	0	0	0	0	3	0	**3**
dynamic querying	0	0	0	0	0	0	2	0	0	**2**
reclassifying	0	0	0	2	0	0	0	0	0	**2**
smoothing	0	0	0	0	0	2	0	0	0	**2**
cross-tabbing	0	0	0	0	0	0	0	0	1	**1**
drilling down	0	0	0	0	0	0	0	1	0	**1**
isolating	0	0	1	0	0	0	0	0	0	**1**
spatial aggregating	0	1	0	0	0	0	0	0	0	**1**
subtracting	0	0	0	0	0	0	0	1	0	**1**

Table 4.1: Total geovisualization interaction mentions by geovisualization experts (P1 – P9) in response to crime and disorder reduction scenario. Interactions are listed in order of number of experts suggesting and then by the total number of mentions.

4.4.1.2 TOOL SUGGESTIONS

Table 4.2 lists the geovisualization **tools** mentioned by the geovisualization experts. Results are listed first in order of the total number of experts mentioning a particular tool, interaction or visualization application, and then by the total number of mentions.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	Total
map	1	2	1	2	3	3	0	18	5	**35**
density/hot spots	0	2	0	4	1	0	1	3	1	**12**
cartograms	0	3	1	3	0	1	0	0	1	**9**
spreadsheet/table/grid	0	0	2	0	2	2	0	12	0	**18**
animation/animated	0	0	0	3	0	1	1	0	1	**6**
parallel coordinate plot	0	1	0	2	0	0	1	0	2	**6**
small multiples	0	1	0	1	0	0	0	9	0	**11**
histograms	0	0	0	1	0	0	4	0	1	**6**
choropleths	0	3	1	0	0	1	0	0	0	**5**
scatterplot matrix/scatterplot	0	0	2	0	0	2	0	0	1	**5**
chi-squared/relative view	0	1	1	0	0	1	0	0	0	**3**
box plot	0	0	0	0	0	0	0	2	2	**4**
inset	0	0	0	0	0	1	0	3	0	**4**
time graph	0	0	0	1	0	3	0	0	0	**4**
multiple maps	0	0	1	1	0	0	0	0	0	**2**
slider bars	0	1	0	0	0	0	0	1	0	**2**
timeline	0	0	0	0	0	0	1	1	0	**2**
space-time cube	0	0	0	0	0	0	4	0	0	**4**
dotmap	0	0	0	0	0	0	0	3	0	**3**
Venn diagram/Sets	0	0	3	0	0	0	0	0	0	**3**
lexicon	0	0	0	1	0	0	0	0	0	**1**
line graph	0	0	0	0	0	0	0	0	1	**1**
Lorenz curve	0	0	0	0	0	1	0	0	0	**1**
radial plot	0	0	0	0	0	0	0	0	1	**1**
SOM (self organising map)	0	0	0	0	1	0	0	0	0	**1**
table lens	0	0	0	0	0	1	0	0	0	**1**
Voronoi polygons	1	0	0	0	0	0	0	0	0	**1**

Table 4.2: Total geovisualization tool mentions by geovisualization experts in response to crime and disorder reduction scenario. Tools are listed in order of number of experts suggesting and then by the total number of mentions. Tools in bold are mentioned in the scenario.

There are 28 tools in total, mentioned 152 times; the top eight tools account for nearly two-thirds of the mentions, and are considered in more detail here. Expert P8 again is seen to account for significantly more mentions than other experts for a few tools – 'map' (18 out of 35); 'spreadsheet/table/grid' (12 out of 18) and 'small multiples' (9 out of 11). These frequencies appear to be caused by the same factors as for interactions, and do not markedly affect the overall rankings.

Encouragingly perhaps for geovisualization-focused research, the most mentioned tool is a **'map'** with 35 mentions from eight of the nine experts. Some characteristic quotes are:

> *"You've got here a map linked to a spreadsheet, linked to a hierarchy." (P3)*
> *"My feeling here is they want the range of maps; they are already used to cartograms." (P4)*

"…plus, you will need a map. So at least two things - one to do this, and then to map. This is what you would need for this kind of task." (P5)
"and for this purpose, they would of course need some map representations" (P6)
"I'm envisaging here a table linked with a map interactively…" (P8)
"The natural instinct of the geographer is immediately to go and map the whole lot" (P9)

With 12 mentions from six experts, references to **'hot spot mapping'** or **'density surfaces'** is second on the list. The fact that 'hot spot' maps are particularly associated with tactical crime mapping appears to be a factor with some of the experts, despite the fact that the CDR team are involved with the strategic side of crime and disorder reduction, not tactical policing:.

"I would argue that of those transformations, the density surface - which is the 'hot spot' - is actually one of the more reliable ones, because it is not unduly influenced by arbitrary spatial aggregations….there may be some separate issues to do with hot spots in the way that they are used emotively - they are seen as "danger maps". (P2)
"If you are looking at the different scales and you are looking at patterns, maybe you want to pick up on these hot spots" (P4)
"you get the number of crimes in each cell…and that gives you a kind of density." (P5)
"I thought about tools which would be useful for this purpose. There are some data mining methods where you use some spatial clustering methods which take into account the population, and try to find hot spots or some phenomena like crime with respect to the population." (P7)
"So we are into… models based on density estimation" (P9)

Five experts, but only nine times in all, mention **'cartograms'**. The scenario refers to cartograms as being a geovisualization tool that the CDR team are familiar with, and certainly some experts notice that with references to "familiar things" and "what they are used to":

"We want familiar things like conventional, probably choroplethic, but certainly spatial mapping, as well as the more sophisticated things like cartograms" (P2)
"…the cartogram is another way this could be displayed with a dynamic link to an actual map. Cartograms are obviously useful in this instance where you are looking at rates of crime." (P3)
"…see what they are used to, which is two scales, the interactions between maps and cartograms which they obviously do like." (P4)
"…probably cartograms would be okay for this. But personally I do not like cartograms, because they are quite hard to understand. And when people see the distorted areas, they don't immediately understand what this is." (P6)
"I am happier with cartograms, and continuous cartograms…I can explain them. I think where the underlying distortions are so great, one might go with discontinuous cartograms…I do think that they are extremely good tools…I am not always totally convinced by some of Danny Dorling's cartograms…" (P9)

A '**spreadsheet**', '**table**' or a '**grid**' receive 18 mentions (12 from P8 as noted earlier) from four experts. Expert P6 makes a useful point suggesting that spatial representation can be replaced by a table to give a more effective visualization.

"…a map linked to a spreadsheet, linked to a hierarchy. These two views (hierarchy and spreadsheet) could be two different views of an underlying database." (P3)
" you have crime 1, crime 2, crime 3, crime 4, and so on. Each of them is assigned to the cell where it happened…the first thing when I look at this, is instead of looking at the crimes, you look at the grid cells and you get the number of crimes in each cell." (P5)
"if you have areas that are very different in size, it is probably better to have a table and use the presentation techniques which are suitable for a table...in a table, you have a benefit that you can do various kinds of reordering. Reordering by population, reordering by size of the area, reordering by the frequency of something - certain type of crimes, and so on." (P6)
"[If] there are tasks where spatial neighbourhood is not so important, then a table is [appropriate]… the table will be really more useful and powerful. Because in the table, you can simultaneously see several attributes." (P6)
"one of the first things I'm thinking of is some kind of map linked with a table...if you started off with some interactive table that just coloured in the squares that weren't zero" (P8)

'**Animation**' receives six mentions from four experts. The experts appear to be divided here on the purpose of an animation – P4 speaks of "[to] present" and P9 of "a movie" indicating a non-exploratory use. P6 clearly has a different motivation and is envisaging animation in a more exploratory way.

"…a series of small multiples as in time series [for] trends. Probably…they need the ability to animate them [to] present…in a much more visual way." (P4)
"I would call it 'animated' - what I mean is that you can interactively choose the moments and go step by step. Not just animation, which is where you just view an interactive animation, but where you have control over it. And in this way, you can analyse how these spatial patterns develop over time." (P6)
"In the initial stage…it might be interesting also to look at some simple animations, maybe for aggregated data. Just for better understanding - when something wrong happens and where." (P6)
"There are lots of different ways then of bringing space and time together….the movie is one of them." (P9)

'**Parallel coordinate plots'** are a well established visualization tool and receive six mentions from four experts. P7 indicates its use in a non-spatial context, looking to combine it with other information visualization tools, while P2 is concerned about presentation of results from parallel plots to the eventual audience.

"…and parallel plots and the like…it always needs to be anchored into something that can be explained to non-experts ultimately." (P2)
"I could see something quite complex on the lines of…multiple maps, parallel coordinate plots, and have the option of pulling those in together." (P4)
"Probably I would not use geographic visualisation tools for this purpose, and would go to…. information visualization tools, starting from parallel coordinates, combining them with some data mining techniques [and] some other tools such as multi dimensional scaling…" (P7).

'**Small multiples**' receive 11 mentions from three experts, with nine of those from expert P8, who develops the idea of a layout into which snapshots from other tools can be dragged, and be used in reporting the results.

"…maybe they have a series of small multiples as in time series so they can see the trends" (P4)
"To me it does suggest multiple views very strongly. That they are looking for multiple views in the data both in space and time, and statistically as well." (P4)
"insets could be dragged into the small multiples - the idea really is that the small multiples are the things ultimately you might want to turn into the report" (P8)
"small multiples - if you wanted to look at, say, six monthly patterns…" (P8)

'**Histograms**' are mentioned six times by three experts. P4 emphasises the familiarity aspect, echoing comments made in respect of cartograms, although histograms are not mentioned explicitly in the scenario. P7 and P9 see histograms used to display temporal changes.

"…histograms and cartograms which they [LCC CDR team] are already used to" (P4)
"…maybe even just simple histograms of 24 bars, corresponding to hours of the day. All seven bars for the days of the week and so on. I would try to find… some special periods when some crime happened, and tries to locate places where such crimes happened." (P7)
"A histogram might be good for showing a display through time…" (P9)

Near the bottom of the rankings are some suggestions from single experts that indicate creativity and some interesting departures from the standard geovisualization canon:

*"…the hierarchy itself is not good enough. You need a more flexible arrangement - I think you need to have the actual sets displayed, looking like a **Venn Diagram** because Venn Diagrams are highly intuitive…except that Venn Diagrams can be non-interlocking…or can be interlocking…I think actually a dynamic interactive Venn Diagram would be a really good way to go for it." (P3)*

*"In this case…I would try to look at spatiotemporal aggregations. I would divide geographical area into **simple rectangular compartments**, then I would divide time intervals into days, for example, and to look to get times of the day when something happens. And to look into each compartment into… and profile how many accidents happen here and where…" (P7)*

*"…if they start to feel they have found a lead within something, and they need to change the classification they need to be able to do that fairly quickly. So that brings the whole different level into the tool. They need a **lexicon** - need to be able to look at the different words and actually pull out a search by word term. It's a bit like one of the qualitative analysis that you use for a standard qualitative analysis process. That's probably one of the things that's missing - the qualitative tools along the quantitative analysis." (P4)*
*"…with absolute counts, there is a nice tool for analysing these - it is this kind of cumulative curve [**Lorenz curve**]." (P6)*

*"there is also the technique of the **table lens**, where you can visually look at the distribution of attributes, and you can compare the distributions of several attributes in several table columns…this is a very good exploratory tool. There are tasks where spatial neighbourhood*

is not so important, then a table…will be really more useful and powerful…you can simultaneously see several attributes. On a map it is difficult…" (P6)

"We could build an alternative hierarchy based on points of interest - so we switch on and off the crimes closest to the taxi-rank - do a ***Voronoi polygon*** *type thing - make a hierarchy that way." (P1)*

There is also an example of negative advice not to use a particular tool:

"A ***dendrogram*** *would be ridiculous. It really would because it wouldn't achieve what you wanted…because the hierarchy is too rigid." (P3)*

As with the interactions, tools with a wide applicability, like "maps" and "spreadsheet", appear near the top of the rankings raising the possibility – as with the interactions – that it is this wide applicability, rather than their particular fit for the needs of the CDR team, that might be the reason for their high ranking. Tools mentioned in the scenario (in order to provide an indication of tool use and suggest expertise) appear high in the rankings (the top four ranked tools are mentioned in the scenario). The raises the possibility that the geovisualization experts are 'playing back' the information in the scenario, and if so, presents a dilemma. The scenario needs to communicate current tool use and experience in order to communicate the subjects' context as fully as possible to the geovisualization experts, but this information may bias the experts' responses.

Another factor is that certain interactions and tools are closely related, and therefore a highly ranked tool may lead to a correspondingly high ranking for one or more related interactions, or vice versa. Some of these interactions and tools co-exist happily; others do not. So a conclusion based on a simple combination of high ranking tools and interactions is not sensible, but needs to take this factor into account.

4.4.1.3 APPLICATION SUGGESTIONS

While the geovisualization experts were not asked explicitly to consider existing applications, a number were mentioned. Table 4.3 records the applications mentioned by the geovisualization experts in referring to either them, or some component of them, being potentially useful to the CDR team. With the exception of GeovistaStudio, all applications are mentioned by just one expert. P7 accounts for four of the nine applications mentioned, two of them information visualization applications (Spotfire, Tableau), and one a data mining application (Weka). There is no explicit recommendation from any expert that the CDR team should simply use one of these applications to perform the work described in the scenario, however this is perhaps unsurprising as geovisualization experts were asked to suggest tools and interactions for an application, not applications themselves. There was an in-built assumption that the CDR subjects' needs would require a tailored application, which went unquestioned by the experts.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	Total
GeovistaStudio	0	0	1	0	1	0	0	0	1	**3**
Google Earth	6	0	0	0	0	0	0	0	0	**6**
GAM	0	0	0	0	0	1	0	0	0	**1**
Geoda	0	0	0	0	0	0	0	0	1	**1**
Google Maps	1	0	0	0	0	0	0	0	0	**1**
Many Eyes	0	0	0	0	0	0	1	0	0	**1**
Spotfire	0	0	0	0	0	0	1	0	0	**1**
Tableau	0	0	0	0	0	0	1	0	0	**1**
Weka	0	0	0	0	0	0	1	0	0	**1**

Table 4.3: Previous applications referred to by geovisualization experts in response to scenario. Applications are listed in order of number of experts suggesting and then by the total number of mentions.

Some of the expert comments on these applications are:

*"And then you have got **GeoVista [Studio]**… the other thing about GeoVista is that it is extensible. So you can start to add things in." (P9)*

*"The thing about **Google Earth** is that it gives you partly the experience of using it. That's a really important thing. You get responses that are based on personal experience…you get this hierarchy of things you can switch off and on, and that maps quite well onto the crime hierarchy. You also get the temporal slider thing that maps on to the temporal nature of the crime data as well." (P1)*

*"**GeoDa** is very nice, but you are stuck with what is in GeoDa, and it is not always easy, as far as I can see…to extend GeoDa" (P9)*

*"I thought about tools which would be useful for this purpose. There are some data mining methods where you use some spatial clustering methods which take into account the population, and try to find hot spots or some phenomena like crime with respect to the population. One of them is **GAM** [geographical analysis machine] from Stan Openshaw and his team." (P7)*

*"…implement basic tools from **Many Eyes**, and add some geography to it…[the outputs] are static, but they support annotation; you can make snapshots of interaction with them. [They] have some basic interaction capabilities like changing scales of values, focusing on intervals, and so on." (P7)*

*"We stick to our own tools, because we work with similar datasets for many years, and we have in our system connection to a **Weka** system. So when you have data on the screen, you can pass lines and numerals across to Weka." [Weka is data mining software] (P7)*

*"I have two excellent examples of tools that are really used by domain specialists, by professionals, for analysing spatial and attribute data together. One is **Spotfire**, it is used for*

genetics, business analysis, and for many other things. What they have now is …so-called "scenario support". Once a specialist in a domain area, for example in genetics, describes how he analyses his data in some formal language, he creates a typical scenario for analyst with this data, and this typical scenario, it's a kind of workflow that involves computational tools and visualisation techniques. And you can just put one button and it can activate with scenario for another datasets, go through the full pipeline of computational and visualisation tools." (P7)

*"The idea is that the system supports multi dimensional aggregational data, also geographical space, and time. And it has simultaneously, computational tools and intelligent visualisation design. So when you select some attributes to be visualised, the system automatically suggests what kind of visualizations are applicable to select for the data. It was called Polaris; the commercial version is called **Tableau**." (P7)*

None of the geovisualization experts mentioned an enabling technology such as an application programming interface (API), nor a specific computer language approach (but nor were they asked to).

4.4.1.4 DISCUSSION

A summary of the advice of the geovisualization experts is needed to advance the creation of a geovisualization application for the CDR team. The 'top 8' interactions and tools as suggested by the geovisualization experts provide a pragmatic starting point. They are: **Interactions**: aggregating, zooming, filtering, clustering, linking, comparing, symbolising and classifying. **Tools**: map, density/hot spots, cartograms, spreadsheet/table/grid, animation, parallel coordinate plot, small multiples and histograms.

Interactions and tools with a wide scope appear more frequently than those with less wide a scope and it is possible that experts' suggestions may be for that reason rather than the particular needs of the CDR team. Density/'hot spot' maps may be ranked highly because of their association with crime mapping. Certain tools and interactions may be ranked higher because of their perceived popularity. There is also a strong link between tools mentioned in the scenario and tools ranked highly in the aggregated geovisualization expert results. This points to a possible conflict between tailoring scenarios with as full a description of tool use and experience in order assist the reader (geovisualization experts in this case) and eliminating as far as possible prompts that might steer the reader in one direction or another. Certainly, the results must carry a caveat for these reasons.

There is a wider point here in that, for pragmatic reasons of time available and focusing on tractable output, the geovisualization experts were asked to suggest tools and interactions.

They were not asked to focus on higher level applications (and indeed mentioned only a few of them), nor to focus on smaller scale elements or lower level symbolism, the components of tools and interactions, nor to suggest enabling technologies (such as APIs), nor particular programming languages. This represents a limiting of the solution space that may be a reflection of the complexity of geovisualization, which would not be the case for a more straightforward application. It is possible that the nature of the scenario and the limited line of questioning steers geovisualization experts away from possible innovation.

With these caveats in mind, the guidance of the geovisualization experts based on 'mentions' for the kind of application to build to meet the 'undreamed of' requirements of the CDR team might be framed as guidance to an application designer (but not as a description with which to return to the CDR team). This statement is concise and appears to have some measure of coherence, in that the tool and interaction suggestions are not obviously incompatible:

"The application should include a map capable of showing crime density. Consider an alternative spatial depiction in the form of a cartogram, if appropriate. Small multiples might be helpful to compare and to store insights as data is explored. Consider different ways to symbolise data that appear on what might be a crowded map. Incorporate flexible navigation to permit zooming and panning of the map. Useful ways to show the crime attribute data include tables, histograms (especially for showing time trends), and - when looking to cluster data - parallel coordinate plots. Incorporate ways to aggregate and filter data that allow the complex and hierarchical nature of the data to be explored flexibly. Attribute tools should be linked to spatial tools to provide the benefit of combined multiple views of the data."

Some experts show a pragmatic awareness of the need for the CDR team to present their results to non-experts (this is a strand in the scenario), and indicate where and how exploratory findings can find their way into end presentations. However they do not show any marked tendency to confuse exploration and presentation, as one might expect from experts whose geovisualization paradigm undoubtedly contains Figure 1.1, "the range of functions of visual methods in an idealized research sequence" (DiBiase, 1990).

So far, only one strand of the evidence available from the scenario/experts process has been considered. The next section deals with the insights from the comments made by the geovisualization experts during the conduct of the interviews.

4.4.2 SCENARIO PROCESS NARRATIVES

In interviewing geovisualization experts, they did not confine themselves to suggesting tools and interactions for the CDR subjects, but commented extensively on the process. Specifically, their comments centered on:

- the **CDR domain**, their perceived need for more data from it, their perceived lack of understanding of subject tasks, their perceived desire to engage with the CDR team, and their commentary on what they believed the CDR team could cope with by way of complex tools and interactions
- the **process -** the difficulties of suggesting interactions and tools, the deficiencies of the scenario (and in particular its broad scope), and **reflections on the process**
- **Advice** and **suggestions;** how some experts communicated through **sketches**

4.4.2.1 THE CDR DOMAIN AND THE GEOVISUALIZATION EXPERTS

Need for CDR data

Expert P1 appears to have a very data-centric approach to constructing geovisualization applications and all the comments on needing more data come from P1:

> *"I really need to start really playing with the data." (P1)*
> *"you need to know something about the layout of this information in order to make decisions about how best to visualize it. " (P1)*
> *" I need to know not only more about the nature of the data but more about CDR and what they do with the data and build their expertise into the application." (P1)*
> *"I really feel I need to do some processing of the numbers and produce some abstract graphics and get high levels of interactions in those things with some context. But I don't know what those things are so those are quite high level responses - they won't surprise you, it's nothing you wouldn't have come up with." (P1)*

Need to engage with CDR team

Three experts (none of whom had had any contact with, or knowledge about this group of CDR researchers) made comments about their desire to work with subjects themselves:

> *"I think it would be quite interesting to actually design something and just work with them I think. Because they can then feed in to what I would actually say." (P4)*
>
> *"I see here how they express their needs, but I would like to see how they work and to try to guess their needs, which are not expressed in this text [the scenario]…this looks very polished; it looks like a straightforward way how to analyse the data. Real life is more complex. I would like to watch how these people work" (P7)*
>
> *"you as the researcher can see it is useful, but you have got to convince the people in there that it is useful, and explain why it is useful, and how it is useful in a particular way. So, what we find over here… what I have found… is that, you go along and say, you know, 'here is my improved mouse trap'; here is and how it works. And they might say, 'well, I'm not so sure that tells a story that we want to do. Could you do such and such? Is it possible to do*

such and such?'. And you go away and back, and what you have actually got in terms of introducing the innovation then, is really… It is an iterative process." (P9)

Subject tasks unclear

Expert P6 feels that CDR team tasks were unclear:

"Before speaking about tools, I would try to identify the users task. From this description, the tasks are not very clear. One task that is quite clear is to investigate the relationship between preventative measures and the level of crime, whether at the preventative measures are effective or not. The other tasks are not clear what they want to investigate. And therefore I first made some guesses what their tasks could be. And one of my guesses was that one of the tasks could be just to look at the spatial patterns of crime, and development over time."(P6)

CDR team capability

Expert P7 reads from the scenario a limitation in the experience and capability of the CDR team, and saw particular difficulties in introducing the notion of combined multiple views:

"they don't have [experience of] combined multiple views, and this is a critical issue. I personally like multiple views very much, but I know that people are not used to multiple views. The people on the street just don't know that multiple views can exist and that they can be used for problem solving. There is no culture of using multiple views…. For the majority of people, their understanding is that you should today look to enter a statistical package or a data mining package, push the button, get results, then present the results as usual, in Excel, or a GIS, and so on." (P7)

4.4.2.2 THE PROCESS AND THE GEOVISUALIZATION EXPERTS

Some of the geovisualization experts, notably P2 and P5, were concerned by the general nature of the scenario and this led to problems engaging with the task to suggest tools and interactions:

"There are very few constraints on the design of the system that makes this different from any other form of visual exploration in that there is potential to look at spatial patterns and statistical patterns and temporal patterns, associations between each of those patterns, and that's generic to any kind of geovisualization, so I don't know what you might be after that would actually say that in this particular context the design needs to be different because we are dealing with these kinds of data, because as far as I can see they could be any kind of data that could be explored." (P2)

"you can't expect very specific advice about particular tools if you are giving very general scenarios. By giving a general scenario what you are getting is a more general discussion about the nature of interactions and the kind of approach I'd be taking." (P2)

"I find this quite difficult because this is quite hypothetical and abstract in terms of what needs to be done. I mean, we've got some constraints…we've got the idea that data are hierarchical…we've got the constraint that this must lead to a more conventional static output…we've got the idea…it needs to be flexible because you don't know in advance what aspect of data that is going to be explored…the system clearly needs to be flexible. It needs to deal with different types of data…it needs to be able to deal with data that emphasise temporal nature; data that emphasises spatial nature, with the possibility that one might be

interested in only aspect of that at any one time, or possibly more than one aspect…we can't prescribe that with too much detail…" (P2)

"my first thought when I read this information that you sent, the scenario, is that it is very, very broad. I don't really know if I can just… try to design a structure or anything, because it is so broad. You don't have a particular topic to look at…What I think is that they just want to explore crime. That is a huge thing." (P5)

P2 and P5 quite rightly point out the broad nature of the CDR team's task as outlined in the scenario, and are critical that it should be more specific. However, the reality of the subjects' context of use is that they do indeed have a multitude of ill-defined exploration tasks that they wish to pursue. Perhaps the solution here is to build a 'basic' system with options for defined, narrower tasks – similar to the approach of multi-function GIS and image processing system such as Idrisi (Clark Labs, 2009).

P2 was asked what an improved, redrafted scenario would contain. P2 replied:

"It would have told me whether I'm dealing with something that has to somehow integrate with hundreds of datasets or just one dataset; it would tell me whether I need to consider spatial and temporal patterns or spatial patterns alone or whether the majority of the insight is going to be in the attribute patterns. Those sort of decisions tell you the importance of the maps as opposed to the statistical and exploratory tools. It would tell you whether the main task is in reducing a large data volume into something manageable, or about looking at very small variations that might be important. Those kinds of thing will give you the more specific rules that would then allow you to say 'small multiples are a useful solution to this kind of problem' , or not, as the case may be." (P2)

It is certainly the case that the response to the scenario and the task from the geovisualization experts is a broad range of engagement. Some, like P2 and P5 are hesitant, even sceptical. But while P2 overcomes this and mentions an average number of tools and interactions compared to the other experts (14 and 15, respectively), P5 remains reticent throughout (mentions of tools: 7, of interactions: 8). Contrast this to the over-enthusiasm of P8 whose tool mentions total 52 and interaction mentions 65). This variation between experts suggests that consulting more than one expert might be a useful approach, as might reformulating the scenario with one expert if gaining the necessary engagement proves difficult with an initial draft.

4.4.2.3 REFLECTIONS ON THE PROCESS AND THE GEOVISUALIZATION EXPERTS

Although P1 does not contribute greatly to suggestions for tools or interactions, P1 has many thoughts on the scenario/expert process, and reflects on them:

"One of the things I really noticed in the scenario was that…I find when I'm thinking about these things…I've learnt from this that I'm much more data focused than application focused." (P1)

"I notice that I'm mentioning the technology quite a lot which is not unrelated to the problem in hand" (P1)

"I'm now close to the point of needing to talk to somebody about criminology and crime statistics. And I don't get enough of that from the scenario. I've got a user scenario - I don't have a kind of handy pack of what a criminologist would do at this stage or how to do crime statistics. I think an interesting aspect of a need I have for going much further with it…" (P1)
"I think one of the things I hadn't realised before I started thinking about this in relation to the scenario and in talking to you is that actually we have different types of idea that deal with different types of concept that are probably interesting to different people who the CDR team serves." (P1)

"I'm going through my own kind of decision-making tree based on the scenario at this level, then I need some feedback, then I need to do some drawings, then I need to see some numbers; I asked about the maps of Leicestershire before as well… or even of specific areas" (P1)

"In terms of what I need to do next I need to get my hands on the spatial data and the attribute data and I need to a bit of coding to see how things work and get an understanding of the data and its limitations, its distribution both in terms of space and time, its sparsity, its quality. I need to script some stuff round the data to see how how it works. Then I need to talk to the CDR team. I probably wouldn't take a technical prototype at this stage. I would probably make some suggestions using paper or a whiteboard within my own kind of universe of possibilities from what I know of the data and what I know of the technical capabilities of the whatever system I think I might use." (P1)

"Can I tell you something? I've never done this before. I have never sat back without a computer and tried to explain to somebody what I would before doing it. And that's been a really useful process. If I had been asked to work on this project without the scenario and without talking to you, I would have done what I did with the [mentions recent application] - just got stuck into the data, gone down that particular path. But it's amazing sitting back and thinking about it first - it's amazing how that has an effect. I don't know what that is yet. What we might find is that is that talking to you for an hour before you do some geovisualization is useful. That would be an interesting finding. It's really interesting." (P1)

"I'm quite pleased with the way it's made me think because I've not thought things quite like this before….I'm quite disappointed what I've come up with in tangible terms - no maps, no graphics, no interactions, no specific views - but in terms of preparing for that, I've never done anything like this before and I'm really pleased with how well I feel I'm prepared for the next step. It's been good to step back and think about things." (P1)

"I'm really surprised; I'm kind of excited about it, because it hasn't been quite how I expected it to be. Because we haven't got an application, and normally I'd have something done, you know. But I'm really pleased that…I feel I know much more about the data now, I feel, I mean…not the data; I feel I know more about my own kind of response to this situation. It's almost like a counselling session - I feel like I'm kind of more aware of my own response being quite a predictable, structured kind of way of doing things. And that's a really good thing to hear." (P1)

P4 and P7 echo the sentiment of P1's reflective comments on the value of undertaking the process:

"I found it interesting just more about talking through it rather than actually designing something because I think that the physical design on the screen is something different I think it's actually the process that's more interesting." (P4)

"It's [been] an unusual procedure for me, because normally what I do is I have some instruments for analysing such data, and it is not typical for me to speak about this, it is more typical to load the data into the system and to try to play with the data." (P7)

Other useful reflections:

"It's certainly the case that with this kind of work you can tell the influence of particular individuals in terms of the design of geovisualization solutions…Now that would suggest that there isn't a universal solution to this, or if there is one then it's not going to found by talking to those individuals because what you get is a reflection of how they tackled that problem in the past. But maybe that's all you one can do - all you can do is open up the opportunities, the options that someone tackling this for the first time should be made aware of. There will be things that make sense to some of us, but won't necessarily make sense to the community. And these techniques take time to learn." (P2)

"From my own experience and from observations of other people, I see that if something gets difficult, people will not use it. Only when they are extremely highly motivated and even in this case they would prefer to use something which is simpler and convenient. Not necessarily simple, but convenient to use. And if some additional effort is needed, people tend to think whether they really need to make this additional effort and what will be the benefits of making this additional effort." (P6)

4.4.2.4 ADVICE AND SUGGESTIONS FROM THE GEOVISUALIZATION EXPERTS

Experts P2 and P3 took the opportunity to impart suggestions that were insightful, and went beyond the rather narrow framework of 'tools and interactions':

"You made quite a lot [in the scenario] of Tufte and the presentational skills of the team, and I think that it's double-edged … there is a danger that a team that is simply very good at producing, if you like, graphical rhetoric, of being persuasive through graphical representation, actually has the danger of hiding the patterns. Because they are so effective in conveying a particular message, that if they don't convey it right they become very powerful in this interaction. And one might want to caution people who look confident in being able to produce attractive looking maps with a clear message that actually they need to have a system that brings out objective patterns that aren't overly influenced by the aesthetics in the final output." (P2)

"If you've got a whole load of [crime] sub-categories - ones that weren't even mentioned here [on the crime types list] then that suggests that perhaps there is some ambiguity as to which category some of these might be recorded under by an individual police officer. So there is some uncertainty there in terms of the categorisation process."It would seem a good principle of any system that explored these data to convey that uncertainty. One way of doing that is to randomly perturb the groups into which offences are categorised based on the most likely ones that could equally be in." (P2)

"If the hierarchy was really well established, one which they all believed in, it would work. But I know people working in crime statistics who don't believe [in] the Home Office [crime] hierarchy." (P3)

" It ought to be possible after that aggregation for someone to tell a decision maker that while you are normally presented your units in Borough form - or whatever it happens to be - you can say 'look, here's the evidence that that's a very poor way of understanding the problem you are having to address. You would be better off - even though you haven't got responsibility for the whole of this area or even though you are not used to seeing these data in postcode format or raster format - actually there are some important patterns here that you need to understand that would have been hidden if you had only dealt with them in this aggregation.'" (P2)

"Get from them the time periods they are really interested in. If what they want is simplicity then they don't want to be manipulating this directly, they want a set of predefined time intervals." (P3)

Note the different advice on the merits working with segmented data (spatial in the first case, temporal in the second) in the last two quotes from C2 and C3, respectively.

4.4.2.5 GEOVISUALIZATION EXPERTS COMMUNICATION THROUGH SKETCHING

One aspect that I noted during these interviews was the way that certain geovisualization experts naturally communicated their ideas by way of sketches. P1 at one point says *"I now need to start drawing. That's the stage I'm at - I need to start drawing."*, and does so over a video link, with limited success. Two other geovisualization experts, one from the pilot group P1-3, and one from the larger group, P4-9, are also 'sketchers', eagerly employing pencil and paper to assist in the communication of their ideas. Other geovisualization experts are equally at ease in communicating ideas wholly in words (even when offered pencil and paper and the opportunity to sketch). This hints at fundamental differences in the way these geovisualization experts might prefer to approach design, and that 'sketchers' may be more productive teamed with each other, and the opposite with 'talkers'. Both 'sketchers' and 'talkers' might wish to be aware of their preferred approach, and to recognise that, for example, heading for the whiteboard to sketch at the first available opportunity, may be counterproductive. This might be a fruitful area for further research. If nothing else, 'sketchers' leave tangible artefacts as records of their design thinking. Some example sketches from the geovisualization experts are given in Figures 4.5 and 4.6 (although to protect anonymity, the the particular experts are not identified).

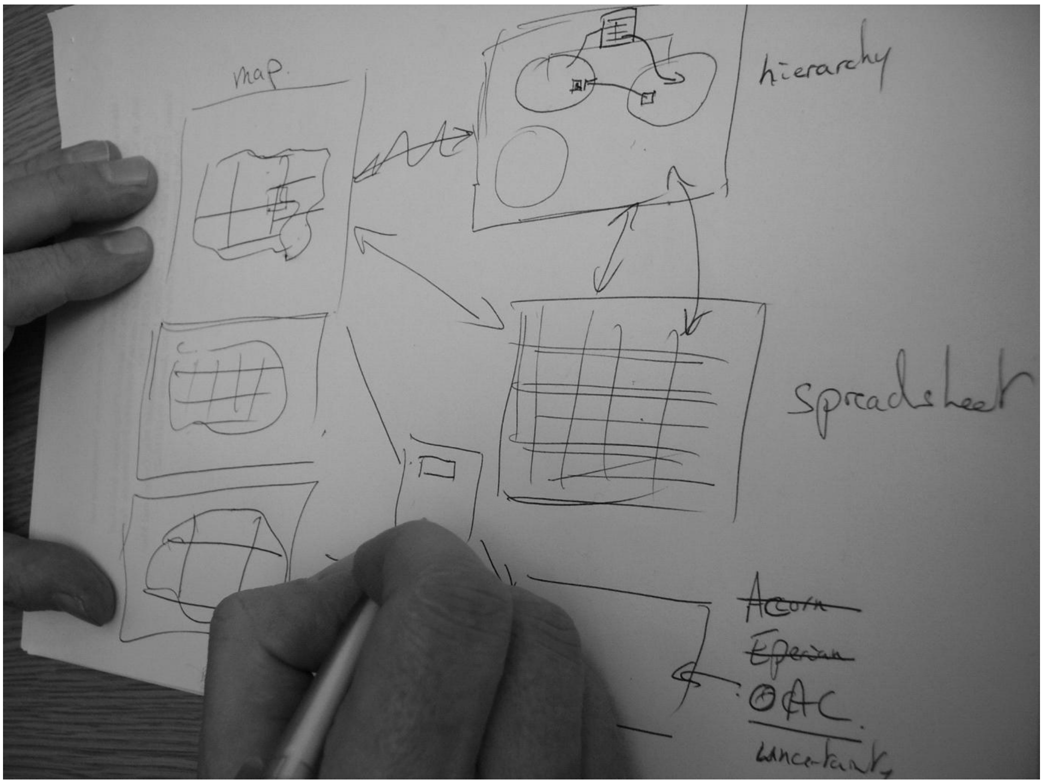


Figure 4.5: Geovisualization expert from P1-P3 group communicating tools and interactions through sketching – linked multiple maps, hierarchy, spreadsheet and demographics

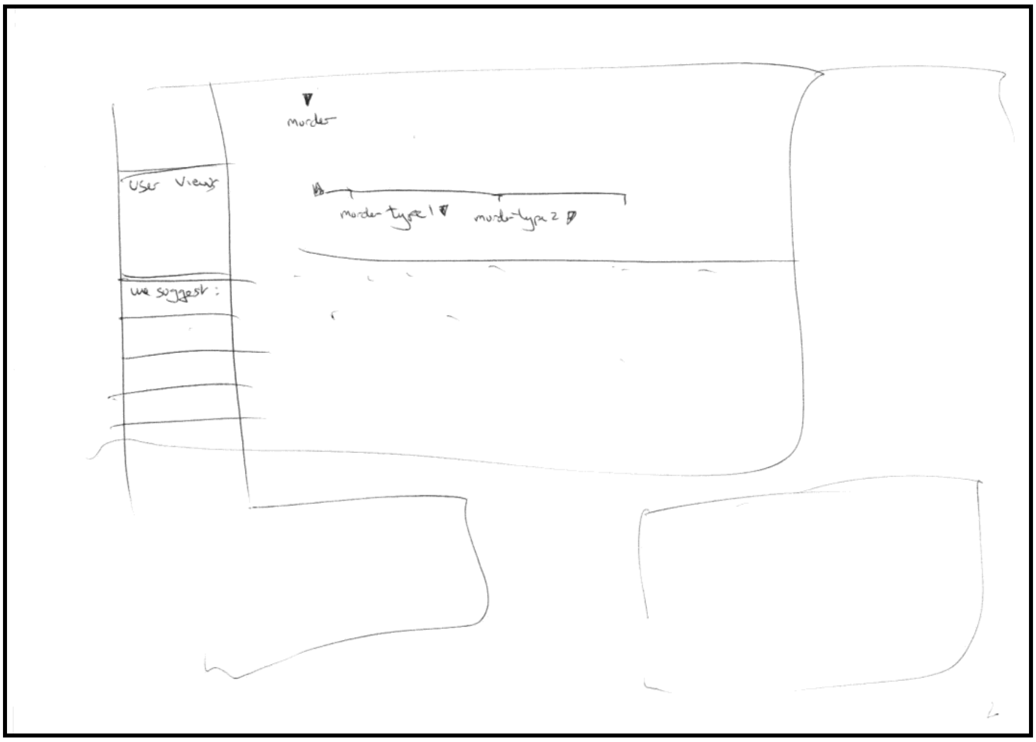


Figure 4.6: Geovisualization expert from P4-P9 group communicating tools/interactions through sketching: aoristic crime with time slider, a "user view" and a hypothesised help system prompting the user with suggestions

4.4.2.6 DISCUSSION ON PROCESS

P2's comments when asked what an improved, redrafted scenario would contain, highlights the expectation P2 has of the scenario. But the medium of the scenario is not capable of carrying the material that P2 desires - scenarios are just stories about *context of use*, after all. It appears that P2 doesn't want stories, but facts – specifically facts about *data in context*. The way I have written the CDR scenario to try and include some descriptions of the data may have misled P2's expectations. The way to proceed may be to keep the scenario completely focused on a narrative of context-in-use, and provide the data-in-context in another way by providing the data itself – 'hinting' at the data is clearly not sufficient. **This insight points to a very real limitation in using scenarios in a geovisualization context, and to the need to supplement scenarios with data in context**. P2 was part of the pilot and as a result of this, geovisualization experts P4 – P9 were provided with sample CDR data and appropriate metadata.

The hypothesis behind consulting geovisualization experts with experience of building applications is that their collective wisdom will converge to a 'best practice' solution. This only holds if geovisualization works through some deep underlying principles that manifest in perhaps slightly different ways in practitioners. To use an analogy, is geovisualization more like engineering or architecture? If the former, then the underlying logic of the properties of materials and the force of gravity will necessarily force a convergence; if the latter, then only the creativity and imagination of the designer is the limiting factor. P2 makes a useful contribution here:

> *"It's certainly the case that with this kind of work you can tell the influence of particular individuals in terms of the design of geovisualization solutions…Now that would suggest that there isn't a universal solution to this, or if there is one then it's not going to found by talking to those individuals because what you get is a reflection of how they tackled that problem in the past. But maybe that's all you can do - open up the opportunities, the options that someone tackling this for the first time should be made aware of. There will be things that make sense to some of us, but won't necessarily make sense to the community. And these techniques take time to learn." (P2)*

The results from the quantitative counts show that there is some kind of convergence, but this is towards 'popular' geovisualization tools, a tool with a clear connection to crime (hot-spot map), or widely-scoped interactions.

There are a small number of misunderstandings or misreadings of the details of the scenario by two of the geovisualization experts. P3 believed that the CDR subjects had access to ACORN and Experian demographic data when it explicitly stated they didn't; and that they had no access to time data at the hourly level of disaggregation, when this was the case. P8 misunderstood that urban areas were available by output areas, not 100m squares. These are minor, and do not betoken any gross misunderstanding or ignorance of the scenario.

One of the aspects of uncertainty in the process must be how seriously the geovisualization experts took the exercise and whether I obtained considered, or less considered responses. Another factor is the stability of expert's guidance. Recent work involving a particular set of geovisualization tools and interaction might lead to a predisposition for those to be in the forefront of an expert's thinking. As P1 commented:

> *"I might have given you a different answer a couple of months ago than the one I have given you now...I think [a few key phrases in the scenario] have led me down my two or three pre-determined paths that I might have gone down. I think it's like it's like one of those old fashioned pinball machines where there are six slots you can end up in, and a couple of pins knock you into a particular solution."*

Sometimes geovisualization experts suffer from being unable to match a particular geovisualization tool with its name:

> *"and there is one where you divide your space up into little rectangles and squares… I can't actually remember… [David Lloyd: treemaps??]….are those treemaps?…it's like a multidimensional scatter… no, not a scatter plot…erm…" (P9)* [P9 may have been trying to recall a mosaic plot]
>
> *"the kind of plot [I was thinking of]…it might be a scatterplot matrix which is why I was using the term "matrix plot". Anyway, it's one of those - it's in Geovista Studio, or similar. It allows you to link between the categorical information and the map." (P3)*

Observing the way geovisualization experts communicate their ideas showed interesting differences in those that uses sketches and those who expressed themselves wholly verbally. These dissimilar approaches may have an impact as experts collaborate together, or as they work with domain subjects.

Two strands of evidence from the scenarios/geovisualization expert process havenow been examined. The third strand consists of the results from the questionnaire completed by the experts at the end of the interview.

4.4.3 SCENARIO PROCESS QUESTIONNAIRE RESULTS

The questionnaire consists of three main portions – a question that asks about research interests, a series of Likert-scale questions about the extent to which the scenario enabled the geovisualization experts to understand aspects of the CDR subject context for a geovisualization application, and responses to open-ended questions that asked for more details of the other questions.

4.4.3.1 GEOVISUALIZATION EXPERT RESEARCH INTERESTS

I am interested in the experts' research interests to understand if there are any possible biases towards such topics in the experts' responses. Table 4.4 gives the self-reported main research interests.

P1's interest in human-centered approaches may account for the interest in, and quite extensive commentary on, the scenario/geovisualization expert process, and the comparatively low number of actual tool suggestions. P3 accounts for 6 out of 11 mentions of 'uncertainty' in the transcripts, and this is due to a research interest in the topic as P3 makes the explicit connection more than once, for example:

"Because of my background in uncertainty, there is a fascinating question here…" (P3)

Geovis Expert	Main research interests
P1	Geovisualization techniques; human-centered approaches
P2	Terrain analysis; geovisualization; spatial object-orientated modelling
P3	Uncertainty; visualization
P4	Geovisualization, virtual reality, multimedia cartography; ecological fieldwork and IT; indigenous spatial literacy, the environment and participatory GIS
P5	Geovisualization; spatial analysis
P6	Geovisualization; visual analytics
P7	Geovisualization; visual analytics
P8	Spatial statistics; geovisualization; crime pattern analysis
P9	Spatial modelling; GIS; socio-economic analysis

Table 4.4: Main (self-reported) research interests of geovisualization experts

P1-3 were involved in the pilot and are from my home institution. Between them they contribute considerably more comment on the process , more reflection and more advice than P4 - P9, as might be expected. P7's interest in visual analytics might account for suggestions of data mining applications. A particular tool – the space-time cube – received four mentions from P7 and no other expert. P7 has researched the use of this tool. P8 had previously worked with the police to conduct research, and applied learning from that experience to the scenario, not always successfully, as the strategic context of the CDR team is different from that of the (tactical) police. P8's spatial statistics background may also account for the very frequent mentions of 'map' and 'spreadsheet/table/grid'.

There is some evidence of some experts offering advice linked to a particular research interest, but it is not clear that these instances materially alter the 'top' interactions or tools in Tables 4.1 and 4.2, respectively.

4.4.3.2 GEOVISUALIZATION EXPERT QUALITATIVE QUESTIONNAIRE RESULTS

Table 4.5 summarises the results from the quantitative part of the geovisualization expert summative questionnaire. Experts are asked questions about:

- how well an understanding the scenario gave of a number of subject aspects – their tasks, range and type of data, goals, end customers, tools, skill sets, and expertise
- Whether the scenario by itself was enough to build a geovisualization application, and whether the scenario plus the interview process was enough to build a geovisualization application
- Which non-scenario materials were referred to
- How well the purpose of the interview was conveyed, and the interview conducted

With the exception of "understanding of type of data available" and "understanding of end customers", geovisualization experts on balance agreed (mode scores of 2 (=agree)) that the scenario gave an understanding of the subject aspects of tasks, range of data, goals, tools, skill sets, and expertise. There was little difference in variance between experts on these scores, although expert P5 gave uniformly low scores (recall P5's perception (see section 4.4.2) was that the scenario was too broad). The expert consensus was that they either disagreed or neither agreed nor disagreed (mode score 4 or 3) that the scenario gave an understanding of end customers. "Understanding of type of data available" achieves a "strongly agree" mode score of 1 from the experts, but the variance is high and scores are particularly low in the pilot phase. The improvement in the describing the type of data because of the poor pilot scores is noticeable.

Not all experts were convinced that the scenario *by itself* gave them sufficient information to build a geovisualization application for the CDR team, their mode score of 2 having a high variance. When asked the same question about the scenario *plus the interview process*, the mode score rose to 1, albeit with the same variance.

Experts were asked (or were observed) if they consulting the three additional sources of information that were provided for their discretionary use. All the experts bar one referred to the list of geovisualization techniques, tools and interactions (Table 1.1) (described to them as the "geovisualization crib sheet"). All experts consulted the data/metadata, and all those not already known to be familiar with the administrative geography of Leicestershire, consulted this data.

The near universal use of the supplemental material, and the improvement in the expert's scoring of having sufficient information to build a geovisualization application for the CDR team with the addition of the interview process is significant. It shows that the context of use scenario is more effective with supplemental information that includes information on geography, geovisualization tools and interactions, sample data and associated metadata, and when an interlocutor is present who can clarify aspects of the material.

In some of the three pilot interviews, the results from the experts were disappointing when they were asked about whether the purpose of the interview was well explained, and the interview itself was conducted well. Changes made to some of the materials were made, in particular to the clarity of explanation, and the subsequent results from experts P4-9 showed a marked improvement, giving more confidence that the results obtained were meaningful.

Geovisualization Expert/Scenario Questionnaire results **<-------pilot-------->**

Quest.	Expert number:	P1	P2	P3	P4	P5	P6	P7	P8	P9	Mode	Av	Var
1	Scenario gave me a good understanding of task	**2**	**2**	**2**	2	4	3	1	1	2	**2**	**2.1**	**0.9**
2	...understanding of range of data	**2**	**4**	**2**	2	4	1	2	2	2	**2**	**2.3**	**1.0**
3	...understanding of type of data	**4**	**4**	**2**	2	4	1	1	1	1	**1**	**2.2**	**1.9**
4	...understanding of goals	**2**	**2**	**2**	3	4	2	1	1	2	**2**	**2.1**	**0.9**
5	...understanding of end customers	**4**	**3**	**2**	2	4	1	3	3	4	**3,4**	**2.9**	**1.1**
6	...understanding of tools	**3**	**4**	**2**	2	3	1	1	2	2	**2**	**2.2**	**0.9**
7	...understanding of skill sets	**3**	**3**	**2**	2	2	2	1	2	4	**2**	**2.3**	**0.8**
8	...understanding of expertise	**4**	**2**	**4**	2	2	2	1	2	2	**2**	**2.3**	**1.0**
9	Scenario by itself enough to build geovis app	**2**	**4**	**2**	3	4	2	3	1	4	**2**	**2.8**	**1.2**
17	Scenario+Interview of use in creating geovis app	**1**	**4**	**2**	2	1	1	3	1	1	**1**	**1.8**	**1.2**
15	Interview purpose conveyed effectively	**3**	**4**	**1**	2	1	1	1	1	1	**1**	**1.7**	**1.3**
16	Interview conducted well	**2**	**3**	**1**	2	1	1	1	1	1	**1**	**1.4**	**0.5**
	Sum of Q1-9	**26**	**28**	**20**	**20**	**31**	**15**	**14**	**15**	**23**			

<-------pilot-------->

		P1	P2	P3	P4	P5	P6	P7	P8	P9
12	Refer to geovisualization crib sheet?	Y	Y	Y	Y	Y	N	Y	Y	Y
13	Refer to crime data sample?	Y	Y	Y	Y	Y	Y	Y	Y	Y
14	Refer to Leicestershire geography?	-	-	-	-	Y	Y	Y	-	Y

Q12 & Q13 were not on questionnaire for first four experts but asked verbally or simply observed.

Q14: Subjects P1-P4 and P8 were known to be familiar with Leicestershire geography.

Table 4.5: Answers by geovisualization experts to quantitative questions posed on questionnaire administered after session was completed
The numbers are points on a scale where 1=strongly agree; 2=agree; 3=neither agree or disagree; 4= disagree; 5= strongly disagree

4.4.3.3 RESPONSES TO OPEN ENDED QUESTIONS

Geovisualization experts P3, P6, P7 and P8 made no qualitative comments on the questionnaire, confining themselves to the 'tick box' questions. Responses made by other experts to these questions are:

Question 10: If you indicated "Disagree" or "Strongly disagree" as a reply to question 9 ["The scenario, by itself, contained enough information to enable me to provide further information that would be of use in constructing a geovisualization application"], could you please indicate what additional information beyond the scenario <u>was</u> or <u>would have been</u> useful to you to help you.

> *"...I need the data to move forwards" (P1)*
>
> *"The scenario was still rather generic, requiring us to provide assistance in generating some 'insight' into some unspecified task. What was expressed was a 'meta-task' (help people use geovis to address tasks) which kept discussion quite abstract. Perhaps some real data with examples of existing solutions to analysing those data giving us an opportunity to suggest improvements and alternatives." (P2)*
>
> *"Although I did not disagree with Q9 (scenario by itself), I found it helpful to discuss the scenario and respond to key prompts. The scenario approach is valuable but a secondary list of key issues would be useful in identifying important applications." (P4)*
>
> *"Scenario was too broad – should have a more focused task or at least topic." (P5)*
>
> *"I needed more information about the data, so the maps and Excel listings were useful." (P9)*

These responses corroborate evidence from the comments made by experts during the course of the interviews. In particular, P1, P2 and P9 request more information about data. P4 feels that more than just the scenario is needed. P5 reiterates comments made during the interview about the broadness of the scenario.

Question 11: If you have indicated "Disagree" or "Strongly disagree" as a reply to <u>any</u> of the above questions [Q1 – Q9], please provide more details.

> *re Type of data: "I needed to get my hands on the data. And I needed maps...perhaps (an) example...should a geovis scenario contain maps?" re End Customers: "This was not particularly clear" re Expertise: "I got an understanding of what the [subjects] might do, but could only infer expertise" (P1)*
>
> *"My 'disagree' to Q2, 3 and 6 all relate to my answer in Q10, i.e. the scenario was still too abstract to pursue in any depth." (P2)*
>
> *"I think I needed a little more context. I'm aware of the CDRPs, but not sufficiently aware of their data needs and analytical requirements to offer initially reliable suggestions. In the*

real world, the adoption of innovation involves lots of iteration with advisors – and takes a much longer time." (P9)

More corroborate evidence here – P1 wanting more data, and maps (this was the pilot); P2 reiterates concerns about the abstract nature of the scenario; P9 wanting to know more about needs for data and analysis.

Question 18: If you have indicated "Disagree" or "Strongly disagree" as a reply to any of the above <u>three</u> questions ["The <u>purpose</u> of the interview was conveyed to me effectively"; " The interview was <u>conducted</u> well"; The <u>scenario plus interview process</u> succeeded in eliciting information from me that would be of use in constructing a geovisualization application], please provide more details

> *"It took a little while before my role in the exercise became clear. The interview was necessary for this as I had to ask questions to establish what was wanted from me. The interview was conducted in a relaxed and friendly manner but would occasionally be quite strongly directed by suggestions and input from David Lloyd. There is therefore a small danger that the results will be shaped by David's view of the solution." (P2)*

This was a comment on the pilot and the context of the interview was explained more clearly to subsequent experts and care taken not to direct them.

Question 19: What – if anything - did you learn about your general approach to constructing geovisualization applications by using the scenario in the interview situation?

> *"That I have a focus on data; that this can bias things". "That it is difficult to 'design' without data, software or users…but that this can be beneficial – at least interesting." "I found this very helpful and that it moved me along a stage in the design process (a stage I might otherwise have missed)." "I thought the scenario was a very beneficial document from the perspective of the 'designer'." (P1)*

> *"I found it useful to think about the range of visualization techniques that are available interesting and learnt a few new ideas, so thank you! I think it is important to consider the whole process and not just the interface design." (P4)*

> *"I start with looking at the exploratory tasks and the data available and then select appropriate methods for visualization." (P5)*

> *"I like to take simple tools and bolt them together. An 'all-singing, all-dancing application would probably be the wrong route." (P9)*

Getting geovisualization experts to consider their thinking processes in constructing geovisualization applications was designed to see if there were similarities or differences that might affect the way they reacted to the scenario. From observing these experts, I have already found difference in the way some use sketching to develop and communicate their ideas, while others do not. These four quotes here express very different approaches – P1 is data-centric; P4 wants to consider a wider range of geovisualization tools and techniques; P5 looks at tasks *and* data; P9 is tools-centric. These approaches are very dissimilar, and as with the 'sketchers/talkers' differences, geovisualization experts would be well to be aware of their personal styles when working with each other, or with research subjects.

4.4.3.4 DISCUSSION ON GEOVISUALIZATION EXPERTS' QUESTIONNAIRE RESPONSES

The questionnaire responses point to the usefulness of the scenario in providing an understanding of the subject aspects of tasks, range and type of data, goals, tools, skill sets, and expertise, although less so when it came to the subject's end customers. Two experts considered the scenario too broad in scope. Although this is just one of many possible scenarios, the positive responses to indicate its overall fitness for purpose.

A significant finding is that five of the nine experts believed that the scenario by itself was inferior to the 'scenario plus the interview process' (which included the supplemental information and having the opportunity to clarify aspects with the interviewer) as a way to eliciting information that would be of use in constructing a geovisualization application. The other four experts considered them the same. All experts looked at the data/metadata samples and maps (where available), and all but one the 'crib sheet' supplemental information. Written comments contributed further evidence to responses to some questions supporting the desire by three experts for more data.

Other comments from experts give an insight into different approach to geovisualization - data-centric, tools-centric, and task- plus data-centric were mentioned. These dissimilar approaches may have an impact as experts collaborate with each other, or as they work with domain subjects as in the case of experts who like to sketch, and those who like to speak, to communicate their ideas.

There is some evidence of some experts offering advice linked to a particular research interest, but it is not clear that these instances materially alter combined results from multiple experts of the 'top' interactions or tools.

4.5 RESULTS – COMMUNICATING GEOVISUALIZATION TO SUBJECTS WITH A LECTURE

These results correspond to case number 6 on Table 2.2 (an extract of which is at the start of this chapter).

An indirect way to attempt to establish requirements for a geovisualization application from the CDR subjects is to mediate an outline of geovisualization tools and interactions to them through a lecture and to use a range of methods to elicit preferences from them for which might be of use in their exploratory crime and disorder reduction tasks.

4.5.1 CARD SORT – USEFUL GEOVISUALIZATION TOOLS/INTERACTIONS

Immediately following the geovisualization tools/interactions lecture, the CDR subjects were asked to sort cards bearing 29 tool/interaction names into stacks representing

- tools/interactions they believed would be most helpful to their in-depth research into single issues to include in a prototype geovisualization application ('tick')
- tools/interactions believe to be least helpful or unhelpful… ('cross')
- tools/interactions that were 'intermediate'... ('dash')
- tools/interactions about which they were unsure or didn't know... ('question mark')

The results are in Table 4.6. The three subjects, C1-3, found 23, 27 and 29 (out of 29) “most helpful”. The card sort was to have been followed by a feedback session whose aim was to reach a consensus on any differences on individual tool/interaction results through discussion between subjects. However, given the results obtained, this was not needed.

While it is possible that the card sorting method was deficient in some way at enabling the subjects to categorise the geovisualization tools/interactions, this seems highly unlikely given the simple nature of the task and the widespread successful use of card sorting techniques. The more likely explanation of the failure of the CDR subjects to differentiate significantly is some combination of:

- the novelty, complexity and quantity of geovisualization tool and interactions to these subjects,
- the abstract nature of the tools and interactions, not relating their use to the CDR domain,
- the absence of real CDR data

However, tailoring a general geovisualization lecture to a plethora of domains with real domain data for each is highly labour intensive and an impractical suggestion for real world implementation.

Tool/Interaction	**C1**	**C2**	**C3**
Box plots	✓	✓	✓
Brushing	✓	✓	✓
Buffers	x	✓	✓
Continuous cartograms	x	✓	?
Density maps	✓	✓	✓
Dorling cartograms	✓	✓	✓
Histograms	✓	✓	✓
Line graphs	✓	✓	✓
Linking	✓	✓	✓
Map algebra	✓	✓	✓
Mosaic plots	✓	✓	✓
Multiple maps	✓	✓	✓
Orthophoto	✓	✓	✓
Panning	✓	✓	✓
Parallel plots	✓	✓	✓
Radial hierarchy	✓	✓	✓
Scatterplot matrix	✓	✓	✓
Scatterplots	✓	✓	✓
Self-organising map	?	✓	?
Simplified maps	✓	✓	✓
Spider plots	✓	✓	✓
Starplot/Glyphs	x	✓	✓
Surface representation	-	✓	✓
Table lens	?	✓	✓
Tag clouds	✓	✓	✓
Thematic maps	-	✓	✓
Thiessen polygons	✓	✓	✓
Treemaps	✓	✓	✓
Zooming	✓	✓	✓

Table 4.6: Results of card sort of 29 tools/interactions by CDR subjects. A tick indicates belief that toll/interaction might be useful to their in-depth research into single issues to include in a prototype geovisualization application; cross indicates ones less helpful or unhelpful; dash indicates an intermediate position; question mark indicates "don't know or don't understand"

The results from the card sort suggest that communicating geovisualization with a lecture on tools and interactions in this way is not conducive to eliciting information from these subjects that could usefully establish meaningful requirements for a geovisualization application.

4.5.2 GEOVISUALIZATION TOOL/INTERACTION RECALL INTERVIEWS

Two weeks after the lecture, the subjects were asked individually to recall which geovisualization tools/interactions they remembered from the lecture. The hypothesis here is that recalled tools/interactions might be ones that are interesting (Alexander, Kulikowich and Schulze, 1994) to the CDR subjects in the context of their exploratory tasks.

There is a risk that recall is triggered, not by the particular usefulness of that tool or interaction for their exploratory work, but by some other aspect - for example the visual image used to illustrate it during the lecture, or the way it was presented. For this reason, the subjects' responses to the recall question and the comments made were recorded to determine to what degree the recollections were related to the subjects' context of use.

C1 recalls glyphs and treemaps. C2 recalls nothing at first, but subsequently remembers treemaps, Dorling cartograms and the mosaic plot. C3 recalls spider graphs, map algebra, parallel plots, thematic maps, radial hierarch, and the table lens. These are shown in Table 4.7. Subjects do describe the tools/interactions that appear to be related to their exploratory work, although they struggle to match the tool to its name at times.

Subject C1 recollections

- *"the glyphs I liked. I think I could see a use for them straight away, in terms of… and how they were presented… although it wasn't using crime information, you could, use them in quite a simple way to look at those areas within the county that have quite a similar characteristics, and quite similar problems. I thought that would be quite an interesting way to do it."*
- *"Also, the treemaps. I thought they would be particularly useful… I often have to do kind of end of year report, kind of things. Or where there are meetings or seminars, etc., where they want to look at last year's crime figures. And also there is quite a high turnover amongst the CDRPs, particularly of the elected member involvement and how that changes. And I think that was quite a useful way to be able to demonstrate… I think a lot of people come to work in CDRPs and don't have a specific background in community safety or crime. They don't really have much idea about what to ask, what are the issues, really, so it is quite useful to (have) quite a simple, straightforward way of demonstrating 'well, actually, it is mostly criminal damage and violent crime. And distraction burglary you maybe have 3 a year', or something. To be able to demonstrate that, I thought that would be quite useful."*

Subject C1 can remember two tools, but from the description given, C1 has the tools in mind for presentation and demonstration rather than exploration, a theme that emerged in looking at these subjects' context of use (in section 3.3). See this exchange where C1 mentions the use of treemaps:

- *David Lloyd: "you are representing it as a presentation tool rather than an exploration tool?"*
- *C1: "I think they too often merge for me in my thinking."*

Tool/Interaction	**C1**	**C2**	**C3**
Box plots	x	x	x
Brushing	x	x	x
Buffers	x	x	x
Continuous cartograms	x	x	x
Density maps	x	x	x
Dorling cartograms	x	✓	x
Histograms	x	x	x
Line graphs	x	x	x
Linking	x	x	x
Map algebra	x	x	✓
Mosaic plots	x	✓	x
Multiple maps	x	x	x
Orthophoto	x	x	x
Panning	x	x	x
Parallel plots	x	x	✓
Radial hierarchy	x	x	✓
Scatterplot matrix	x	x	x
Scatterplots	x	x	x
Self-organising map	x	x	x
Simplified maps	x	x	x
Spider plots	x	x	✓
Starplot/Glyphs	✓	x	x
Surface representation	x	x	x
Table lens	x	x	✓
Tag clouds	x	x	x
Thematic maps	x	x	✓
Thiessen polygons	x	x	x
Treemaps	✓	✓	x
Zooming	x	x	x

Table 4.7: Recall of geovisualization tools and interactions two weeks after the lecture by CDR subject. A tick indicates unprompted recall, otherwise a cross is shown.

Subject C2 recollections

- *"there was the tree analysis one* ***…****I do tree analysis on SPSS and it was a case of being able to present the findings in an understandable format."*
- *"there were proportional maps, according to how big the segmentation of the variable was according to another variable. Trying to think what they were called. Was it mosaic… mosaic was one name for them…*
- *"it's remembering the names of them. I can remember [what they look like]"*
- *"there were [maps of] blobs that were proportionate in size"* [cartograms].

Subject C3 recollections

- *"the one that sticks in my mind that most - and I can't remember its proper name - it was like all the little spider graphs."*
- *"And then there were the more obvious ones-like the grid mapping and the cell calculations between them."*
- *"it is funny actually, because it shows how visualisation works, because I can picture them in my head, but I can't recall them…"*
- *"you know the one with all the car components, I have seen it before…."* [parallel plots]
- *"And some of the more obvious ones like choropleth maps* [thematic maps]
- *"… and that was like a circle with, like hierarchical…I suppose you would use it for crime types. With the major categories on the outside…* [radial hierarchy]
- *"and the one with the states of America… that showed the smokers mortality "* [table lens]

It is clear that subjects C2 and C3 have difficulty in recalling the names of the tools/interactions. Either they describe them in terms of what they look like, or the example used to illustrate them in the lecture. This '**nomenclature problem**' parallels the difficulty that two of the geovisualization experts had in remembering the names of geovisualization tools (see section 4.4.2). Nomenclature is not in itself important as long as subjects can convey their recalled preferences somehow. Verbal description imposes a barrier, in fact. Recording and transcribing what the subjects said was important to reach this understanding. Future researchers should seek ways to ensure that this 'nomenclature problem' does not hinder their interactions with domain experts or lead to misleading conclusions about what domain experts do and do not comprehend and recall about geovisualization. Bear in mind C3's revealing comment: "I *can picture them in my head, but I can't recall them…"*

Also noteworthy from the transcripts of the CDR subjects recall sessions, is that **all three subjects recall just tools, not interactions**. This is an important result, and points to a limitation of the recall method in a geovisualization context, where interactions represent such an important aspect.

4.5.3 SKETCHING GEOVISUALIZATION

Tohidi (2006) provide evidence from a study that shows "how user sketching can elicit reflective feedback that is complementary to that which is obtained using conventional techniques (e.g. questionnaires, interviews, and think aloud protocols) and which might otherwise be missed. The technique also provides reactive data that is comparable to that obtained with those same conventional techniques."

It is not realistic to expect that the CDR subjects, if asked, would produce sketches of working geovisualization prototypes or significant fragments of them - "users are not designers" (Nielsen, 1993). Nevertheless, swift sketches may contain information that gives insights into the subjects' treatment of tools and interactions that might contribute to establishing some aspect of their requirements. The CDR subjects were asked to produce individual sketches on the themes of 'fear of crime', 'racial crime' and the 'night-time economy'. In the time available, C1 produced three sketches, C2 and C3 two each. These are shown in Figures 4.7 – 4.13.

Examining these sketches, some aspects are apparent:

- Only one sketch (C3; night-time economy) depicts an application interface. All the others are sketches of a process or processes.
- Within these processes, representations of geovisualization tools appear throughout C1's and C3's sketches, whereas they do not appear at all in C2's. C1's and C3's sketches are noticeably richer than C2's.
- A large amount of text is employed in all sketches.
- Interactions are sometimes indicated through a sequence of sketches linked by arrows to indicate flow, as text (for example "drill down to detail", or "link together"), as buttons (for example with 'zoom' and 'pan' on them), and in one sketch, a zoom and pan interaction is depicted with icons of a magnifying glass and hand, respectively.
- Some subjects sketch ways to filter data. For example, C3's night-time economy sketch has "choose date range"; "choose time interval"; "choose crime type"; C2's night-time economy sketch has "selection" from a timeline.

The degree of text in these sketches indicates that these are not so much sketches as narratives, and that an alternative way of asking the subjects to represent a geovisualization application might have given results that were more tractable for subjects and researchers alike. An alternative might have been to ask the users to draft one or more scenarios of themselves in the context of exploring a dataset of, say the night-time economy, using a hypothetical geovisualization scenario and to tell the emerging story in their own words.

An interesting observation is that there are multiple ways of depicting interactions. This is an indication that there is no common way to depict interaction in a sketch and that sketches are not ideally suited to the complex, linked multiple view environment of geovisualization.

Subjects were observed during their sketching and their comments noted. They describe the difficulty of representation, of the task, and general fatigue:

> *"… difficult to draw/visualise things to do like zooming…how to describe what you want to do on paper." (C1)*
> *"Think I am past the point of being able to think" (C3)*
> *"I feel like I've failed you miserably, I can't think in this way, got too many things in my head." (C3)*

While it is difficult to extract much from these sketches considering them as representations of applications, it is possible to study their tool and interaction components to gain an insight into what these subjects might find useful in an application. Tohidi et al (2006) outline an exploratory analysis based on counting ideas found in sketches. By making a numerical count of the components within each CDR subject sketch, it is possible to derive quantitative information. Tools and interactions that appear frequently on sketches from more than one subject or multiple use of the same element will indicate recall of these geovisualization components and a perceived utility to the exploratory task in hand. Tables 4.8 and 4.9 show subject and task based counts of elements, respectively, separating those appearing in the lecture from others.

Seven user sketches produced 78 elements of which 30 were from the 29 tools/interactions techniques of the geovisualization lecture, for three crime tasks. These contained an average of 2.0, 3.5 and 6.3 elements, respectively, the last being "night-time economy crime". This is the candidate crime task that generates the most possibilities of the three for a prospective geovisualization application. Perhaps this is not unrelated to the fact that the CDR team find assault (a large part of night-time economy crime) particularly interesting.
Ten of the 29 geovisualization techniques in the lecture are absent from subject sketches, eleven are used once; six twice; "star plot/glyph" three times; "line graphs" four times. The total number of 'lecture' elements in these sketches is 30.

Of the 21 elements that appear in the sketches but not in the lecture, there are 48 instances in the seven sketches. Of these, 15 are associated with filtering and aggregation, 18 with various kinds of data (nine of them crime data), and the generic "map" appears five times, leaving ten others. This is a useful insight of the particular importance of filtering and aggregation, and of the crime data to these subjects, in these representative tasks.

Subjects were encouraged to make use of the geovisualization tools and interactions to which they had been exposed, and this perhaps leads to an over-emphasis of such elements. However, this reductive way of examining the sketches does appear to be a useful and quick way to determine the relative acceptability of geovisualization tools and interactions to these subjects in the context of particular tasks.

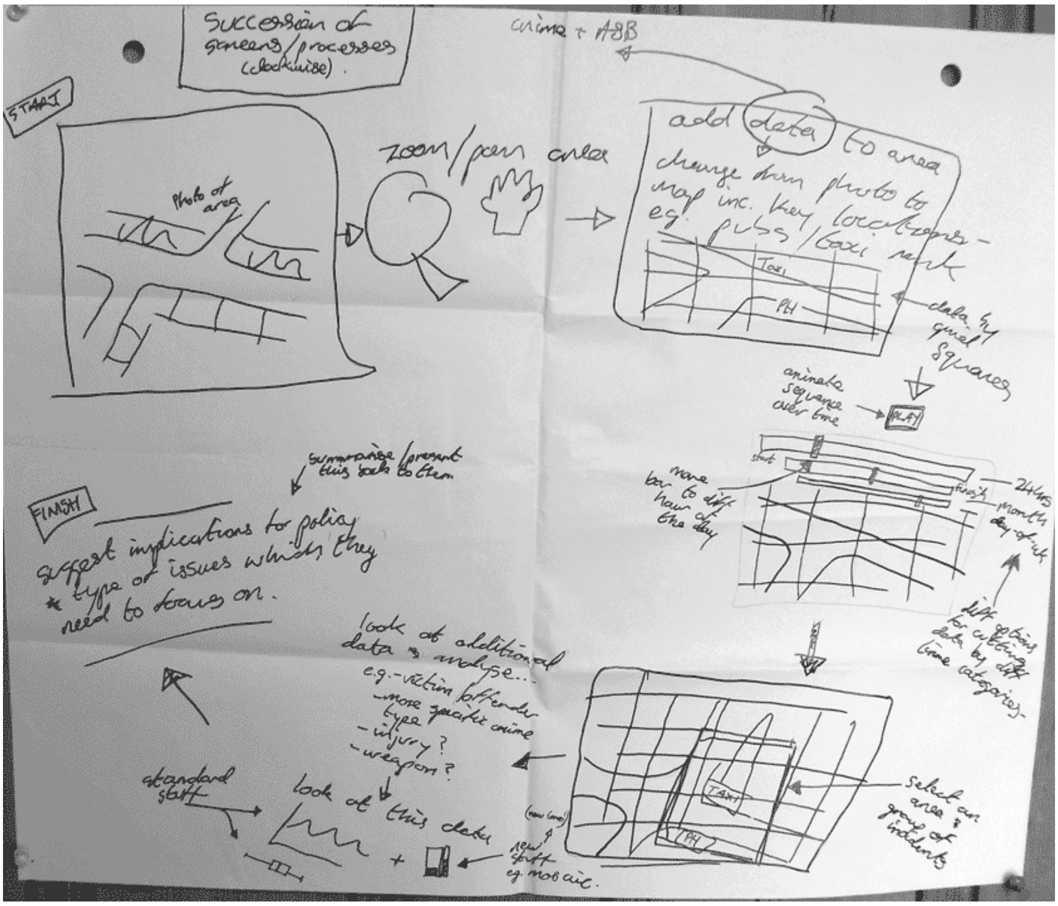


Figure 4.7: Sketch of geovisualization applications for 'night-time economy' by CDR subject C1

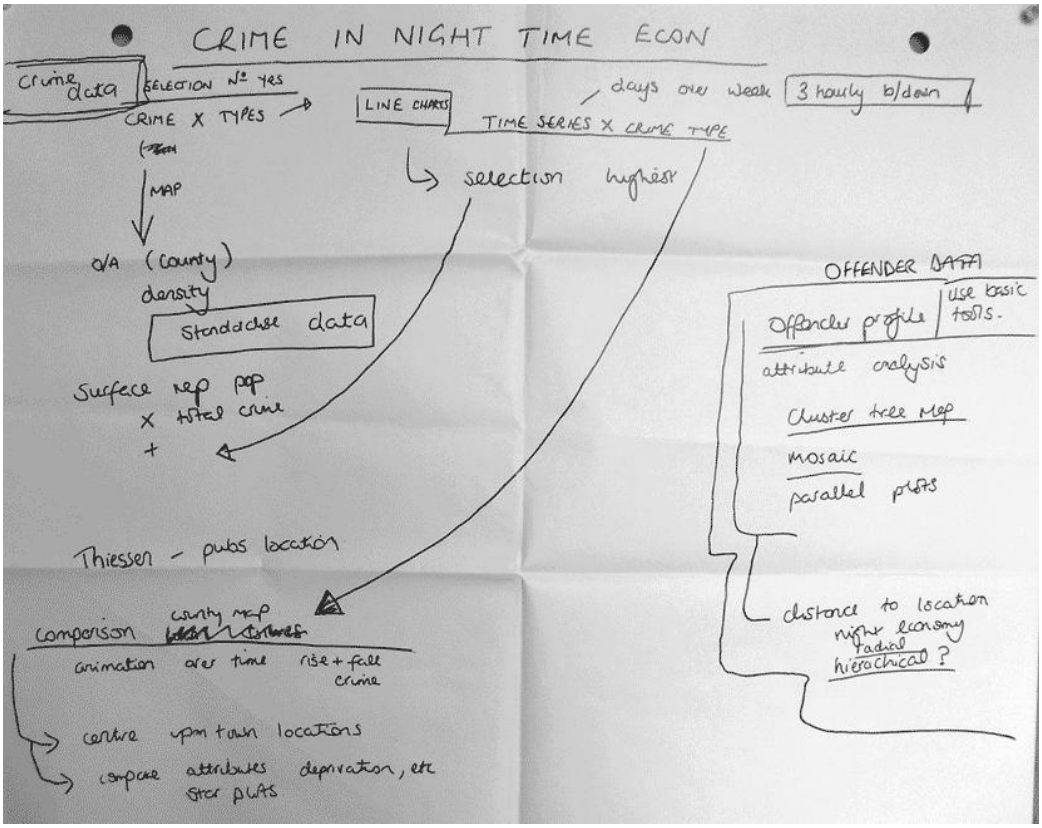


Figure 4.8: Sketch of geovisualization applications for 'night-time economy' by CDR subject C2

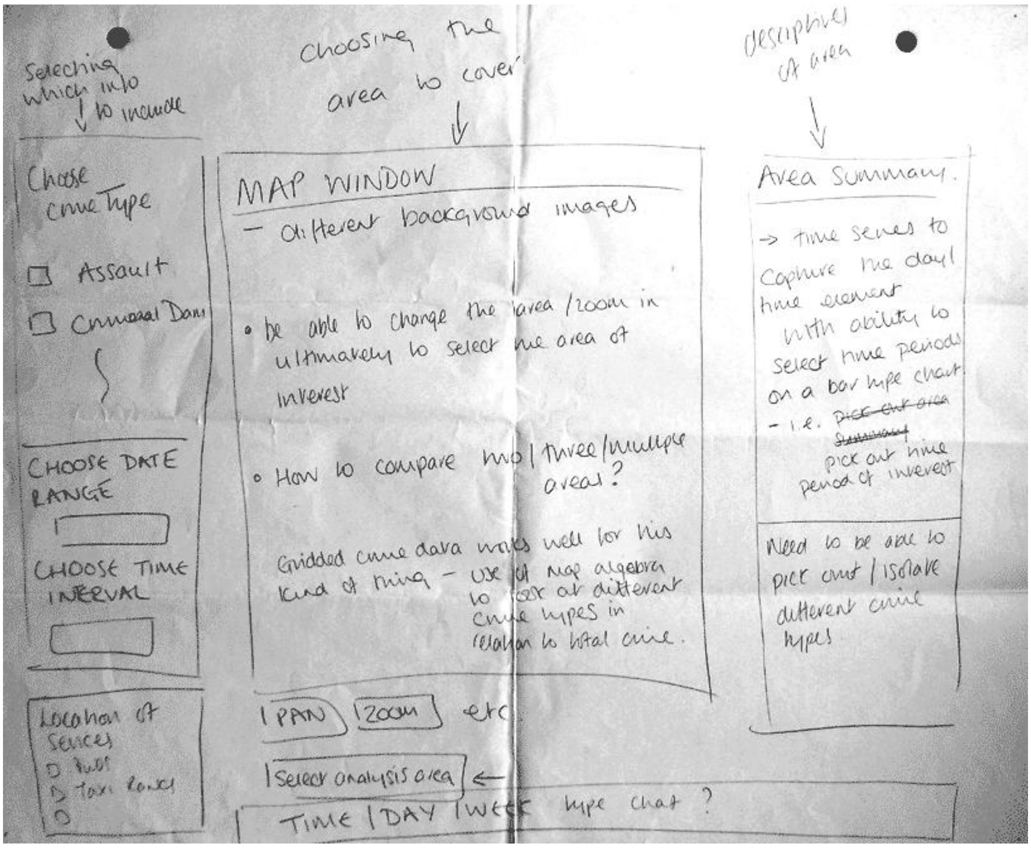


Figure 4.9: Sketch of geovisualization applications for 'night-time economy' by CDR subject C3

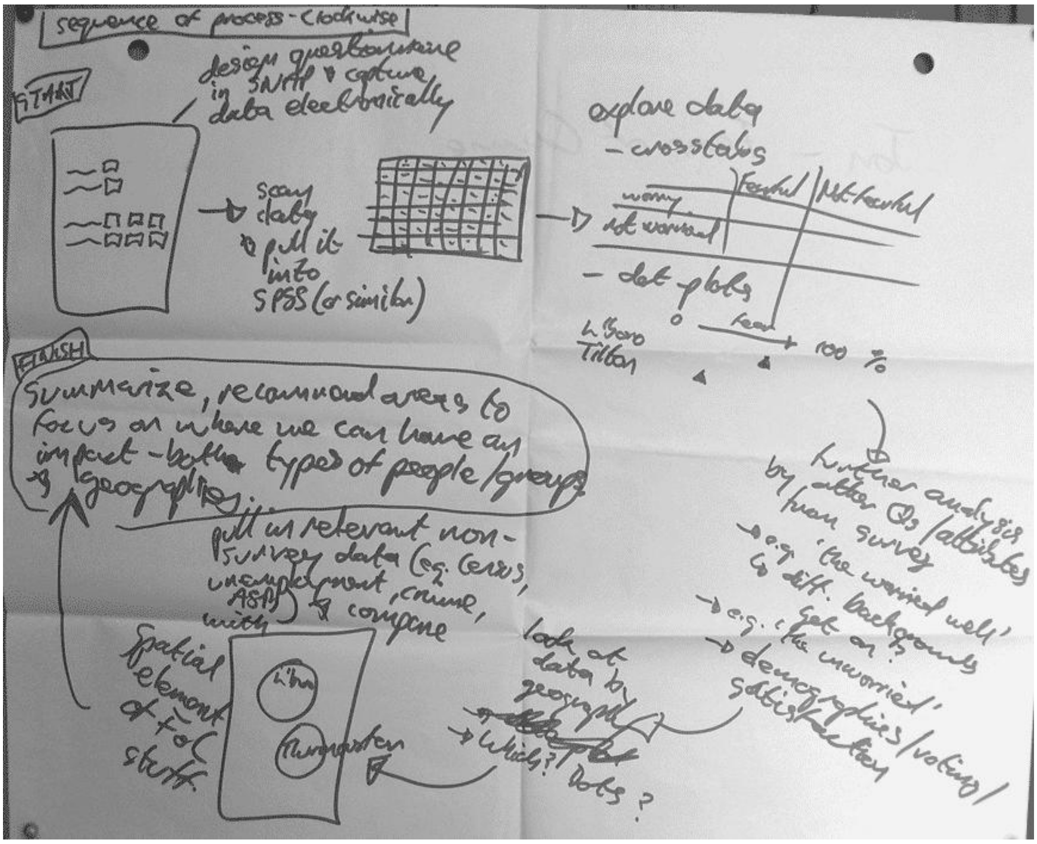


Figure 4.10: Sketch of geovisualization applications by CDR subject C1 for 'fear of crime'

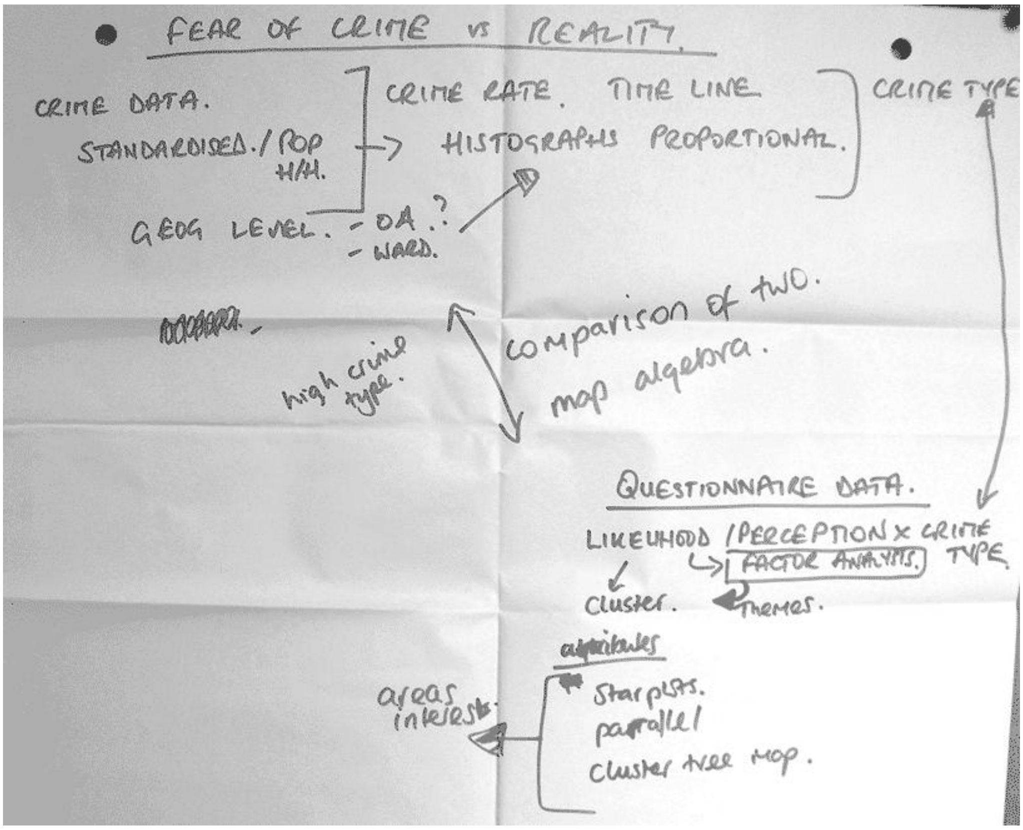


Figure 4.11: Sketch of geovisualization applications by a CDR subject C2 for 'fear of crime'

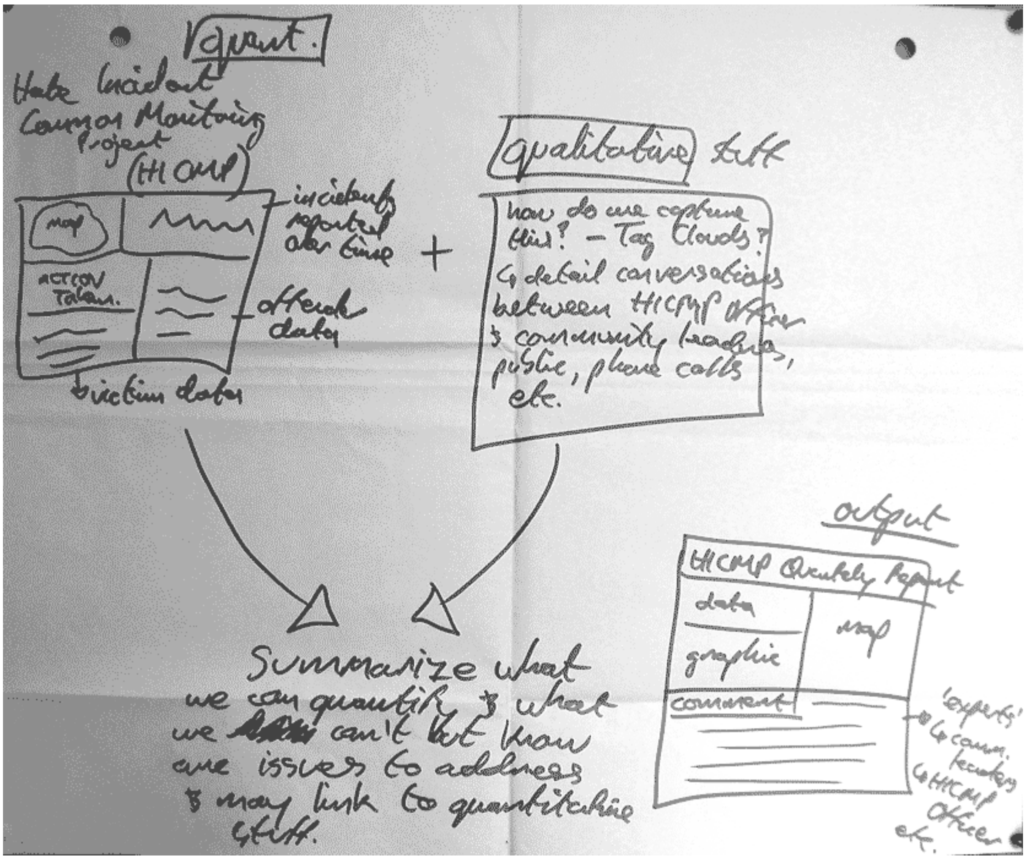


Figure 4.12: Sketch of geovisualization applications by CDR subject C1 for 'racial crime'

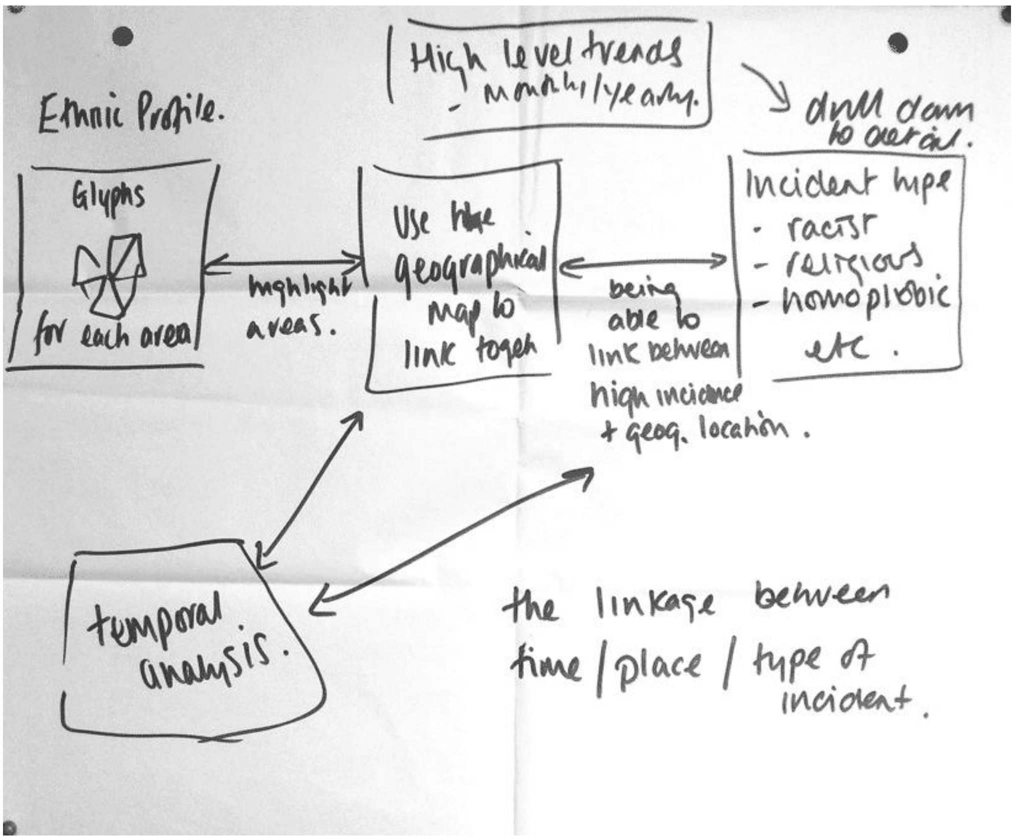


Figure 4.13: Sketch of geovisualization applications by CDR subject C3 for 'racial crime'

Sketcher	C1			C2		C3		
Topic	**Night-time Econ**	**Racial Crime**	**Fear of Crime**	**Night-time Econ**	**Fear of Crime**	**Night-time Econ**	**Racial Crime**	**Total**
Box plots	1							1
Brushing	1							1
Buffers								0
Continuous cartograms								0
Density maps				1				1
Dorling cartograms								0
Histograms					1			1
Line graphs	1	1		1	1			4
Linking							1	1
Map algebra					1	1		2
Mosaic plots	1			1				2
Multiple maps								0
Orthophoto	1							1
Panning	1					1		2
Parallel plots				1	1			2
Radial hierarchy				1				1
Scatterplot matrix								0
Scatterplots			1					1
Self-organising map								0
Simplified maps								0
Spider maps								0
Starplot/Glyphs				1	1		1	3
Surface representation				1				1
Table lens								0
Tag clouds		1						1
Thematic maps								0
Thiessen polygons				1				1
Treemaps				1	1			2
Zooming	1					1		2
sub-Totals	7	2	1	9	6	3	2	**30**
Aggregate by time				1				1
Animate over time	1			1				2
Census data			1					1
Crime attribute data	1		1	1	1	1	1	6
Crime incident data	1	1					1	3
Cross tabulation								0
Demographic data			1					1
Deprivation data				1				1
Different background images						1		1
Ethnicity data							1	1
Filter by crime	1			1		1	1	4
Filter by Geography	1		1		1	1		4
Filter by time	1			1		1	1	4
Grid squares	1						1	2
Map	1	1	1	1			1	5
Pubs, taxi rank data	1			1		1		3
Questionnaire data			1		1			2
Standardise the data				1	1			2
Statistical analysis			1		1			2
Temporal analysis							1	1
Time "sliders"	1					1		2
sub-Totals	**10**	**2**	**7**	**9**	**5**	**7**	**8**	**48**
Total	**17**	**4**	**8**	**18**	**11**	**10**	**10**	**78**

Table 4.8: Element count of CDR subject sketches by subject; top: elements present in card sort; bottom: elements not in card sort (both are shown alphabetically)

Sketcher	C1	C2	C3	C1	C3	C1	C2	
Topic	**Night-time Econ**	**Night-time Econ**	**Night-time Econ**	**Racial Crime**	**Racial Crime**	**Fear of Crime**	**Fear of Crime**	**Total**
Box plots	1							1
Brushing	1							1
Buffers								0
Continuous cartograms								0
Density maps		1						1
Dorling cartograms								0
Histograms							1	1
Line graphs	1	1		1			1	4
Linking					1			1
Map algebra			1				1	2
Mosaic plots	1	1						2
Multiple maps								0
Orthophoto	1							1
Panning	1		1					2
Parallel plots		1					1	2
Radial hierarchy		1						1
Scatterplot matrix								0
Scatterplots						1		1
Self-organising map								0
Simplified maps								0
Spider maps								0
Starplot/Glyphs		1			1		1	3
Surface representation		1						1
Table lens								0
Tag clouds				1				1
Thematic maps								0
Thiessen polygons		1						1
Treemaps		1					1	2
Zooming	1		1					2
sub-Totals	7	9	3	2	2	1	6	**30**
Aggregate by time		1						1
Animate over time	1	1						2
Census data						1		1
Crime attribute data	1	1	1		1	1	1	6
Crime incident data	1			1	1			3
Cross tabulation								0
Demographic data						1		1
Deprivation data		1						1
Different background images			1					1
Ethnicity data					1			1
Filter by crime	1	1	1		1			4
Filter by Geography	1		1			1	1	4
Filter by time	1	1	1		1			4
Grid squares	1				1			2
Map	1	1		1	1	1		5
Pubs, taxi rank data	1	1	1					3
Questionnaire data						1	1	2
Standardise the data		1					1	2
Statistical analysis						1	1	2
Temporal analysis					1			1
Time "sliders"	1		1					2
sub-Totals	10	9	7	2	8	7	5	**48**
Total	**17**	**18**	**10**	**4**	**10**	**8**	**11**	**78**

Table 4.9: Element count of CDR subject sketches by crime task (night-time economy, racial crime, fear of crime); top: elements present in card sort; bottom: elements not in card sort (both are shown alphabetically)

4.5.4 COMBINING CARD SORTING, SKETCHING AND RECALL INTERVIEW RESULTS

	Card sort after lecture			Element count from sketching			Interview after two weeks		
Tool/Interaction	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**	**C1**	**C2**	**C3**
Box plots	✓	✓	✓	✓	x	x	x	x	x
Brushing	✓	✓	✓	✓	x	x	x	x	x
Buffers	x	✓	✓	x	x	x	x	x	x
Continuous cartograms	x	✓	?	x	x	x	x	x	x
Density maps	✓	✓	✓	x	✓	x	x	x	x
Dorling cartograms	✓	✓	✓	x	x	x	x	✓	x
Histograms	✓	✓	✓	x	✓	x	x	x	x
Line graphs	✓	✓	✓	✓	✓	x	x	x	x
Linking	✓	✓	✓	x	x	✓	x	x	x
Map algebra	✓	✓	✓	x	✓	✓	x	x	✓
Mosaic plots	✓	✓	✓	✓	✓	x	x	✓	x
Multiple maps	✓	✓	✓	x	x	x	x	x	x
Orthophoto	✓	✓	✓	✓	x	x	x	x	x
Panning	✓	✓	✓	✓	x	✓	x	x	x
Parallel plots	✓	✓	✓	x	✓	x	x	x	✓
Radial hierarchy	✓	✓	✓	x	✓	x	x	x	✓
Scatterplot matrix	✓	✓	✓	x	x	x	x	x	x
Scatterplots	✓	✓	✓	✓	x	x	x	x	x
Self-organising map	?	✓	?	x	x	x	x	x	x
Simplified maps	✓	✓	✓	x	x	x	x	x	x
Spider plots	✓	✓	✓	x	x	x	x	x	✓
Starplot/Glyphs	x	✓	✓	x	✓	✓	✓	x	x
Surface representation	-	✓	✓	x	✓	x	x	x	x
Table lens	?	✓	✓	x	x	x	x	x	✓
Tag clouds	✓	✓	✓	✓	x	x	x	x	x
Thematic maps	-	✓	✓	x	x	x	x	x	✓
Thiessen polygons	✓	✓	✓	x	✓	x	x	x	x
Treemaps	✓	✓	✓	x	✓	x	✓	✓	x
Zooming	✓	✓	✓	✓	x	✓	x	x	x

Table 4.10: Results from the three geovisualization elicitation techniques, by subject, arranged chronologically. The card sort took place immediately after the lecture; the sketching four hours later, and the recall interview a fortnight afterwards.

Table 4.10 pulls together the results of the card sort on geovisualisation tools and interactions held after the lecture, the element count from the sketching exercise, and the recall interviews, and illustrates a progression of declining CDR subject recall and hence interest

(Alexander, Kulikowich and Schulze, 1994) in geovisualization over time (Table 4.10) as expressed though the different elicitation techniques.

In Table 4.10, for the card sort, a tick indicates belief that tool/interaction might be useful in a geovisualization application; a cross indicates ones less helpful or unhelpful; a dash indicates an intermediate position; and a question mark indicates "don't know or don't understand". For the element count from sketching, a tick indicates one or more inclusions, otherwise a cross. For the recall interview, a tick indicates unprompted recall, otherwise a cross is shown.

4.5.5 DISCUSSION – COMMUNICATING GEOVISUALIZATION TO SUBJECTS

Communicating geovisualization to CDR subjects using a lecture and then asking them immediately afterwards to identify possible useful tools and interactions for exploratory work using a card sort results in subjects appearing overwhelmed by the possibilities and unable to differentiate usefully between them.

Sketching based on defined subject crime tasks and recall interviews can provide a tangential way of gauging subject engagement with geovisualization, but the results are meagre other than showing a decreasing subject recall and hence interest (Alexander, Kulikowich and Schulze, 1994) over time. The results do not materially help in establishing requirements to progress a geovisualization design. What we have at the end of this process is a few tools that the subjects have gained familiarity with and feel have a resonance for their exploratory work. This 'short list' is perhaps as limited as just treemaps and glyphs (both recalled by C1 after two weeks and related to CDR's exploratory work) and thematic maps (recalled by both C2 and C3 although without reference to the work context).

The complexities of geovisualization make it hard to provide concise and tailored lectures about the tools and interactions for these subjects. Subjects find it hard to choose between the alternatives initially, but hard to recall all but a few after a fortnight, the latter indicating a lack of impact (Alexander, Kulikowich and Schulze, 1994). Subjects find it hard to sketch geovisualization tools and interactions. Attempting to bridge the gap between geovisualization researchers and these CDR domain experts by "(educating) domain experts to define visualizations themselves" (van Wijk, 2006) with a geovisualization lecture and human-centered analysis methods such as card sorting and user sketching employed, does not succeed in establishing requirements for a geovisualization application.

4.6 CONCLUSIONS

Research question 2 asks: **How well do human-centered approaches concerned with establishing requirements work in an applied geovisualization context? How does the nature of geovisualization affect the process of establishing requirements from prospective users?**

The nature of geovisualization (novelty, complexity, interactive, exploratory nature, its spatial and multiple components) may mean that e**stablishing requirements using a template** - a standard HC approach to bridging the gap (van Wijk, 2006) between the domain experts such as the CDR team, and application designers – may be problematic.

RQ2.1 How well do human-centered approaches concerned with establishing requirements work in an applied geovisualization context?
The direct approach to establishing requirements is by asking prospective users with a template such as Volere, that have been created to facilitate that process. There is **strong evidence** that CDR subjects are unable to contribute answers to direct questions from the Volere about the content or the motivation for such an application. Where 'tangential' Volere questions are asked, then some, limited, insight is obtained, but insufficient to inform a geovisualization designer. The results are similar across all three CDR team members (section 4.3). When one of the CDR subjects has the Volere questions repeated after 18 months of learning about geovisualization, and experience with geovisualization wireframes and prototypes (section 4.3.1 and especially 4.3.2) the Volere template still cannot elicit useful requirements about a future geovisualization application's content.

I recommend that geovisualization researchers avoid the Volere template approach to establishing requirements from subjects. There is good evidence (section 4.3.1.1) that the proposition of a geovisualization application does not elicit requirements from subjects, whose responses indicate its "undreamed of" nature. Nevertheless, the Volere template might help researchers by providing a long 'check list' of issues, and yielding additional context of use information. The kind of information a designer needs to build a geovisualization application depends on an understanding of the characteristics of subject s' data and associated metadata – spatial and attribute (and possibly temporal). This is not implicit in the Volere template and needs to be gathered as a separate exercise.

RQ2.2 How might human-centered approaches concerned with establishing requirements work in an applied geovisualization context be changed?
Volere lacks any clear thrust towards asking about subject data, and by extension, using it as a way to get subjects to talk about the ways to visualize it, which is a particular weakness in the context of geovisualization.

RQ2.3 How does the nature of geovisualization affect the process of establishing requirements from prospective users?
The findings obtained and outlined in section 4.3 are a combination of the CDR domain, the nature of geovisualization, and the approach employed by the Volere template. Since Volere enjoys success elsewhere, and the crime and disorder domain benefits from successful commercial and open source applications, **it is probable** that it is the particular nature of geovisualization that is the issue. The failure of Volere to establish substantive geovisualization requirements means that alternative methods of elicitation are needed to move forward to the design of a geovisualization application, which are addressed in the responses to research question 3.

Research question 3 asks: **How well do human-centered approaches concerned with mediating between the geovisualization domain and prospective users work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of mediation between the geovisualization domain and prospective users?**

The response to this research question focuses on two approaches. The first attempts to communicate the context of the CDR subjects to geovisualization experts with a scenario in the expectation that their collective suggestions would form a basis for alternative requirements – a way forward for the designer of a geovisualization application for these subjects. The second attempts to inform the subjects about geovisualization through a lecture so that they have sufficient knowledge to be able to suggest what tools and interactions might be useful for the exploratory work.

RQ3.1 How well do human-centered approaches concerned with mediating between the geovisualization domain and prospective users work in an applied geovisualization context?

Geovisualization experts and a scenario

Creating a scenario based on the CDR context and using it with nine geovisualization experts to elicit their tool and interactions suggestions yields **strong evidence** from transcribed interviews and from questionnaires, of prioritised, concise, coherent and compatible suggestions for which geovisualization tools and interactions to employ (section 4.4.1). The top ranked interactions and tools suggested by the geovisualization experts are: aggregating, zooming, filtering, clustering, linking, comparing, symbolising and classifying. (interactions); map, density/hot spots, cartograms, spreadsheet/table/grid, animation, parallel coordinate plot, small multiples and histograms (tools).

Many of these have a wider scope than other, less lowly ranked suggestions, and it is possible that experts' suggestions may be for that reason rather than the particular needs of the CDR team. There is also the possibility that the suggestions might favour those that have a historical connection with use in a crime context. This needs further research to untangle these factors. With these caveats in mind, it is nevertheless possible to combine the advice of multiple geovisualization experts into a coherent and concise statement that might be useful advice to a designer (if the designer was a different person from the one carrying out the enquiry with the geovisualization experts).

I recommend that geovisualization designers should consider the use of scenarios to describe subject context of use, as they usefully concentrate such information in an accessible way.

I commend novice geovisualization designers use scenarios as a way to convey context-of use information to one or more geovisualization experts as a prelude to using them to suggest context-appropriate geovisualization tools and interactions

I recommend that **further research** is conducted to see if multiple geovisualization experts' suggestions for particular tools and interactions are focused on subject needs, or on simply popular and/or widely scoped tools and interactions.

Geovisualization lecture

There is **good evidence** that delivering a lecture on geovisualization to subjects and immediately asking them to identify possible useful tools and interactions for domain exploratory work using a card sort **fails** to do so (section 4.5.1). Subjects appear overwhelmed by the possibilities of geovisualization and cannot differentiate usefully between them. The card sorting approach does have merit in eliciting information on the effectiveness of communicating geovisualization.

There is **good evidence** that delivering a lecture on geovisualization to subjects and asking them to sketch domain-related applications to identify possible useful tools and interactions for specific domain tasks **fails** to produce meaningful results (section 4.5.1). The technique itself, allied to a count of tools and interactions within sketches, does have merit as a way of eliciting information on the effectiveness of communicating geovisualization in this way.

There is **good evidence** that asking subjects to recall geovisualization tools and interactions after a fortnight from the lecture (section 4.5.2) **fails** to elicit more than a very small number of tools, indicating that communication of geovisualization via a lecture format does not work in the case of these subjects and the particular lecture given to them. Nevertheless, the recall approach does have merit in eliciting information on the effectiveness of communicating geovisualization.

I recommend that researchers be cautious in attempting to bridge the gap between themselves and domain experts by using a lecture format to educate domain experts in geovisualization tools and interactions.

I recommend that researchers use card sorting on domain tasks, domain task sketches and recall interviews as useful techniques to understand the success or otherwise of communication efforts.

RQ3.2 How might human-centered approaches concerned with mediating between the geovisualization domain and prospective users be changed?

Geovisualization experts and a scenario

While the scenario was useful in aiding geovisualization experts' understanding of many aspects of the subjects' context of use, there is **strong evidence** from the summative questions asked of the nine geovisualization experts (section 4.4.3) and from comments made by at least one geovisualization expert during the interviews (section 4.4.2) that indicate the importance of supplemental information such as maps and a geovisualization tools and interactions 'crib sheet', but in particular subject data and metadata. There is particularly **good evidence** (section 4.4.3.2) that data/metadata is important to the geovisualization experts as they **all** consult it to supplement the scenario.

This suggests that **when used in a geovisualization context, the HC scenario approach should be modified** to include this supplemental information, especially domain data and metadata. The scenario, by itself, is not as effective a vehicle to help geovisualization experts make suggestions that might lead to a application for the CDR team as the scenario plus the interview process that provided additional opportunities for interaction and supplemental information in the form of data/metadata, maps, and a tools and a techniques 'crib sheet'.

I strongly recommend that the use of scenarios in a geovisualization context should be supplemented with information on subject data and metadata, and where appropriate, spatial data on subjects local geography structure. Having a list of tools and techniques used successfully in the past can be a useful aid to memory and to nomenclature.

RQ3.3 How does the nature of geovisualization affect the process of mediation between the geovisualization domain and prospective users, and vice versa?

There is **good evidence** (section 4.4.3.3) that geovisualization experts express their ideas differently and have different starting points when addressing a geovisualization problem – some data-centred, some task and data-centred, and some tool-centred. Some experts also have a strong preference for communicating ideas in the form of sketches whereas others are content with speech alone. This suggests that awareness of personal styles might be important in interactions when experts work with each other or with subjects with other experts or domain subjects (sections 4.4.2 and 4.4.3)

There is **some evidence** (section 4.4.1.3) that geovisualization experts do not tend to recommend the use of existing applications.

I **recommend** that geovisualization experts should take account of their personal styles of approaching the creation of geovisualization applications and/or communicating information about them, when interacting with other experts or subjects.

4.7 DISCUSSION

I have used three techniques to attempt to establish requirements for a geovisualization application, two from established human-centred literature (requirements template and scenarios), and one suggested by a visualization source to educate domain experts to define visualizations themselves. In the first I use the widely used Volere template (Robertson and Robertson, 2006a). In the second, I create a scenario (Carroll, 2000) of the CDR subjects' work that attempts to capture their exploratory tasks and their context. Taking this to nine European geovisualization experts, I use it to elicit suggestions for tools and interactions that might be of use to the CDR team in their exploratory work. In the third I take the suggestion of (van Wijk, 2006) to provide a lecture on geovisualization tools and interactions to the CDR subjects, who are invited to decide which of these might be useful to their exploratory work by means of a card sort (Nielsen and Sano, 1995), an established HC approach. Subjects are asked subsequently to create sketches of an application of particular crime tasks choosing freely from the geovisualization tools and interactions in the lecture. Sketches allow for "a dialog between the sketch and the viewer (even if the viewer is the sketcher himself) that facilitates better understanding of the problem and in turn generation of new ideas" (Tohidi et al., 2006). Two weeks later, subjects are asked to recall (Alexander, Kulikowich and Schulze, 1994) the tools and interactions that had a particular resonance for their work.

The analysis of these experiments involves a mixture of quantitative and qualitative methods in an attempt to triangulate multiple sources to provide a body of evidence. Quantitative methods include counts of tools and interactions from both geovisualization experts and CDR subjects, and the tabulation of the results of a summative questionnaire from the geovisualization experts. Qualitative information from both CDR subjects and geovisualization experts comes from the coding and analysis of audio recordings made of the Volere template sessions, the scenario interviews with the geovisualization experts, from the lecture sessions with card sorting and sketching, and subsequent recall interviews.

The results from the use of the Volere template show that for the CDR users, the nature and possibilities of geovisualization represent 'undreamed of' requirements. The Volere template can establish peripheral requirements but not enough of substance to be of use to a geovisualization application designer. The Volere template also fails to give weight to the collection of subject data and metadata, which – as demonstrated in Chapter 3 – is of key importance in the process of constructing geovisualization applications.

Taking a scenario to individual geovisualization experts and using it to garner their suggestions on the tools and interactions that might be of use to the CDR team in their exploratory work is a more fruitful exercise. While two experts found the scenario too broadly scoped, all were able to make suggestions on tools and interactions, as well as providing commentary on the process and their approach to geovisualization application building. The experts felt that the interview process that included the possibility of accessing supplementary information in the form of sample data with metadata, maps explaining administrative geography and a 'crib sheet' of geovisualization tools and interactions, improved the process, particularly the provision of the sample data and metadata. The experts came up with a large number of suggestions for tools and interactions, with the 'top eight' of each accounting for over 60% of all 'mentions'. These 16 suggestions can be combined into a concise, coherent and compatible statement that would be of use to a designer building a geovisualization application for the CDR subjects. However there is a concern that the most mentioned tools and interactions may owe their position to these being those with the widest scope, the most popular, those with the greatest past use where crime data is involved, or those included in the scenario. It is also possible that highly ranked interactions will owe their positions to their relatedness to highly ranked tolls, or vice versa. This needs further research.

There is no evidence that attempting to communicate geovisualization tools and interactions to the CDR subjects as a means to establish requirements using a lecture is successful. Subjects initially cannot differentiate between the possibilities (using card sorting) and a fortnight later, their recall of tools and interactions that might be of use to them in their work is limited to a handful. Although sketching is a new technique that has shown promise in the field of interface design, there is no evidence it elicits meaningful requirements where the focus is geovisualization with its multiple tools and complex interactions. It is clear that researchers may need to consider other, more radical, methods to establish requirements successfully.

Notwithstanding some of the results, some limited information has been elicited that is of use – the guidance from the geovisualization experts (section 4.4.1.4) and a few tools that the subjects have gained familiarity with and feel have a resonance for their exploratory work – treemaps, glyphs and thematic maps. This is put to use in design and early prototyping, the subject of Chapter 5.

With the failure to establish adequate requirements from either of the two techniques involving the CDR subjects (Volere and the geovisualization lecture), there is clearly a need to find other approaches. Work that goes under the name of 'patchwork prototyping' may indicate a way forward. Patchwork prototyping envisages:

> "combining of open source software applications to rapidly create a rudimentary but fully functional prototype that can be used and hence evaluated in real life situations. The use of a working prototype enables the capture of more realistic and informed requirements than traditional methods that rely on users trying to imagine how they might use the envisaged system in their work, and even more problematic, how that system in use may change how they work." (Jones, Floyd and Twidale, 2007)

Such an approach has its own challenges, not least how the degree of flexibility required to develop prototypes in a collaborative environment with prospective users can be achieved.

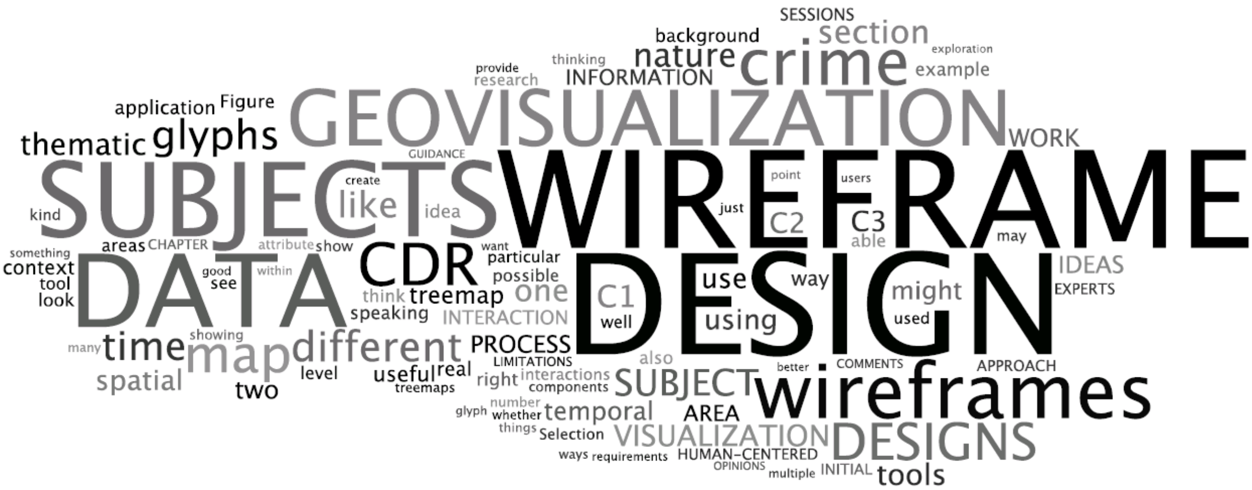
Another possible approach is that advocated by Maiden, Gizikis and Robertson (2004) is to encourage creative thinking during the requirements process: "stakeholders are increasingly creating and inventing ideas that they express as requirements. Requirements engineering, with its focus on elicitation, analysis, and management, has yet to fully grasp this trend."

Another approach from the human-centred field, although not mainstream, may offer a clue. Gaver, Dunne and Pacenti (1999) describe a different but parallel situation when they were attempting to engage 10 elderly community members in a study looking at "novel interaction techniques to increase the presence of the elderly in their local communities". They describe the encounter:

> "We were at the last site, to get to know the group a little. An important preamble, then, well delivered by the coordinator, but the explanation was of necessity fairly complicated. On our arrival, the 10 elderly members had been friendly and enthusiastic, if a little puzzled. Now they were looking tired.
>
> Finally the time came. I stood up and said, "We've brought you a kind of gift," as we all passed the clear blue plastic envelopes to the group. "They're a way for us to get to know you better, and for you to get to know us." Already people were starting to unwind the strings fastening the envelopes. "Take a look," I said, "and we'll explain what's in them."
>
> An assortment of maps, postcards, cameras, and booklets began accumulating in front of them. Curious, they started examining the materials. Soon they were smiling and discussing them with their neighbors. As the feeling of the group livened perceptibly, we started explaining the contents. Worry transformed to excitement. Perhaps the probes would work after all.
>
> The cultural probes—these packages of maps, postcards, and other materials—were designed to provoke inspirational responses from elderly people in diverse communities….The probes were part of a strategy of pursuing experimental design in a responsive way. They address a common dilemma in developing projects for unfamiliar groups. Understanding the local cultures was necessary so that our designs wouldn't seem irrelevant or arrogant, but we didn't want the groups to constrain our designs unduly by focusing on needs or desires they already understood. We wanted to lead a discussion with the groups toward unexpected ideas, but we didn't want to dominate it." (Gaver, Dunne and Pacenti, 1999)

What would a 'geovisualization probe' look like? An alternative might be to present a smaller set of tools and interactions to subjects in a different format. One way might be to use existing academic geovisualization applications to demonstrate tool use in some detail with data from a different domain (for example, demonstrate the mosaic plot using, say, the application Mondrian (Theus, 2002) with the Titantic survivor dataset). Another way would be to use an existing application to replicate some desirable functionality of a tool with user data (for example, use a GIS such as ArcMap to show the effects of displaying crime data at different resolutions). Yet another approach might be to use visualization toolsets such as Many Eyes (Viégas et al., 2007) with subject data to create 'quick and dirty' visualizations of tools without any attempt at combined interaction between them. Perhaps a wireframe prototype (discussed in the next chapter) could be used or modified to act as 'geovisualization probe'? Approaches like these may provide different solutions to the requirements establishing problems encountered in parts of this chapter, but that is work for future researchers.

This concludes Chapter 4 on establishing requirements. The next chapter looks at human-centered approaches to **design and early prototyping**.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5 DESIGN AND EARLY PROTOTYPING

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ABSTRACT

Having worked with subjects and investigated ways to elicit requirements, creating outline designs and exposing them to subjects will explore how well the human-centered method of wireframe prototyping ('wireframes') operates in a geovisualization context. It also provides the context for future work on human-centered paper and digital interactive prototyping described in Chapter 6.

The complex design process that a geovisualization application necessitates is considered, and the many influences from the different domains of human-centered approaches and geovisualization that both help and – by their very multiplicity – hinder the design process. The iterated design of two wireframes for the crime and disorder reduction subjects is described, and the way in which the wireframes are modified to take into account the complexities of geovisualization.

The results from the wireframes related to the geovisual nature of the application show that the particular wireframes chosen were successful in eliciting subjects' opinions, queries, concerns about limitations, and ideas for improvement, leading to expressions of approval for various aspects of the wireframes and ultimately to the choice of which wireframe to develop to the next stage of prototyping. The key finding is the importance of using real, and not dummy, data for geovisualization, even at this early and low-level stage of prototyping.

The wireframes also succeeded in eliciting material on particular tools, tool components and tool interactions from the subjects that might help shape the next iteration of the proposed application - turning the designs into prototypes.

5.1 INTRODUCTION

RQ4: **How does the nature of geovisualization affect the process of design of geovisualization applications with prospective users? How well do human-centered approaches concerned with design work in an applied geovisualization context, and how might they be changed accordingly?**

In earlier chapters, I have sought to understand potential users of a geovisualization application and elicit their requirements. With prospective users to work with, some idea of what they might want to achieve, and what tasks they might wish to apply it to, these inputs provide the starting point for initial design ideas. However these need to be conditioned by design guidance from the visualization/geovisualization and human-centered traditions. These derive from separate, multiple disciplines. The nature of these varied strands is identified and discussed, in particular the difficulties associated with integrating this body of knowledge into practical design. This chapter approaches the task of initial design and the early stages of communicating these designs to CDR subjects and determines what can be learned about how the nature of geovisualization changes the HC approach employed. The HC method designed "to provide an early approximation to a software idea" (Arnowitz, Arent and Berger, 2007) is the wireframe prototype (wireframes). These "range from the classic sketch on the back of a napkin to full design comprehensives used for documenting the design for programmers." (Arnowitz, Arent and Berger, 2007)

It is appropriate to produce wireframes that are as simple and as easy to comprehend as possible. This is because as well as conveying the nature of possibly novel tools themselves, the wireframe process is also attempting to convey the many possible states of these tools, and the interactions between tools.

Public library subjects have a clear requirement to be able to identify customer segments to market to customers with tailored messages. Before engaging in design work for a new application to meet this need, the human-centered approach of competitor analysis is appropriate, as noted by Maguire (2001) - in this case seeing what geovisualization and indeed other approaches already exist. The sifting of possible, extant, applications is described in detail in section 6.2.2.3 of Chapter 6 and its conclusion militates against designing a geovisualization application from scratch. This chapter therefore focuses on the initial design process for, and the communicating of it to, the LCC CDR team, whose needs are broad and exploratory in nature, and confined to their specialist domain. As Chapter 4 shows, there are difficulties in establishing requirements from the CDR subjects using a template or communicating geovisualization to them using a lecture format. Using a scenario to communicate these subjects' context to geovisualization experts in an attempt to elicit tools and interactions that may be of use is more successful, albeit with caveats.

Prospective users are concerned with the fit of the design to their own needs and their comments when exposed to wireframes reflect that. However, it must be reiterated that designing a geovisualization application is a means to an end in the context of this research that explores the usefulness or otherwise of HC approaches in a geovisualization context. Design is a phase that has a large component that does not involve the subjects. While there is a need for interaction between a geovisualization designer and a developer, much designer effort is solitary and creative. A one-person narrative (autoethnographic) approach (Ellis, 2004) to this portion of the research is appropriate.

In summary, this chapter covers:

- the influence of visualization, geovisualization and human-centered approaches on design
- the process of geovisualization design creation based on an understanding of attempts to establish CDR subjects requirements (described in Chapter 4)
- the process of communicating simple designs to the CDR subjects using wireframes modified for geovisualization
- the results from communicating to CDR subjects, both in terms of how wireframes can be applied to geovisualization applications, and the how the design can be iterated for further development

5.2 METHODS

Case No.	ISO 13407 methods	Population	Sample	Units	Objective	Research Design
7	**Design and early prototyping** (wireframes)	Prospective geovis application users in LCC Research and Planning department	Crime & Disorder Reduction team	CDR team members	Understand CDR subject reactions to different wireframe designs; evaluate wireframing.	(b) Case Study II

Extract from Table 2.2: Design and early prototyping (Research Question 4) - the section of this research showing case study details by type according to Gerring (2004).

The case study schema reproduced above outlines the framework for the research in this chapter. Section 5.2.3 contains findings from autoethnography that does not fit into Gerring's case study framework.

5.2.1 INTRODUCTION TO THE DESIGN PROCESS

It is appropriate, given the limited success in establishing requirements, outlined in Chapter 4, to begin this section with some thinking by design experts on the design process, how visualization designers learn design, and how they report their design thinking.

Whiteside, Bennett and Holtzblatt (1988) believe "The enterprise of…design…cannot be treated as a routine process. Each of us must develop our own expertise, while we build on the work of others. But in this inquiry and in the reduction to practice we should not expect that there are "rules" that will lead unerringly to meeting the goals we set."

Olsen (2002) comments that "you can't research your way to good design, you can't test your way to good design; you can only design your way there." and

> "…designers must realize that regardless of the kind of user involvement one chooses, it does not mean that users will be able to provide upfront, straight answers or requirements on the new system. Users know what they want to achieve at present and, given time, they may have great ideas and visions about other tasks that maybe could be performed in a new system. They can easily express such knowledge and visions in their own domain vocabulary. Nevertheless, users who deliver requirements on demand are rare, and consequently you cannot hope to capture requirements by involving users. Designers are the ones who must transform task and domain knowledge, perhaps delivered in narrative form, into requirements."

Greenberg and Buxton (2008) assert "we should look to other disciplines to consider how they judge design worthiness" and quote examples from architecture and industrial design, where "people develop ideas into artifacts, and where surrounding people are expected to engage in discussion about these artifacts as they are being formed " and that "constructive criticisms and probing demands that designer and criticizers alike develop and share a deep understanding of the design idea and how it interacts within its context of use." Kosara et al (2008) state that "Visualization is in many respects similar to design and art: We know a good visualization when we see it (or run a controlled user study on it), but it's impossible to define constructive rules that tell us how to design an effective visualization. Critiquing can be a useful tool for teaching, developing better techniques, and deeper thinking about visualization."

This raises the issue of how visualization researchers learn design – currently not obviously in the way that Greenberg and Buxton propose. Bertini (2007) makes the point that "Interaction requires dynamics and real demonstrations. Ideally, students should directly "do" the things to learn and criticize…" Kerren, Stasko and Dykes (2008) agree emphasising " 'learning through doing' as opposed to a transmissive approach to learning." Dykes, in Kerren, Stasko and Dykes (2008), comments that "Portfolios or long-term developing group projects that provide opportunities for feedback and critique can be very beneficial ... It should be noted that portfolios are frequently used in the arts where critiquing and redesign are key learning activities."

Without a background in a culture of criticism and redesign, as proposed above, it may be particularly difficult for visualization/geovisualization experts to create effective designs. But this is not well documented– the geovisualization literature on how exactly designs come into being is remarkable silent. As an example, Gahegan (2002) describe GeoVista *Studio* with a section 'The design of *Studio'* in their paper. But this contains no details of the creative process, of the options considered and rejected, of the thinking around the human interaction with the application, and so forth. Instead, *Studio* appears to emerge fully formed, like Athena from the brow of Zeus. By the second sentence of the section. the narrative is already speaking of the "component-oriented software building system" and "visual programming environment". This **absence of a design creation narrative** is common in the visualization literature – for example, the papers announcing the geovisualization applications cdv, Descartes, CommonGIS and GeoDa are similarly silent. I perceive this is a possible blind spot in the work of visualization researchers, who perhaps feel that their route to the summit is less interesting that the view from the top. But both are of service, and I propose that more work is done to explore the detail of creative design in geovisualization. As a response to this perception , this chapter section discusses the process of creating the wireframes for the CDR subjects in some detail. It bears little resemblance to the birth of Athena.

As a starting point, designing applications needs to synthesise the inputs from theory and practice in both the human-centered and the visualization and geovisualization domains with the understanding gained of the subjects and their requirements. These are considered in section 5.2.2.

5.2.2 APPROACH TO DESIGN

Design guidance is available from both geovisualization and human-centered traditions, each of them composite domains, drawing on other fields for expertise as well as their own. From the human-centered tradition:

> "On the machine side, techniques in computer graphics, operating systems, programming languages, and development environments are relevant. On the human side, communication theory, graphic and industrial design disciplines, linguistics, social sciences, cognitive psychology, and human performance are relevant. And, of course, engineering and design methods are relevant." (Hewett et al., 1992)

From the geovisualization tradition: “approaches from visualization in scientific computing (ViSC), cartography, image analysis, information visualization, exploratory data analysis (EDA), and geographic information systems." (MacEachren and Kraak, 2001)

The next two sections are an overview of some of the available design guidance from these two domains.

5.2.2.1 DESIGN GUIDANCE FROM THE HUMAN-CENTERED TRADITION

Patterns

Based on the pioneering work of Alexander, Ishikawa and Silverstein (1977) on a pattern language for towns, building and construction, Dearden and Finlay (2006) suggest a pattern language for human-computer interaction.

Cognitive psychology

GOMS is a well-used model of a user's cognitive structure: "…the user's cognitive structure consists of four components: (1) a set of Goals, (2) a set of Operations, (3) a set of Methods for achieving the goals, and (4) a set of Selection rules for choosing among competing methods for goals. We call a model specified by these components a GOMS model" (Card, Moran and Newell, 1983). John and Kieras (1996) compare and contrast popular variants of the GOMS family.

Sweller (1988) introduces a theory of cognitive overload that provides "guidelines intended to assist in the presentation of information in a manner that encourages learner activities that optimize intellectual performance" (Sweller, van Merrienboer and Paas, 1998). Chandler and Sweller (1992) explore the split-attention effect, when material is presented simultaneously in different positions in the field of view, increasing the cognitive load. This is particularly pertinent to geovisualization situations where combined multiple views are employed. Mayer and Moreno (2003) and Harrower (2007) discuss how to reduce cognitive overload in the contexts of multimedia learning and the use of animated maps, respectively.

Visual attention and the notions of fixation/saliency are important in domains such as geovisualization where eye-brain interaction is crucial, and models of these are considered by Itti, Koch and Niebur (1998). Eye tracking is a technique using to study fixation and saliency, and (Brodersen, Andersen and Weber, 2002) have applied eye tracking techniques to study map perception and design. Cognitive map design is directly relevant to geovisualization and has its genesis in the influential 'The Look of Maps' (Robinson, 1952). Montello (2002) reviews the extensive history of cognitive map-design research.

Human performance

Heuristics like Fitts Law (Fitts, 1992) indicate the relationship between speed, amplitude, and tolerance when humans employ their motor system (such as moving and clicking a mouse in response to an on-screen stimulus).

Design methods

Many text books on human-centered methods have sections on design (particularly interface design), among them Shneiderman (1998), Preece, Rogers and Sharp (2002), Cooper and Reimann (2004), Dix et al (2004). Greenberg and Buxton (2008) emphasise the importance of generating multiple designs in order to get the right design: "Early design demands many idea sketches, reflecting on this multitude of competing ideas, and choosing the one(s) that appear the most promising. The promising idea is then further varied and developed until it can serve as a testable prototype."

5.2.2.2 DESIGN GUIDANCE FROM THE VISUALIZATION TRADITION

Geovisualization has its own contribution to make to the design process both from its cartographic heritage and from neighbouring disciplines such as information visualization.

Prior art and visualization competitions

Clearly, a designer can call upon the collective experience in visualization techniques, tools and interactions provided by other practitioners (see Table 1.1) and of existing visualization applications (see Section 1.1.1).

Competitions such as the InfoVis contest (Plaisant, Fekete and Grinstein, 2008) and VAST Challenge (Plaisant et al., 2008) encourage good design. The 2009 VAST Challenge explicitly requests submissions that describe the process used to arrive at the answer (as well as the 'answer' itself). The work of Fuhrmann and Pike (2005) shows how collaborative design can be achieved using an eDelphi methodology.

Visualization taxonomies

As enumerated in Section 1.1.2, the literature contains a number of taxonomies of information visualization tools and techniques; these taxonomies are useful as assistance in tool selection. An additional example is a taxonomy of temporal techniques (Daassi, Nigay and Fauvet, 2002)

Graphics and exploratory data analysis

There are guidelines in Tufte (1986) for the display of static data graphics, such as maximising data-ink, eliminating chart junk, the use of small multiples. Tukey (1977) gives guidance for data display techniques such as the stem and leaf plot for exploratory data analysis.

Heuristics

Heuristics for visualization include the "Visual Information Seeking Mantra" (Shneiderman, 1996) (and its further development by Craft and Cairns (2005)) and the "Visual Analytics Mantra" (Keim, 2005). The "8 golden rules of interface design" (Shneiderman and Plaisant, 2005) are well known, as is Norman's "seven stage model of interaction" (Norman and Collyer, 2002). There are also long-established rules of composition to guide layout – for example the "rule of thirds" (Smith, 1797). Baldonado, Woodruff and Kuchinsky (2000) propose four design rules for employing multiple views in information visualization: "diversity, complementarity, decomposition and parsimony".

Pattern languages

Visualization also has a literature on representing its components as pattern languages. Examples are for identification and cartographic visualization (MacEachren and Ganter, 1990), for interaction design (Borchers, 2001) and for the design of interfaces (Tidwell, 2005).

Use of design experts

Tory and Moller (2005) and Acevedo et al (2008) have both sought to improve visualizations using external graphic and visual design experts, respectively.

Cartographic tradition

Geovisualization designers can call upon an extensive cartographic tradition of map design and the use of visual variables (Bertin, 1983; Brewer, 2004; Brewer, Hatchard and Harrower, 2003; Cleveland and McGill, 1984; MacEachren, 1994a, 1995; Robinson, 1952). Fuhrmann et al (2005) provide an introduction into methods and research questions on user-centered geovisualization tool design.

This landscape of heritage, practice and guidance from both human-centered and visualization traditions is formidable body of knowledge to synthesise and use to create a practical design. It is difficult to hold in the mind during the design process. In practice, I found I created rough designs by "just doing it", and evaluated and critiqued them against the body of HC and geovisualization knowledge subsequently as a separate, often internal, process.

5.2.2.3 DESIGN INPUTS FROM WORK WITH EXPERTS AND CDR SUBJECTS

The outputs from the process to establish requirements from the CDR subjects (Chapter 4) comprise the 'short list' a few tools: treemaps, glyphs and thematic maps, and the 'guidance to an application designer' from the geovisualization experts:

> "The application should include a map capable of showing crime density. Consider an alternative spatial depiction in the form of a cartogram, if appropriate. Small multiples might be helpful to compare and store insights as data is explored. Consider different ways to symbolise data that appear on what might be a crowded map. Incorporate flexible navigation to permit zooming and panning of the map. Useful ways to show the crime attribute data include tables, histograms (especially for showing time trends), and - when looking to cluster data - parallel coordinate plots. Incorporate ways to aggregate and filter data that allow the complex and hierarchical nature of the data to be explored flexibly. Attribute tools should be linked to spatial tools to provide the benefit of combined multiple views of the data."

Above all, there is the data context of the CDR subjects - the combination of spatial, temporal and crime attribute data that makes up the nature of the exploration space in their domain. The fact that crime attribute data is made available to the CDR subjects in two different forms of aggregation is also pertinent. Being able to combine and to filter/aggregate in terms of space, time and attribute is clearly an important design aspect. One factor that stands out from the context-in-use of the CDR subjects is the limited linking of crime data to external (non-crime) data, suggesting this could be a fruitful area to explore.

5.2.3 INITIAL DESIGNS

This section is autoethnographic in nature, and records the route travelled to create the designs that became wireframes and were exposed to the CDR subjects. It is of necessity in the form of a single-person narrative, and as Sparkes (2000) acknowledges, "the emergence of autoethnography and narratives of self within the social sciences has not been trouble free, and their status as 'proper research' remains problematic." Nevertheless, (Duncan, 2004) provides a useful parallel:

> "the autoethnographic method I employed in the study of my work as a hypermedia designer was the only method that could have answered my research question. I wanted to know how I could improve my design practice...Every day, I had to answer hundreds of questions about the visual and interactive style of the program for which there were no widely accepted standards. Generally, I would rely on my background in graphic design, computer-based presentations, and education to make decisions...In my mind, I played through a constant dialogue of possibilities, experiences, predictions, if-then statements, and learner scenarios to help make the choices necessary"

My starting point for thinking about design was to begin with the nature of the CDR data – the data-centric approach being a characteristic of a number of the geovisualization experts interviewed (see section 4.4). The CDR subjects have two different crime data sets available to them – one of aggregated monthly data and available at census output area (OA) level; the other with full temporal information but spatially limited to town centres and a resolution of $100m^2$.

5.2.3.1 DESIGN 1 – OUTPUT AREA DATA BASED

Thinking first about the OA data, I believed this offered potential for linking with external information, given the wide availability of data based at OA level, not least the 2001 Census - I had familiarity with, and had used, census OA data in the past (Lloyd and Dykes, 2006). I was particularly interested in the potential of emerging work that became the output area classification (OAC) - an 'open' demographic classification at OA level from the 2001 Census (Vickers and Rees, 2007). The CDR team does not have access to commercial demographic databases such as MOSAIC (Experian, 2009) and OAC would open up many possibilities. Since the OA crime data is aggregated by month, the temporal aspect is largely absent and so this could be excluded from consideration when considering the design.

The link between a demographic strand and crime and disorder reduction was made in my mind when I recalled a conference presentation I had attended (Poole and Scott, 2006) that identified MOSAIC demographic classifications with particular characteristics such as high fear of crime and related them spatially to crime patterns. Poole and Scott (2006) describe an useful insight that the MOSAIC category with the highest fear of crime in Exeter lived in housing that lay between pubs & clubs on one hand, and taxi ranks & takeaways on the other, and thus suffered high levels of late night anti-social behaviour.

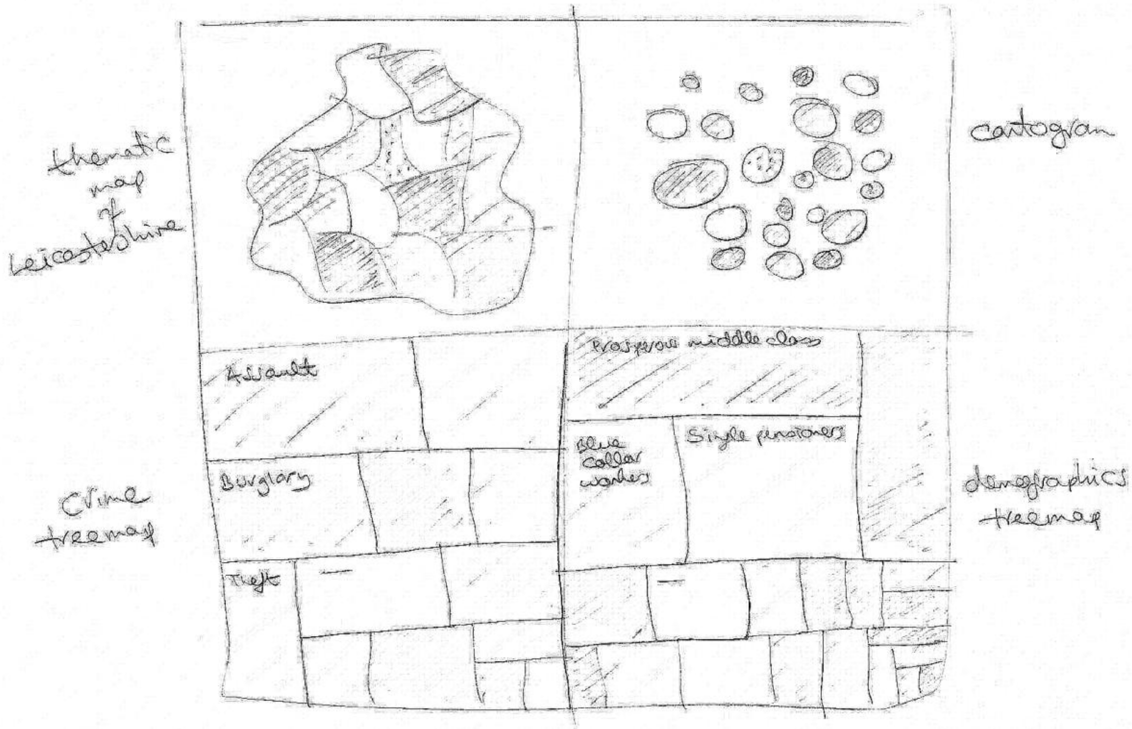

Figure 5.1: Sketch of Output Area initial design (Design 1)

Influenced by the CDR subjects' affinity for thematic maps and treemaps, I conceived of an initial design (a pencil sketch of this (Design 1) is at Figure 5.1) that combined a thematic map of OAs in Leicestershire with two treemaps – one that represented the hierarchical nature of crime data, and another that represented the hierarchical nature of the OAC. I then added a Dorling cartogram as an alternative spatial representation (prompted by the geovisualization expert guidance) to better represent the underlying population. This also balanced the design to create a compact 2 x 2 form. I considered this arrangement would provide the potential for rich exploration between the crime and demographic attributes, in both geographical and social spatial contexts.

5.2.3.2 DESIGN 2 – 100 METRE SQUARE DATA BASED

Considering the 100m squared resolution data, available for town centres, the grid format initially suggested an approach based on a raster model, with manipulation of the underlying data using map algebra to permit modeling. This however is merely the functionality of raster/surface analysis software such as Idrisi (Clark Labs, 2009) or Landserf (Wood, 2009). The availability of full resolution temporal information with this dataset demands its inclusion in the design. Because some of the CDR subjects had an affinity for glyphs, they seemed the obvious starting point to represent the temporal data with 7-sided glyphs for days of the week, 24-sided for hours of the day, and 12-sides ones for months of the year, with glyph arm length proportional to data numbers. While it was known that the CDR subjects were interested in the pattern of crimes such as assault by time of day, it was not known whether they had an interest in weekly or monthly data representations. Because the data was available only for town centres, this made the representation of space problematic. To show town centres in their true relation to each other for the whole of Leicestershire would lead to a sparse map. Consequently I decided that the design should show one urban centre at a time, and chose the town of Loughborough as a focus, both because it has the highest crime rate in Leicestershire (giving the design a 'fair wind') and because its size is 5kms x 5 kms, making the display compact. The design for Wireframe 2 contained a background map (for orientation and navigation), squares of thematic colours (corresponding to the 100m squared grid and aggregations of them), and temporal glyphs overlaying these. Wanting to include crime attributes explicitly, the crime treemap was 'borrowed' from Wireframe 1 to complete the initial design (Design 2) – see Figure 5.2.

5.2.3.3 WIREFRAME DESIGNS AND THEIR LIMITATIONS FOR GEOVISUALIZATION

In order to communicate these design ideas to the CDR subjects, and to receive feedback from them, the most appropriate human-centered approach is that of the **wireframe** prototype.

> "Wireframes range from the classic sketch on the back of a napkin to full design comprehensives used for documenting the design to programmers. An early wireframe is intended to provide an early approximation to a software idea. Regardless of the medium in which it is created, the wireframe has a short lifespan. Its quick production allows experimentation with many different visualizations during the early stages of product design." (Arnowitz, Arent and Berger, 2007)

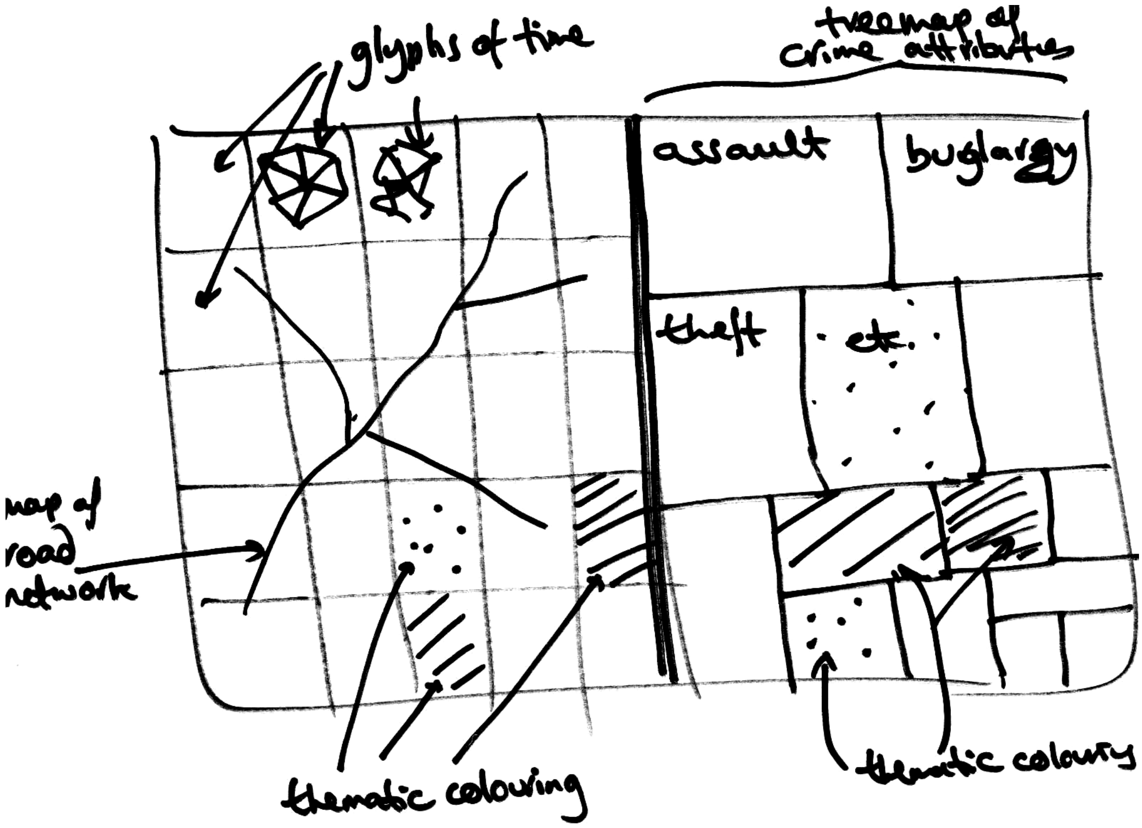

Figure 5.2: Sketch of 100m square initial design (Design 2)

Arnowitz, Arent and Berger (2007) give seven tactical goals that wireframes can serve in the software creation process that include ones relevant to the task in hand: "provide an idea sandbox to play around with different product ideas, functions, and requirements"; "define scope of ensuing design and production work"; and "inform planning of more diligent prototyping methods". They outline their practical benefits and limitations in these areas:

> "Because wireframes are quick and easy to create, the design team can generate many alternative designs or quick variations. Quick sketches lower the costs and reduce the effort of iteration….Wireframe prototypes can also be used to string together several ideas into a task flow...It is important that a wireframe remain focused only on the structure of the design. Save the detailed visual and interaction design for later stages when prototypes need a higher degree of visualization and interactivity."

The last point raises the question of the extent that wireframes are suitable for geovisualization, where layout and structure are incidental to the goal of achieving interactive exploration. Clearly there is a balance to be struck between presenting overly simple sketches (such as shown in Figures 5.1 and 5.2) that convey little beyond a representation of tools and (irrelevant) layout, and stretching the wireframe medium into something approaching a full prototype by including more complex elements, negating its 'preliminary' nature, low creation cost and short lifespan.

The design sketches at Figures 5.1 and 5.2 are overly simple as designs to show to the CDR subjects. Their deficiencies include:

- colour hues are a crucial way to depict variables within the design. They enable discrimination between areas on thematic maps, cartograms and treemaps that reflect different magnitudes. Crude greyscale shading or stipling can only portray this inadequately. In addition, greyscale shading or stipling cannot convey different forms of representation – for example the difference between absolute values and signed chi-statistic (hereafter 'chi-squared') representations.
- the effect of spatial autocorrelation is absent if area colouring/shading or glyph components are randomly generated, and the sketch will lack the power that comes from seeing similar intensity attributes within a clustered spatial area, or similarly shaped glyphs close to each other.
- the sketches do not show subtle interactions that inform the visual exploratory process such as the relationship between the same area on a thematic map and cartogram that are very different in size (but which carry the same colour hue).
- Static, paper representations cannot convey the myriad possible states of the application nor interaction behaviour.

Figure 5.1 and 5.2 are similar in many ways to the sketches produced by the CDR subjects (section 4.5.4). These fail to capture the essence of geovisualization exploration and it was clear that a successful geovisualization wireframe was going to require more than a sketch.

5.2.3.4 ATTEMPTS TO OVERCOME DESIGN DEFICIENCIES

The deficiencies above are all bound to the nature of geovisualization and represent a way in which a human-centered approach (wireframes) needs to be modified. The challenge is to see what can be retained of the nature of wireframes - their ease of creation, their low commitment in terms of creation time, their 'throw away' nature - in a geovisualization context.

To overcome the limited representation of sketches for Design 2, I experimented with an analogue lightbox and transparencies carrying the three spatial layers – background map, thematic colouring and glyphs. The idea was that by changing one layer at a time it would be possible to show a range of different states of the wireframe effectively – absolute and chi-squared colouring; map backgrounds at different scales or as an aerial photograph; glyphs depicting different temporal aggregations.

Figure 5.3 shows the results of a mock-up using a photographic lightbox. This had a number of deficiencies. The different transparent layers were difficult to handle, did not always lie flat and did not enable a smooth transition by changing the transparencies; the transparencies themselves were far from wholly transparent and the lowest layer (the background map in Figure 5.3) was difficult to see; colours on the transparencies appeared either washed out or (as in Figure 5.3) highly saturated; and finally, layers failed to align precisely when printed on two printers (one for colour, the other for grayscale). It is also questionable whether an analogue lightbox actually constituted a wireframe or whether I was engaging in a different form of prototyping. The analogue lightbox idea was dropped.

Figure 5.3: Transparency of background map, thematic colouring and glyphs superimposed using an analogue lightbox (background map ©Crown Copyright/database right 2008. An Ordnance Survey/EDINA supplied service)

I returned to paper to represent the wireframes, deciding to derive components for the wireframes using available software and to assemble them in an application such as Visio or Powerpoint ("…anything from paper and pen to a software program such as PowerPoint or Photoshop can be used for sketching." (Arnowitz, Arent and Berger, 2007)). This proved time-consuming, which is at variance with "quick production" (Arnowitz, Arent and Berger, 2007)). A thematic map of Leicestershire was created in the GIS application ArcView (ESRI, 2009), the associated cartogram with another GIS application MapView (Golden Software Inc, 2009), the treemaps with the Treemapper add-in (Microsoft Research, 2006) to Excel and the glyphs time-consumingly 'hand crafted' in Powerpoint. Screenshots from each application were imported into Microsoft Visio, which provided a 'windows' frame for each component. Visio also provided the tools to create a mock-up of interface components such as temporal filters.

Designs for Wireframe 1 are shown in Figures 5.4 and 5.5. The latter shows the effect of zooming into the cartogram and thematic map, chi-squared bivariate colouring, and a different number of hierarchies shown in the treemaps. Designs for Wireframe 2 are shown in Figures 5.6 and 5.7. The former shows the thematic shading of the grid, and the latter the placement of temporal glyphs. Both Wireframe 2 designs show the treemap as a small inset.

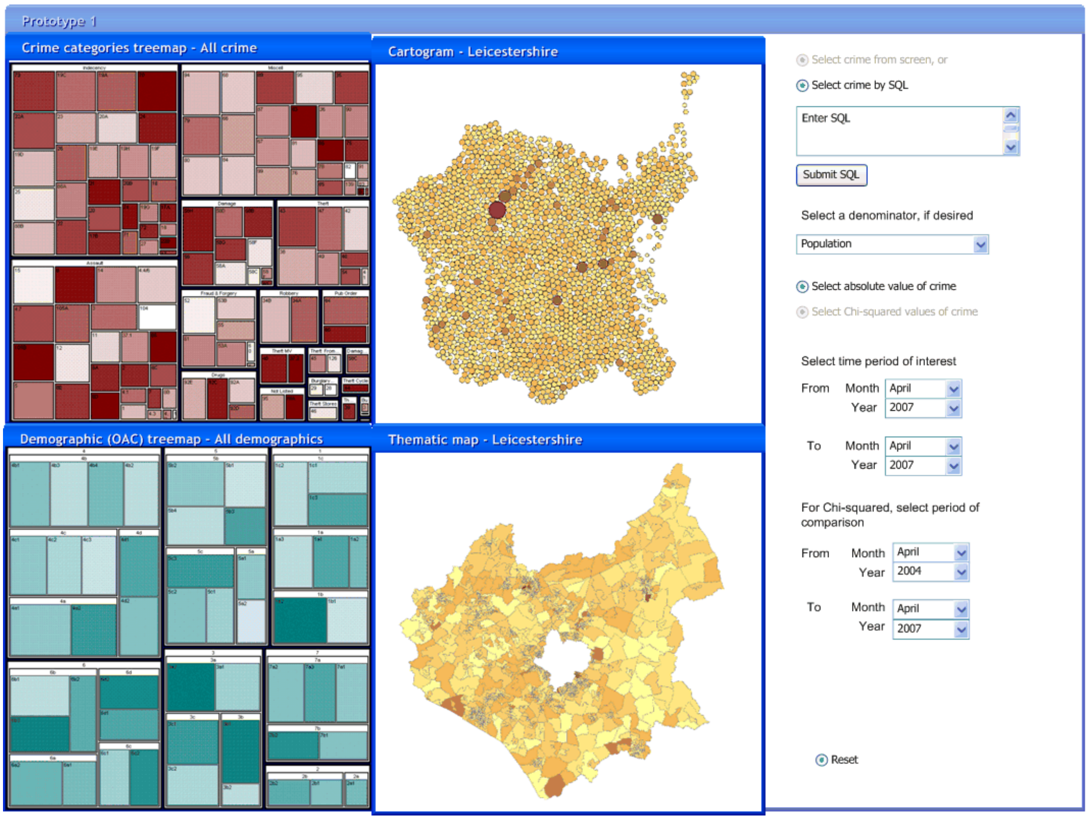

Figure 5.4: Early design for output area wireframe
(map ©Crown Copyright/database right 2008. An Ordnance Survey/EDINA supplied service).

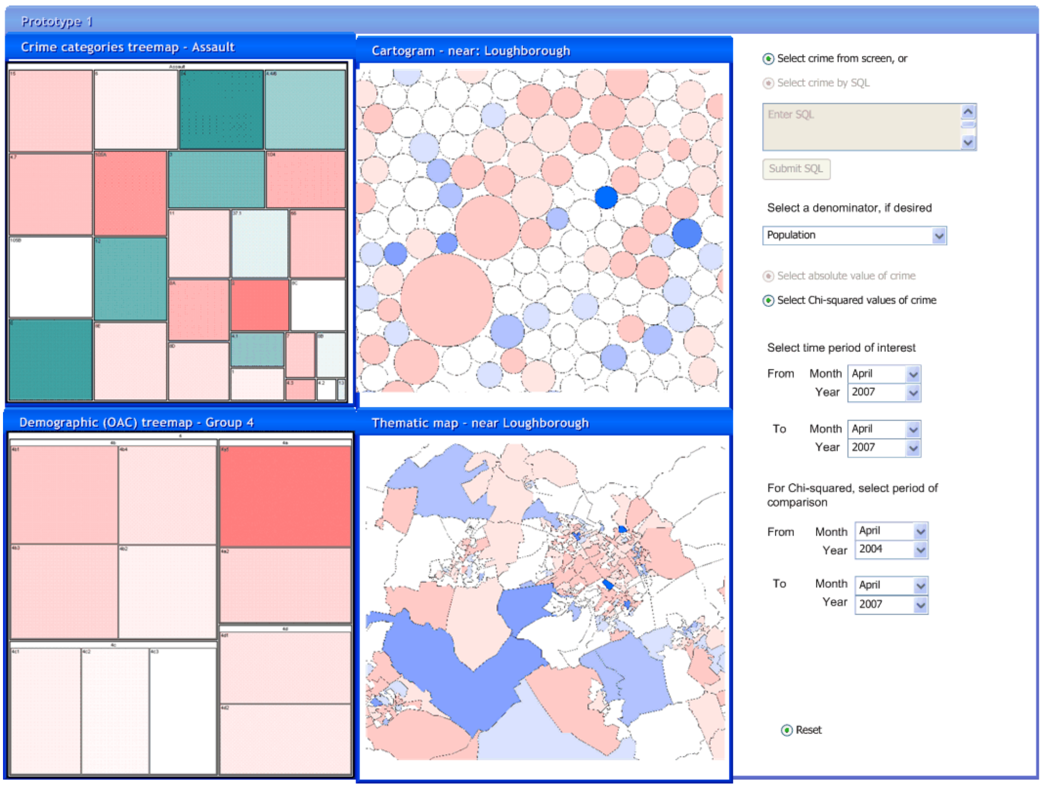

Figure 5.5: Different display of output area wireframe
(map ©Crown Copyright/database right 2008. An Ordnance Survey/EDINA supplied service)

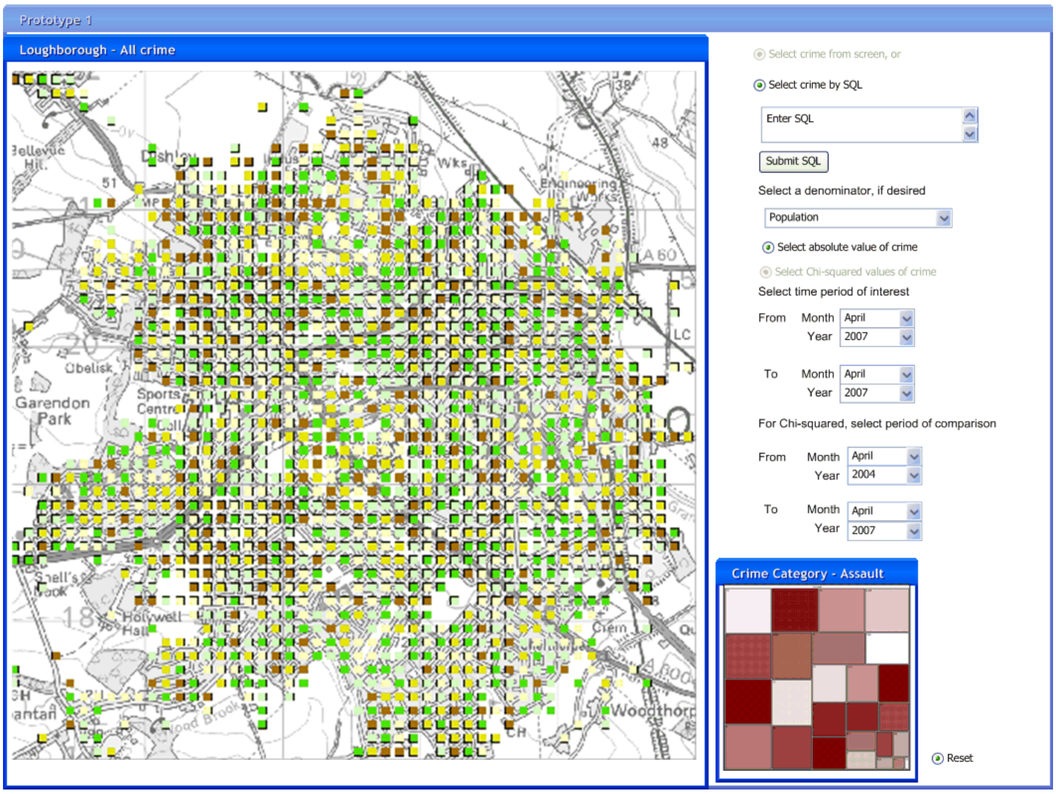

Figure 5.6: Early design for a 100m2 wireframe showing thematic shading and crime treemap (map ©Crown Copyright/database right 2008. An Ordnance Survey/EDINA supplied service)

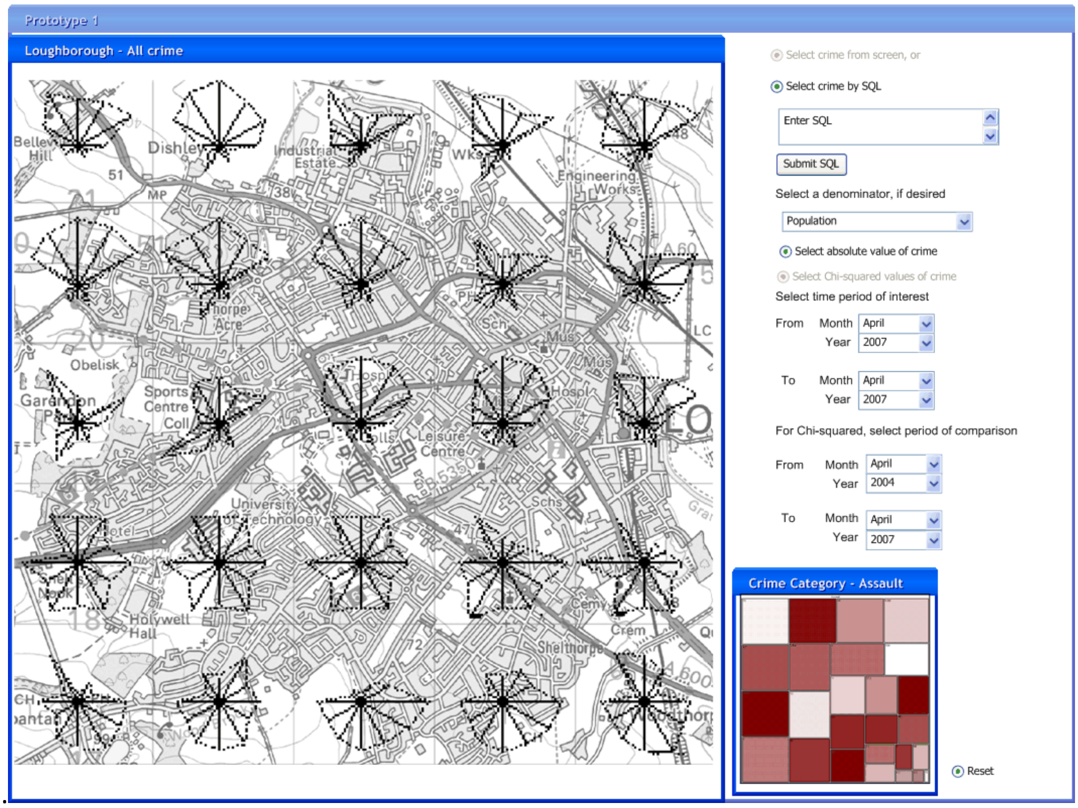

Figure 5.7: Early design for a 100m2 wireframe showing temporal glyphs and crime treemap (map ©Crown Copyright/database right 2008. An Ordnance Survey/EDINA supplied service).

5.2.3.5 CRITIQUE OF INITIAL WIREFRAME DESIGNS

Having created these initial designs for wireframes, I felt the need to move them from the realm of an (autoethnographic) solus designer and subject them to external scrutiny with a geovisualization expert, and sought this as part of the PhD supervision process. The combined comments and criticism on these designs are:

- the designs are explicitly data-led, and were preceded by a month spent understanding, cleaning and manipulating a large body of CDR data. While this approach is pragmatic and one adopted by geovisualization experts, it may be limiting – a superior design might be possible by thinking beyond current data constraints.
- the choice of Loughborough in Wireframe 2 with its 'fair wind' 5 x 5 km area has an insidious influence on design. It is not clear how an initial design would work with a radically differently shaped area. Designs (in the form of on-screen layout) are clearly influenced by the spatial extent of the target area. I conjecture that geovisualization researchers who have dealt with the same spatial datasets for a long period of time may have had their layout designs influenced by them. An example is Jern et al (2007) with their work with GAV using (elongated) Sweden as the basis for design. Others have used a mixture of different spatial extents in reports of their designs. For example, Improvise (Weaver, 2006a) and Geovista Studio (Chen, Guo and MacEachren, 2005) explore the relatively compact spatial extent of continental USA and also the relatively elongated spatial extents of Michigan, Ohio and Pennsylvania, and of Pennsylvania, respectively. That their designs are 'stretched' to accommodate such different spatial extents is not commented upon, neither the limitation that such 'stretching' cannot continue indefinitely to accommodate all spatial extents of likely interest. It is doubtful that any 'one-size' design could cope if the spatial extent of interest was 'the area 10 miles either side of the US-Canadian border', for example.
- it is not clear how Wireframe 2 scales up to county level with the empty areas between towns. Nor is it clear whether navigation would become confused in Wireframe 1 when zooming and panning within the thematic map with no background, and especially within the cartogram. Subjects might need a way to go immediately to areas of particular interest, such as individual districts, perhaps with dedicated buttons to facilitate such selection.
- PowerPoint (at the time of the creation of these designs) had limitations on how it could handle transparency for a 3-layer graphic (although PowerPoint does permit colour selection by RGB). Representations using PowerPoint will therefore not fully

reflect the possibilities for interactions involving changed order or transparency of layers.

- the facility with which Visio constructs neat interface controls is a probable source of distraction to the CDR subjects, who might focus on elements of this mock interface rather than on the geovisualization tools and the possible interactions between them and on the depiction of space and symbolism in the design. In geovisualization, the map *is* the interface. This is a case where the desire to produce a design that is 'convincing' is at odds with the wireframe rasion d'etre of focusing on the essentials of the design and the need to focus on the special aspects of geovisualization.
- the 'finished' look of the wireframe designs is at odds with their preliminary nature. The CDR subjects might be more likely to criticise a rough-looking design than one that appeared to have incorporated a higher degree of commitment from the designer. A parallel effect I noted was an increase in my attachment to the wireframes - as Cooper (1999) notes "After code is written it is very difficult to throw it out. Like writers in love with their prose, programmers tend to have emotional attachments to their algorithms". This is echoed by Rettig (1994): "Developers resist change. They are attached to their work because it was so hard to implement. Spend enough time crafting something and you fall in love with it." The 'throw away' nature of the wireframe has always to be borne in mind.
- Wireframe 2 does not aggregate data within a particular spatial resolution, and there is therefore a risk that decisions could be based on small and inconsequential amounts of data. The design lacks a way to signal this to the prospective user.
- there a question as to whether it sensible to deploy a design wireframe if the components already exist in a working digital form. Specifically, if a treemap application (Treemapper (Microsoft Research, 2006) or TreeMappa (Wood and Dykes, 2008)) is available, it might be better to show this to the CDR subjects loaded with their own data, and ask them to consider the tool as one component of the whole design. However, this would cease to be wireframing and becomes a form of exploratory, collaborative prototyping, such as the patchwork prototyping advocated by Jones, Floyd and Twidale (2007).
- There is an opportunity to increase the usefulness of the Wireframe 2 designs by using additional glyphs superimposed on the treemap to indicate the temporal distribution of crime attributes. However, there is a potential problem with this in that the distribution of same-level crime attributes within the treemap has no spatial

correlation. Subjects, used to the effects of spatial autocorrelation might create hypotheses about similar shaped glyphs that were clustered together, erroneously applying the same reasoning to the treemap glyphs.

- There is no good reason for the size of the crime attribute treemap to be different between the two wireframe designs. In Wireframe 2, the treemap had shrunk to accommodate the (superfluous) mock-interface, and it could be enlarged to the same dimensions as the map – particularly as it could thereby include temporal glyphs.

5.2.3.6 ITERATED WIREFRAME DESIGNS

Considering the above, I produced an iterated design for each wire frame, to:

- recognise pragmatically the data-centric nature of both wireframes. But I made a note that the designs might be reconsidered or 'stretched' at some future time.
- recognise explicitly the limitations of the 'fair wind' Wireframe 2 design, and regarded generalisation as a problem to be solved at a subsequent time.
- incorporate changes to incorporate navigational cues if Wireframe 1 was developed to a prototype but not to incorporate such changes into the next wireframe.
- accept – pragmatically - the limitations of PowerPoint with respect to transparency.
- assemble the next wireframes solely within PowerPoint and eliminate Visio's 'gloss' and the unhelpful mock interface components. In particular, to free individual tool components of any particular 'look and feel' by not connecting them together (except where they were by necessity due to superimposition).
- keep a watchful eye on my attachment to the wireframe designs and emphasise to the CDR subjects that although the wireframes looked professional, there were 'throw away' in nature, and to encourage them to scribble on or amend these wireframes as they saw fit.
- incorporate a way to indicate to the user that decreasing amounts of data are being displayed in Wireframe 2. My solution to this was to successively remove glyphs as the data count reduced to some predetermined level (to be discussed with the CDR subjects) and when even the aggregated count became too small, to suppress the thematic colouring and 'grey out' the relevant square.
- incorporate temporal glyphs in the next iteration of Wireframe 2, deciding that the additional functionality outweighed the risk, if sufficient warning was given to users. A point arising is that as rectangle size decreases for smaller crime attributes, progressively less room is available for a superimposing a glyph on the treemap.

- increase the size of the crime treemap in Wireframe 2 to match the size of the thematic map grid.

To attempt to cope with the problem of showing multiple states of the design in a static format, I decided to create a series of multiples simultaneously on sheets of A3 paper. The idea was to show individual components together - for example different scale background maps, different thematic colouring to reflect absolute and relative values, different sided glyphs, and also sample combinations of states, for example progressive glyph removal and 'greying out'. So that while I was pointing to one particular aspect of the design, the subject would always be aware of the other, simultaneous, possibilities that the design was capable of showing. **This is a deviation from standard wireframe practice occasioned by the complex nature of geovisualization**. Figures 5.8 and 5.9 show the redesigns for Wireframe 1, and Figures 5.10, 5.11 and 5.12 those for Wireframe 2. Figures 5.8 and 5.10 are initial, 'overview' representations of each of the two the designs, whereas Figures 5.9 (Wireframe 1), 5.11 and 5.12 (Wireframe 2) are representations of multiple design components and multiple possible alternate states of the designs.

These formed the basis for individual sessions with the CDR subjects that attempted to see to what extent these geovisualization-amended wireframes generating useful queries, ideas, opinions, and expressions of limitations on the range of tools, interactions and use of data employed. The methodology is described in section 5.2.4 and the results obtained from them in 5.3.

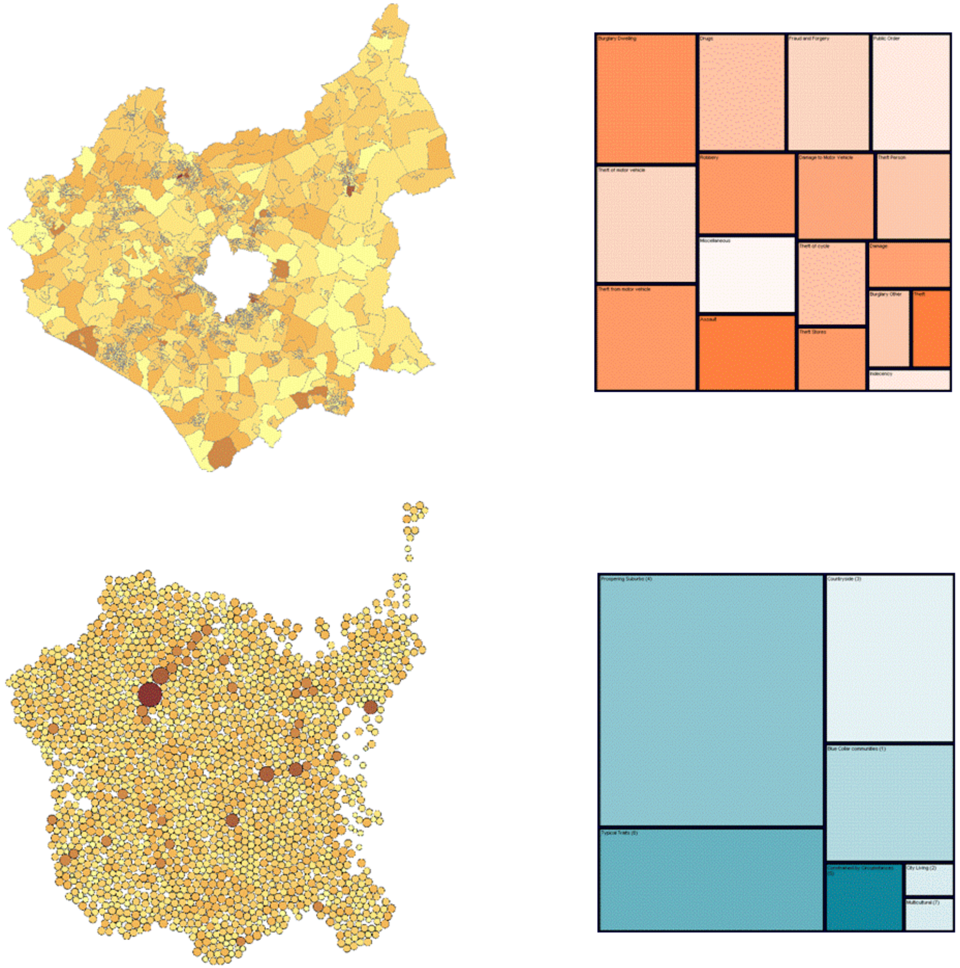

Figure 5.8: Wireframe 1 redesign (1 of 2) comprising thematic map of output areas, cartogram of output areas, crime treemap and demographic treemap
Original is A3; dummy data. (LCC OA map© Crown Copyright/database right 2008. An Ordnance Survey/EDINA supplied service).

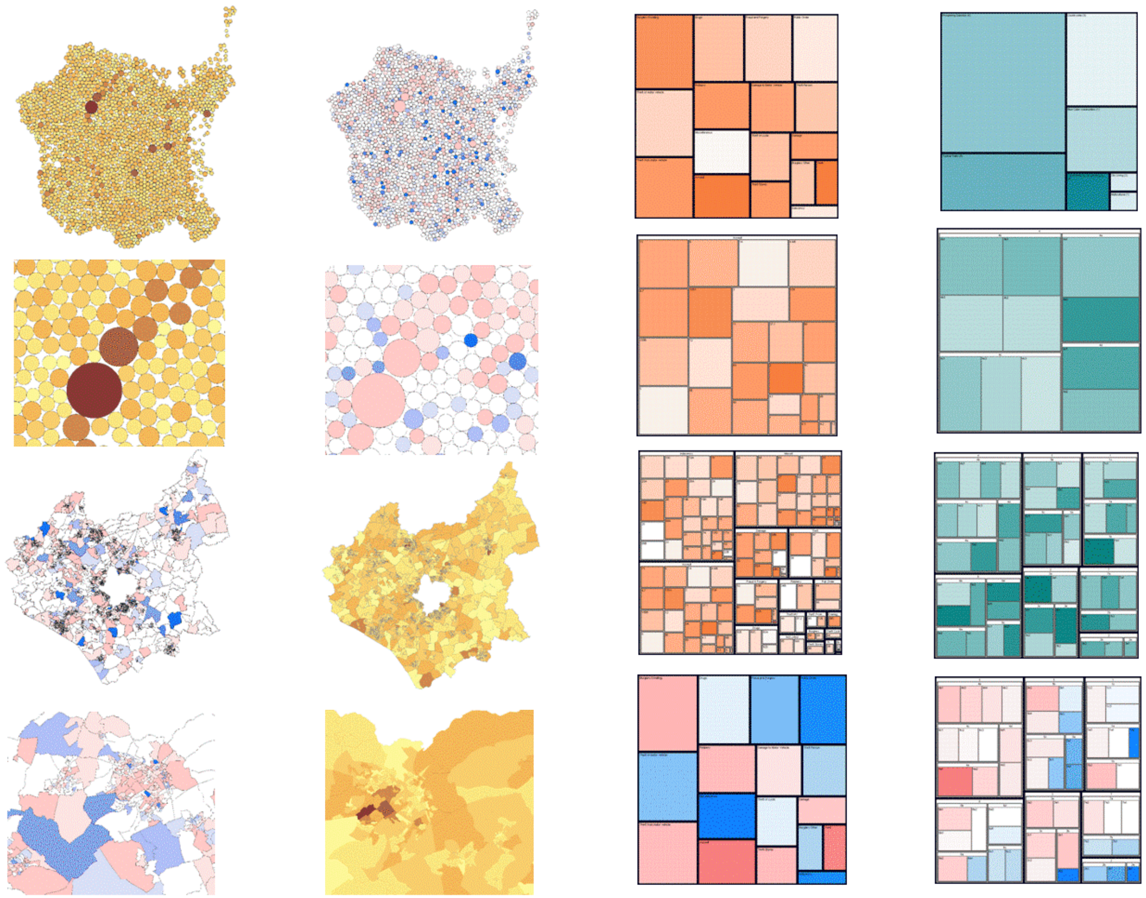

Figure 5.9: Wireframe 1 redesign (2 of 2) showing variants on thematic map and cartogram (zoomed out/in; absolute (yellow-orange-brown)/chi-squared relative shading (pink-white-blue) thematic map of output areas) and treemap variants (crime/demographic treemaps at three different levels (top three treemaps – crime coloured orange shades and demographics blue shades) and with chi-squared relative shading (pink-white-blue). Original is A3; dummy data. (map© Crown Copyright/database right 2008. An Ordnance Survey/EDINA supplied service).

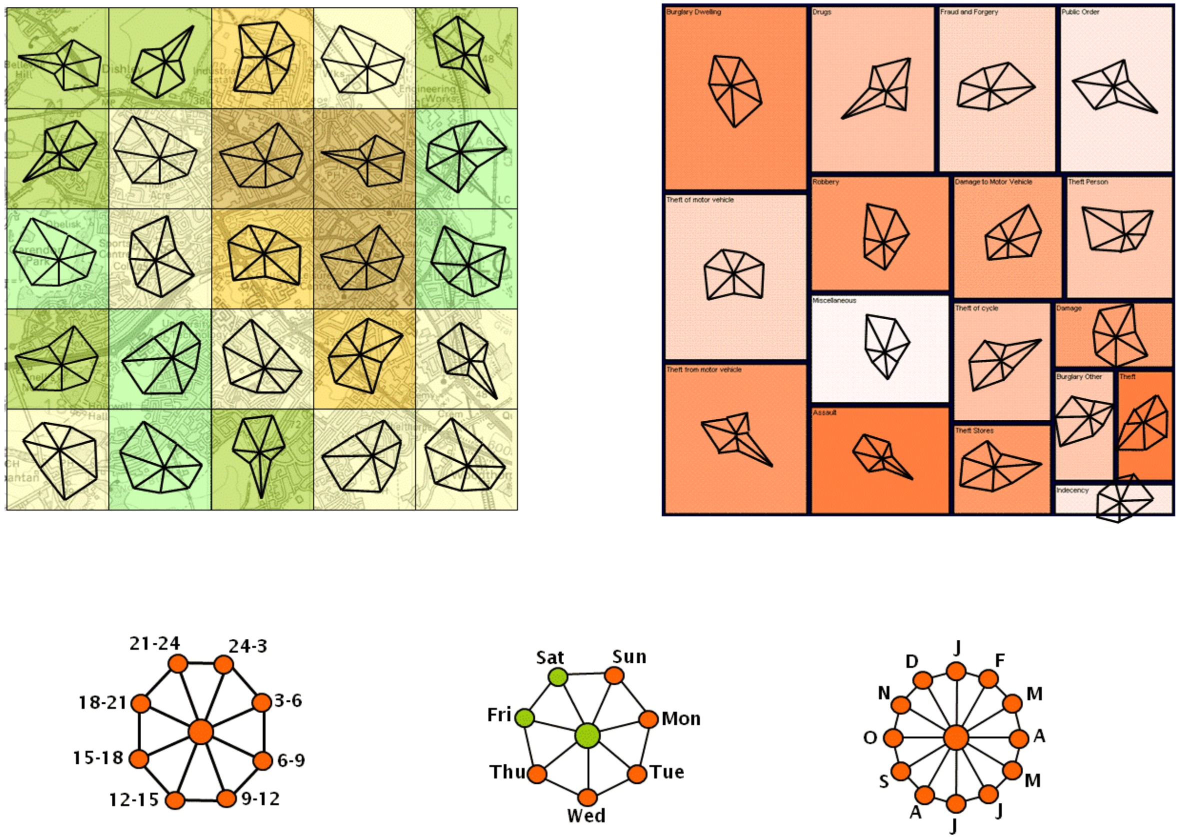

Figure 5.10: Wireframe 2 redesign (1 of 3)

Shows time glyphs for a 1km square superimposed on a thematic maps with a 5x5 kms Loughborough map as background (top left); time glyphs for each crime category superimposed on a treemap of crime categories (top right); time glyphs of 3-hours day segments, days of week and months of the year (bottom, left to right) – the days of the week glyph is in green to indicate that it, and specifically Fridays and Saturdays, have been selected for display. Original is A3; dummy data. (background map© Crown Copyright/database right 2008. An Ordnance Survey/EDINA supplied service).

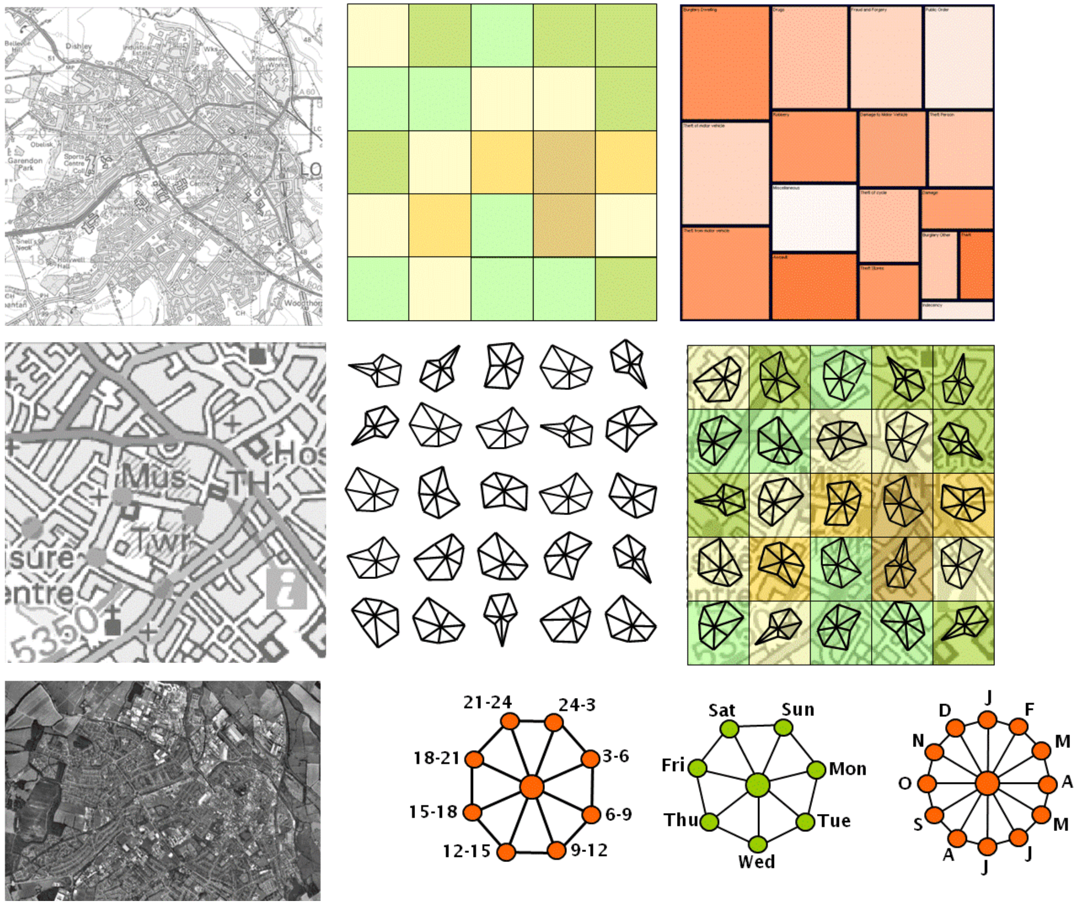

Figure 5.11: Wireframe 2 redesign (2 of 3)

Shows components parts of the wireframe. Possible backgrounds (two map at different scales and an orthophoto (left)); thematic map (top centre); time glyphs (centre); crime treemap (top right); combine time glyphs, thematic map and map background (right centre); and time glyphs for hour segments, days and months *bottom centre & right). Original is A3; dummy data. (background map© Crown Copyright/database right 2008. An Ordnance Survey/EDINA supplied service).

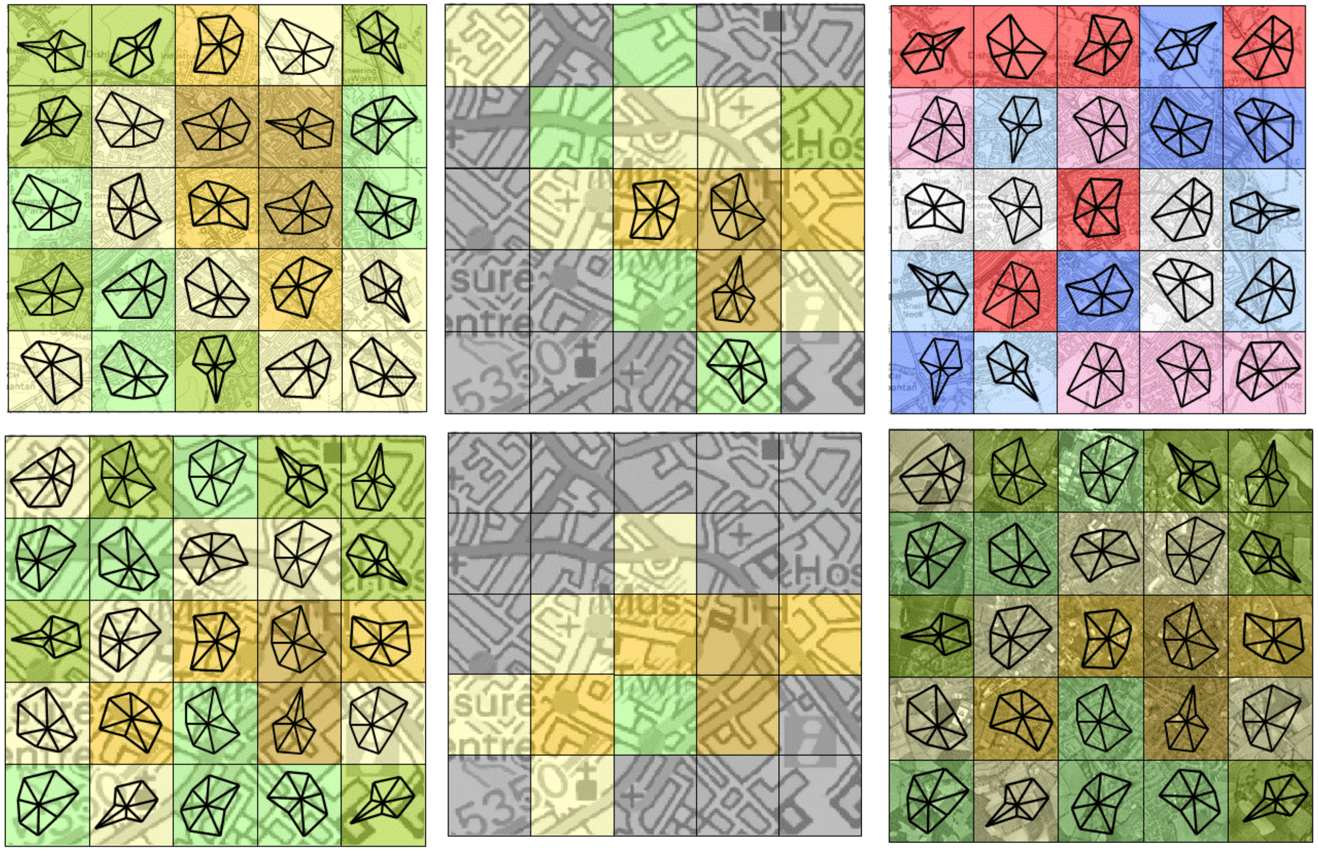

Figure 5.12: Wireframe 2 redesign (3 of 3)
Shows time glyphs and thematic map against a 5x5kms map (top left) and a 1x1kms map (bottom left); the effect of data becoming insufficient – suppression of some time glyphs and thematic map partially 'greyed-our' (top centre) and suppression of all time glyphs and thematic map partially 'greyed-our' (bottom centre); substitution of a chi-squared relative shading for absolute shading (top right); and time glyphs, thematic map over an orthophoto background (bottom right). Original is A3; dummy data. (map© Crown Copyright/database right 2008. Ordnance Survey/EDINA service).

5.2.4 COMMUNICATING WIREFRAME DESIGNS TO CDR SUBJECTS

To explore the CDR subjects' subjective reactions to the wireframes (Tullis, 1998), individual sessions were conducted with the three CDR subjects. These took place at their offices but away from their desks in a secluded area and lasted approximately two hours each. The wireframes' scope, structure, layout and proposed interactions were explained. Subjects were asked to think aloud (van Someren, Barnard and Sandberg, 1994) as they considered the wireframes and their words were recorded, with their consent, for later transcription, coding and analysis. The subjects were initially shown the 'overview' sheet for Wireframe 1, and then the additional representations were added. This process was repeated with the 'overview' and additional representation sheets for Wireframe 2.

The sessions were piloted on R who focused on issues about the use of real data as opposed to dummy data, and the ability to turn off layers such as the background maps. The fact that the data *was* "dummy data" was the cause of a real issue in the pilot session. R had not grasped initially that the data were simulated, and was clearly struggling with the second wireframe. It emerged that he had been attempting to relate the patterns he observed to his knowledge of crime patterns in Loughborough – in particular, the concentration of violent and related crime in the town centre from 11pm – 3am on Fridays and Saturdays. The lack of known patterns in the wireframes had confused him. The 'finished' appearance of the wireframes undoubtedly played a part in this, as sketches would have given better clues as to 'rough and ready' nature of the wireframe and perhaps the status of the underlying data. On reflection, my attempts to make the wireframes more convincing by providing convincing, but nevertheless simulated, thematic colouring, was a contributory factor.

This issue was addressed in the three CDR subject sessions by emphasising very firmly the dummy nature of the representations. The 'provisional' nature of the representations was also stressed and subjects encouraged to draw or scribble on the wireframe sheets if they wished to in order to illustrate ideas, changes and the like. The 'think aloud' protocol (van Someren, Barnard and Sandberg, 1994) was used with pre-generated questions to be used as necessary to prompt user responses about the designs, their relevance and potential. Sessions were audio recorded for later transcription and analysis. At the end of each session, subjects were asked which of the two wireframes was preferred. The aims of the individual sessions were primarily to see to what extent the 'geovisualization-modified' wireframes were able to elicit subjects' engagement in the form of ideas about the design, design criticisms, queries, opinions and expression of approval or of limitation, given the context of previous difficulties in communicating geovisualization possibilities. By using three subjects and two wireframe designs, there is an opportunity to assess whether the elicitation of subject engagement is consistent across wireframes and subjects where appropriate (for example, Wireframe 2 has an explicitly temporal aspect, whereas Wireframe 1 does not), and thus add weight to the evidence.

In addition, the sessions provided the 'normal' functions of a wireframe design, to:

- provide the subjects with an idea of the overview of the designs to convey suggested scope, structure and rough layout
- explain the envisaged possible interactions with the wireframe through multiples of different states of the design
- determine whether the designs met a real CDR team need and to understand better the particular circumstances of possible use.
- provide opportunities to amend the wireframes, generate new ideas and generally improve the designs through the photographic capture of any sketches or amendments to the wireframes, as well as by recording the subjects' comments as a record of the process of ideation around wireframe prototyping
- establish the basis for moving forward with one of the two designs with more complex prototyping approaches

The prompt questions were used only to introduce a line of thinking to the subjects and were not intended to be asked exhaustively of every subject given the exploratory nature of the discussions around the wireframes. The prompt questions related to elements in the design of the wireframes and were intended to probe aspects such as user expectations when interacting with the design, the spatial, temporal and attribute detail needed, and some questions of the design itself relating to symbology, component density, background, and default settings. The list of pre-generated possible prompt questions were:

- What interactions would you want to do here?
- When you clicked on this point/square here, what would you want to happen here?
- What would you expect to happen if you clicked here?
- What kind of spatial detail would you want here (e.g. OAs, SOAs, wards, districts)?
- What kind of display would you like to see once it zoomed in to this level?
- Would information at this level of detail be useful to you? What would you use it for?

- What kind of time band aggregation should the glyphs have – when to start/stop?
- Can you get useful information from colours? The glyphs?
- Which periodicity glyph is of most interest? Slightest interest?
- What temporal periods would you want to look at – numerator and denominator?
- When should "Saturday" and "Sunday" actually be (should the 'day' start at midnight, 3am, 6am?)?
- Is the 5 x 5 matrix the right kind of number of boxes/glyphs to show? Would fewer/more be better?
- Is having a photo underneath better than having a map, or vice versa? Or would both be useful but for different things?
- Apart from the map or photo would anything else be useful to show in the background? (Prompt if not mentioned: location of pubs, taxi ranks, takeaways, petrol stations, places of entertainment, car parks etc)
- On the treemaps, would you prefer to see the top level to start with and then drill down, or see the whole hierarchy right from the start?

A coding scheme was designed to separate out two basic kinds of information, although the details emerged from closer consideration of the data. The first major coding category is that relating to the interaction of the subjects with the wireframes (in order to determine the effectiveness of the 'geovisualization-modified' approach) – their opinions, ideas, queries, expressions of the wireframes' limitations, and expressions of approval. The second major coding category categories subject commentary related to specific tools (thematic map, cartogram, glyphs, treemaps), to the underlying data (spatial, temporal, crime attribute, demographics) and to interactions (zooming, navigating, selecting, comparing, obtaining details on demand). Subject comments were allocated to multiple categories as appropriate. The coding scheme is shown in the form of a network diagram in Figure 5.13 – this construct is not merely a useful graphic, but reflects a means to select, filter and aggregate codes in a powerful way using qualitative data analysis software (Muhr, 2004).

The analysis of the data was straightforward. Firstly, a count of the number of instances of the code categories and code sub-categories provides a comparison by subject and by wireframe to spot major differences, similarities and any outliers. Secondly, the count information was used to focus attention on the subject think aloud comments to provide richer, contextual data about the subjects' interactions with the wireframes.

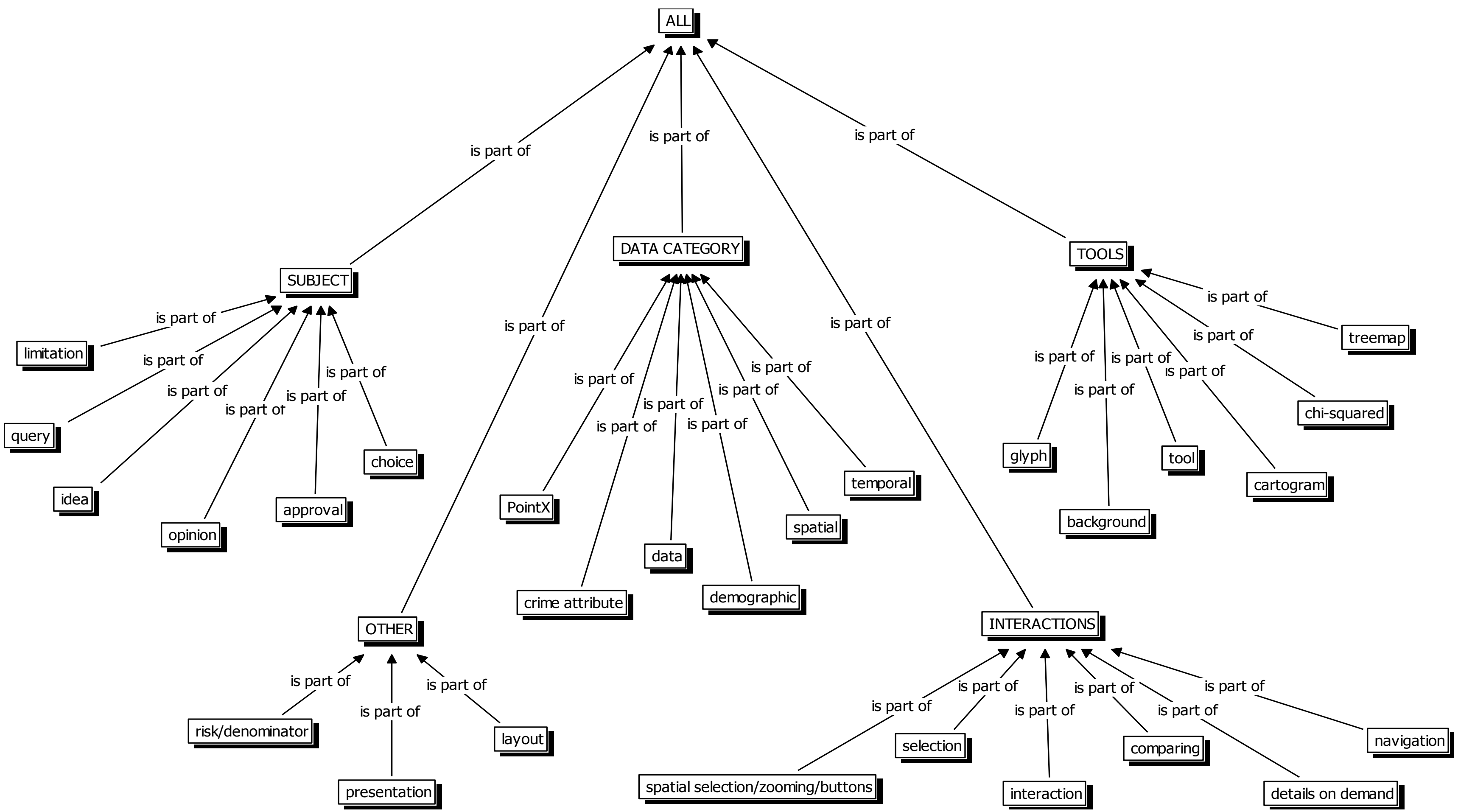

Figure 5.13: Network diagram showing the coding scheme for the analysis of the Wireframe 1 and 2 interviews with CDR subjects

This concludes the methodology section which has considered the design process, the influences on that from theory and practice, both from human-centered approaches and from visualization; the input from working with geovisualization experts and the CDR subjects; the production of earlier designs; a critique of design deficiencies and an assessment of their applicability in a geovisualization context; their transformation into wireframe designs and the methodology of communicating them to the CDR subjects. Section 5.3 outlines the results from the last of these.

5.3 RESULTS

These results correspond to case number 7 on Table 2.2 (an extract of which is at the start of this chapter). This section details the results from communicating the wireframe designs to the CDR subjects. Table 5.1 shows the count of text blocks associated with the interaction of the subjects with the wireframes ('subjects' in Figure 5.13) – the issue of interest to this research. Also shown in Table 5.2 are tools, interactions, data ('data category' in Figure 5.13) and other, by code and sub-code categories that assist in the organisation and presentation of the data. The same text block can appear under multiple sub-codes, and in practice, the vast majority of unique text blocks appear in the 'subjects' category. Table 5.1 shows the CDR subject's broad response to the wireframes – 17 queries about the wireframes, 25 opinions voiced about them, 25 ideas generated during the sessions examining and discussing the wireframes, 14 instances of limitations in the wireframes, and 19 expressions of approval (note that some text blocks are coded under multiple sub-codes).

SUBJECT	subject	wireframe 1	wireframe 2	subject total
approval	C1	3	4	7
	C2	3	4	7
	C3	1	4	5
	Total	*7*	*12*	*19*
idea	C1	5	5	10
	C2	2	6	8
	C3	2	5	7
	Total	*9*	*16*	*25*
limitation	C1	0	5	5
	C2	2	3	5
	C3	2	2	4
	Total	*4*	*10*	*14*
opinion	C1	1	5	6
	C2	2	8	10
	C3	4	5	9
	Total	*7*	*18*	*25*
query	C1	0	0	0
	C2	6	4	10
	C3	4	3	7
	Total	*10*	*7*	*17*
	Grand Total	**37**	**63**	**100**

Table 5.1: Count of text blocks for 'subject' sub-codes for CDR subjects C1, C2 and C3, for Wireframes 1 and 2 The same text block can appear under multiple sub-categories

INTERACTIONS	subject	wireframe 1	wireframe 2
comparing	C1	1	3
	C2	1	0
	C3	0	0
details-on-demand	C1	0	0
	C2	1	0
	C3	1	0
interaction	C1	1	0
	C2	0	0
	C3	1	0
navigation	C1	0	2
	C2	1	0
	C3	1	1
selection	C1	1	3
	C2	2	2
	C3	2	0
spatial selection, zooming, buttons	C1	0	1
	C2	2	0
	C3	2	0

DATA CATEGORY	subject	wireframe 1	wireframe 2
crime attribute	C1	0	1
	C2	0	1
	C3	3	1
data	C1	1	3
	C2	4	2
	C3	2	3
demographic	C1	1	0
	C2	1	0
	C3	0	0
PointX	C1	0	0
	C2	0	1
	C3	0	1
spatial	C1	0	1
	C2	1	1
	C3	0	2
temporal	C1	0	4
	C2	1	1
	C3	0	3

TOOLS	subject	wireframe 1	wireframe 2
background	C1	0	0
	C2	0	1
	C3	0	2
cartogram	C1	2	0
	C2	3	0
	C3	0	0
chi-squared	C1	1	1
	C2	0	0
	C3	1	0
glyph	C1	0	1
	C2	0	2
	C3	0	3
tool	C1	1	1
	C2	0	0
	C3	0	1
treemap	C1	1	0
	C2	1	1
	C3	2	0

OTHER	subject	wireframe 1	wireframe 2
risk/ denominator	C1	1	0
	C2	1	0
	C3	1	0
layout	C1	0	0
	C2	0	1
	C3	0	0
presentation	C1	0	0
	C2	1	0
	C3	0	2

Table 5.2: Count of text blocks for different codes within interaction, tools, data and 'other' main categories for CDR subjects C1, C2 and C3, for Wireframes 1 and 2. The same text block can appear under multiple sub-categories

The distribution between subjects appears relatively equal – 28 responses by C1, 40 by C2 and 32 by C3. The main difference between the subjects is the absence of queries by C1. This is possibly due to C1's style when presented with a novel concept of pausing and thinking deeply about what had just been communicated, rather than asking for repetition, restatement or clarification.

Significant difference lies in the total number of interactions prompted by Wireframe 1 (37) and Wireframe 2 (63). Queries are higher for Wireframe 1 (10) compared to Wireframe 2 (7), but for all other forms of interaction (approval, idea, limitation and opinion), Wireframe 2 consistently produces about double the number of Wireframe 1. This may be due to either the greater complexity of Wireframe 2, or the fact that all subjects were asked about Wireframe 2 after Wireframe 1.

Based on these simple counts, there is good evidence that the wireframe sessions have proved effective at generating feedback from the CDR subjects, and in a fairly consistent way. But the real quality of this feedback is shown in examining the subjects' words in detail, by wireframe.

5.3.1 INTERACTION OF SUBJECTS WITH WIREFRAME 1

5.3.1.1 SUBJECT OPINIONS

Subject opinions on Wireframe 1 are a mixed, but wide-ranging, collection – concerns about data selection and aggregation, an expression of confidence to handle spatial selection by attribute, the usefulness or not of cartograms at the scale of OAs, the relative merits of zoom versus pre-selection buttons to explore districts, and the difficulty of standardising on a level of hierarchy for crime attributes to display given dependency on a particular crime.

> *"I am querying the cartogram at output area level…what is that going to contribute..."(C1)*
>
> *"[speaking about options for ways to access different geographies including SQL querying] …but to be honest though, that [SQL commands] would be quite simplistic. I mean, I think I could do searches… to draw out a geography." (C2)*
>
> *"[speaking about ways to select and aggregate crimes] You are not talking about predetermined ways of cutting, are you?...because it is all very blurred as to what they incorporate into what definition. And different districts might see it in a different way." (C2)*
>
> *"[speaking about crime attribute hierarchy detail] You find some crime hierarchies are better than others… for assault you've got a hell of a lot, but with burglary it is a lot more limited. But I do go into these. If there is something that catches my eye, about that particular area, then I will go and extract the crimes out of it, and get it at this very detailed level and then I will see what I can do with it, if I can put groups together. But we have not got a formal structure from which to create groups below this top level. But it would be useful to be able to do that, particularly with the violent crime, where we always end up grouping them into things like arson, harassment and threats, common assault..., on the basis of seriousness." (C3)*
>
> *"[speaking about spatial selection of a district] No, I think [zoom]… because if it is on the border, then the geography is kind of irrelevant in some ways. If you are around here [points at map] then you are on the border of two districts maybe...I should think the [CDR] partnership will be just as interested in what is happening over the border if influences their district and helps explain what the problem was." (C3)*

5.3.1.2 SUBJECT IDEAS

Wireframe 1 generates a fair number of ideas from the CDR subjects relevant to the wireframe and some others as well. Examples of the former are different ways to aggregate crimes and define and areas, and ways in which interaction between tools might work. Examples of the latter is the use of glyphs to facilitate area comparison, using treemaps to explore fear of crime questionnaire data, and reporting the results of exploration using the wireframe application.

> *"[speaking about attribute selection] could you have something which looked at different ways of categorising it as well? For example, there are a standard set of classifications, which you could use, then you could also have an option to do something different. Say, like… 'all acquisitive crime' to be grouped together." (C1)*

> *"[on being asked if there were other ways to display data in treemap] Racial - definitely…. thinking about it, "crime against property" as against " crime against the person"… you've got things like theft from person, things like assault and violent crime. [Also] where the government sets a strict guideline, in terms of 'we are monitoring the level of this crime nationally, at local authority level.' – 'these are the crimes we want you to get your figures on'… you would be creating a picking list, I suppose, from these..user defined." (C3)*

> *" it would be useful if we could have a number of other defined areas that we chose. Like "the Shelthorpe Estate" in Loughborough. If you sit in CDRP meetings, they talk about particular areas like that… or likewise "the neighbourhood management priority areas that are a specific part of the Melton Mowbray town centre", for example. And they have teams of people working in those areas it would be really useful for them to be able to say " this is what is happening in the county; this is what is happening in Melton; this is my area; this is the other area" and to be able to go through those different things, and [ask] "why are we having more of a problem with criminal damage to vehicles, whereas actually, compared to the rest of the county, things are [quieter?]" (C1)*

> *" say something has made one [crime type] stand out… what if I want to throw it back, and maybe say 'now it is showing me a place that I am interested in, if I select that place, is it going to rejig this [the treemap] to say ' this is the profile of this place'? (C3)*

> *"[speaking about boundaries] The thing about [police] beats is that they change them at will. The boundaries are poorly digitised…[…]…The police say "wards mean nothing to us", and everyone else would say "beats mean nothing to us". But there is some coming together, in a sense in that people will say "what is happening in the Melton town centre?" and by and large, however they define that, if we can show them and say "this is the area we're talking about"… so I think it would be useful to have a number of different user-defined areas, in that sense." (C1)*

> *" I am wondering about the glyph stuff, I kind of mentioned... is there something we can usefully contribute in terms of… of being able to say to community safety officers, for example, "actually, this problem that you've got at Foxton Locks at Market Harborough is very similar to this problem at Beacon Hill in Charwood", or whatever? They are two beauty spots, and [the issue] is vehicle crime." (C1)*

"[speaking about extending the treemap to current work] that was going to be my next question: say I had questionnaire data - we have fear of crime in four categories - and I had it cut by a certain variable, could I use this? (C2)

" …the reporting side of it - how will this translate into paper, in terms of sending this out? Or is this entirely relative to doing analysis in here? (C2)

5.3.1.3 SUBJECT QUERIES

Subjects C2 and C3 ask questions about the wireframe freely with a preponderance about the data, its manipulation and display.

"[speaking about crime/demographics approach] are you saying this is fixed in stone, in terms of you will be using this instead of Mosaic or [one of the other demographic systems like ACORN]…? We could slot anything in there?" (C2)

C2: "so for continuous data, so you are saying you would have to manually categorise it?"
David Lloyd: "Yes. But in doing that you're throwing data away… there are more ways of showing continuously varying data."

"[discussing the need for aggregating areas] we do get requests for different geographical areas that can be parish up to a man made area… so to be able to dictate that geography, a little bit more would be [useful]… creating a cartograms for each, is that [possible]?" (C2)

C3:"I am confused re the size of the boxes in the treemap."
[David Lloyd explains size relates to long-term five-year average]
C3: "Right. Ok… so you aren't considering two aspects of each crime within that treemap?"
DLL: "size is long-term trend; colour is…"
C3: "…the short-term."

"Can I ask - with that [map], because each crime has its own range, would that be standardised in some way? (C3)

5.3.1.4 SUBJECT EXPRESSIONS OF WIREFRAME LIMITATIONS

Subject C1 does not raise any issues of limitation with this wireframe (although does with Wireframe 2), but C2 and C3 do. The topics are the constraints on easy temporal exploration, the need for a legend and/or a details-on-demand feature, and data selection limitations.

C2: " the main areas that we would work to in a project would be to look at a time and date, and you are saying that I could literally feed into there any set of dates and times?
David Lloyd: " this allows you, at the start, to insert a time period that you are interested in. And if it is a chi-square, to pick another time period, to compare it with. In order to change the time frame, you would have to go all the way back and change it from the start."

"I assume there is a key [a legend] here into what these interpret into…" (C2)

"This is where all the tools that you come across fall down. They do all the nice bit at the end, but ultimately if you cannot select the subset of information that you want…" (C3)

"I take it there would be some kind of key to the level, or is the colour purely indicative of a general level? The thing being, if you were looking into it, and you pick an area, you want to know how many crimes [are there]" (C3)

5.3.1.5 SUBJECT EXPRESSIONS OF APPROVAL WITH WIREFRAME

All three CDR subjects express approval for the wireframe or aspects of it. Good spatial selection features in three out of four major comments, while C1 likes the flexibility of the hierarchical treemap tool [Section 4.5.3 shows that C1 has good recall of treemaps and speaks positively about them].

"[speaking about crime treemap] yes. I like that. I like the idea that you could have "all" showing, but that you could have… for example, using assault as an example there, that you could look at it and be able to see it as one square like this, as being assault. You know, that you could pick it out, but within that, there are sub-categories, but it stands out fairly well… so assault is about a quarter, or whatever [of all crime?] and then you could click on that and zoom into assault specifically. And then you get back from there. And then have a look at, vehicle crime or whatever… or whatever that is. I like that." (C1)

" [speaking about selection possibilities] yeah. I think that will be brilliant. I think the thing about being able to say "let's look at Charnwood" and then it changes to that is really good… (C1)

"[speaking about spatial selection] in terms of using the two together, I think that is quite useful. Obviously the idea is to highlight areas that are proportionate rather than a little pinprick there and being lost. So, I follow that -- that is great, that is fine. And we are using more and more of those too in conjunction with the reporting side of it. So, that is great." (C2)

"so could you actually select a group of [OAs]? ..sounds good… " (C3)

5.3.2 INTERACTION OF SUBJECTS WITH WIREFRAME 2

Overall, Wireframe 2 attracts more commentary from the three CDR subjects in almost all areas, compared to Wireframe 1. This may reflect the common order of presentation (Wireframe 1 followed by Wireframe 2) and hence greater subject familiarity by the time they encountered Wireframe 2, or possibly because Wireframe 2 has more potential to elicit creative thinking from the subjects.

5.3.2.1 SUBJECT OPINIONS

Topics considered include the choice of map background, the compromises of superimposing temporal glyphs on the crime treemap, the desirability of absolute/relative thematic maps, and reflections of the overall balance between the elements of the design.

"[speaking about map background] I usually use two layers this one (1:50,000), and another with street names on (Streetmap)." (C2)

" [asked about the the glyph extending beyond the boundaries of the treemap square it is in] I know it doesn't look pretty but if you changed it might be interpreted as something else. And you can't change the proportionality of it because then you're not showing proportions correctly" (C2)

"[Talking about alternative thematic map representations] you need both .[absolute and chi-squared]" (C2)

" I prefer this [the glyphs]. It's simple. It is easy to understand it. Because you have got colour as your crime, your shape is time, and it is two different things. If you introduce the colour on the time aspect as well, then I don't think you would be able to show it, would you? The differences in your colours for your crime would affect how the colours [on the underlying thematic map]…" (C3)

5.3.2.2 SUBJECT IDEAS

Wireframe 2 generates a great many ideas from the CDR subjects. C1 is prompted by the use of a 5 x 5 grid to consider whether their 25 'priority neighbourhoods' might not be displayed and compared as a series of insets instead of spatially continuous Loughborough – a creative notion that could take the design into another direction. C1 and C2 both extend the temporal glyph idea to selecting through multiple temporal filters – again something not considered originally (there is of course the issue of filtering down so far that the amount of data left is too small to be meaningful). C1 sees the design as one that could be used to explore the effect of the timing of public holidays, and its flexibility in toggling layers on and off useful to identify locations. C2 expresses a desire to introduce statistical measures to supplement visual insights, and also considers whether the design could help explore crimes that were linked. C3 responds to concern about excessive filtering with a suggestion involving temporal aggregation, showing a keen sense of filtering-aggregating trade-off. C3 extends the use of toggling off layers (seen by me as a way to reduce clutter) as a way to unbias prior thinking about which geographic areas are of interest. C3 also investigates whether treemaps could be extended to lower spatial aggregations such as districts while retaining their structure, and considers how the output from exploration could be used for presentation – a theme that has been observed before with these subjects. In summary, there is a richness about the subjects' ideas provoked by the wireframes that stands in stark contrast to their response to the attempt to communicate geovisualization to them with a lecture.

"The other thing that it makes me think about it, the 5 x 5, … and what we are kind of doing here, I think there might be something like 25 priority neighbourhood areas… but they are all over the place…geographically, they wouldn't all be together…but..I am just thinking about it as an idea because what we would then be able to say…'this is Loughborough, and these are all parts of Loughborough, and this grid relates directly to what is below it.'…it might be interesting to be able to look at all the neighbourhood priorities together, in terms

of what their glyphs are like…using the data to compare neighbourhood priorities…" [spatial arrangement] *(C1)*

" could you combine these? We could say ' let's look at Friday and Saturday, between 9pm and 3am in December…" [multiple temporal filtering]" (C1)

" the idea is that…we have got a year's data and we are interested in the night-time economy and crime related to it…[…]… but then you can look at Friday and Saturday, look at different months, and maybe, for example, in some of the summer months you might have more of a peak on a Sunday, because there are two bank holidays in the month, and Christmas and New Year fall on a Tuesday or whatever, and how that affects different months. But having at ability, to combine and look at the different areas, I think is potentially useful." (C1)

"[speaking about turning off the background map] I think that would be really useful… when you look at this, you might want to say ' what is in this square?' again and just be able to quickly go down into it. You know, lose the glyph, lose the [thematic shading] thing and just look at it [the map] or down to a photograph. And then go back just as easily…" (C1)

"The other thing I have been thinking about is the more qualitative side of it…. the information that we have, and what we know about these areas, and whether we could tie that in some way to an application? So we would have the main drag in Loughborough, and some way of being able to update some kind of [data about it] - like the idea behind police beats… I mean that they fill out their beat profile and update it and that is a tremendously useful source of information. They won't share it with anyone, partly because it says things like 'Mr Adams at number 19 thinks that Mr Smith at number 24 is dealing crack cocaine' or whatever. But other stuff, like this pub has just had its licence extended to a certain time, or this is thought to be happening here, all this has closed down and there's a new taxi rank here; this is part of this scheme, or whatever - to have that kind of [information] when you are looking at these [visualisations] and trying to make sense of what we have here… how we link that to some more explanatory kind of [data]…" (C1)

David Lloyd: "Different glyphs could show hours of the day; 12-sided for months of the year…"
C2: "Or a combination…?"

"Is there any way of looking at patterns of similarity in terms of measures of similarity?... I'd prefer figures underneath it to give me a correlation- it is a trust thing. The patterns are fine, in terms of similarity of those are such and such. But when you come to draw the similarity of these, they are harder to do….because it may be that one particular crime happens predominantly on a Sunday afternoon throughout the whole area. The volumes are going to be different, the colours are going to be different, other times might be the same." (C2)

" say you want to select those two together… that's not going to work, is it?... It is just that crimes don't happen in isolation, and I would say that on a Saturday night, certain crimes tend to happen in conjunction with each other. And it is whether you do them all individually, or whether there is something that can be done up front." (C2)

David Lloyd: "the problem is that the numbers start to go really low." [concerned about excessive filtering]

C3: "unless you did it over a number of years" [responding by suggesting temporal aggregation]

David Lloyd: " we could let you to simply toggle off any of the layers… to switch off the navigation [map] say, if you know you're in the centre of Leicester…"
C3: "you would probably do that to start with, to unbias your judgement as to where places were…"

"what I was thinking was if we had one of these [treemaps] for all of the crime in Leicestershire, could you have one for each district, and each district remaining in the same place? We could build one of those quite easily by building the shape in MapInfo… the importance is in how it all links together. And how you interpret it." (C3)

"If you have used all these tools to identify a particular time, a particular spatial pattern, or a particular area that you're interested in, then ultimately, you are going to want to deliver that information to a third party… so would we be able to maybe turn these off in order to make the map in a report ultimately? And will we be able to use these ultimately to identify the area of interest, and this would provide all of the context to describe it? We are just trying to make our job easier, ultimately." (C3)

5.3.2.3 SUBJECT QUERIES

Unsurprisingly, subject queries are predominantly ones of clarification, seeking to understand the scope of the wireframe.

"[asking about temporal selection via glyph interface] so you are filtering out by the former, and actually dictating the glyph by the final choice? (C2)

[querying the state of the wireframe] that is "all crime" at the moment?

" but I am assuming that these [glyph arms] are like percentages, or something?" (C2)

" the only issue I would have with that, I suppose, is that your Saturday, I take it, finishes at midnight?

"[querying glyph sizing]: so, what it is that scale, there, proportion of, or…? …[David Lloyd explains]…so the glyph is not representative of the amount of crime at all - it is an indicator of distribution by time?" (C3)

" so what if you want to look of crime in a higher resolution? This is almost 100 m, isn't it? [David Lloyd explains it is 200m resolution]…oh right. Okay. So it would still do the glyphs [at 100 m resolution] and cancel much of the data…[if insufficient]?" (C3)

5.3.2.4 SUBJECT EXPRESSIONS OF WIREFRAME LIMITATIONS

In spite of being warned about the use of dummy data, C1 states clearly how the lack of real data hampers his connection with the data through the design. C2 also speaks about liking the glyphs better if the data were real. This is evidence that the use of real data is essential for a geovisualization wireframe at the earliest stages of communicating designs to potential users. C1 sees the possibility to use glyphs to compare related crime attributes as well as in a temporal role, and seems to be aware of the difficulties in their use to describe discrete attributes. Other issues concern overplotting/data density, use of inappropriate background maps, and the stability of treemaps.

> ***" one of the things that is perhaps hampering my limited imagination is because it is random data…I immediately try and make sense of it, kind of thing. 'Ah, theft from vehicles is very similar to…oh no it isn't - it's just random'. I immediately start to try to interpret it instead of just trying to leave it at the level of [an example]… (C1)***

> *"I am not sure about the glyphs here [on the treemap]. I think it would be interesting to see if the pattern of public order offences is very similar to assault…[but] you [would be] using the glyphs in two different ways." (C1)*

> *"I suppose then you would then have the issue that you would have three different shapes here, with the same thematic colour behind. And you will be guessing 'oh well, this one probably applies to about there'…" (C1)*

> *"[talking about the data on the wireframes not being real]…then I might like these [glyphs] a little bit better. If you are saying that the pattern is not just in the colour it's going to be in the glyphs, it would probably make [a difference]." (C2)*

> *"you can get a better background map that [1:50k]…OS Streetmap is better than that." (C3)*

> *"[speaking of the order of treemaps and their stability] [there is] the difficulty of showing multiples in that the same crime doesn't necessarily appear in the same place. You can't compare." (C3)*

5.3.2.5 SUBJECT EXPRESSIONS OF APPROVAL WITH WIREFRAME

As with Wireframe 1, all three CDR subjects express approval of the wireframe or aspects of it. Aspects of Wireframe 2 that are commented on include the breath of the tools and representations, the opportunity for absolute and relative mapping, the flexibility to examine crime at a range of temporal resolutions, the additional exploration capabilities generally. A notable quotation is from C2 who, **as a result of seeing the glyphs in the wireframe, changes from hating them when presented them in a lecture** (see section 4.5) **to liking them**.

> *"It is certainly useful to look at the data in these two ways, to look at it spatially and to look at it thematically [by crime attribute]." (C1)*

> *"I like the coloured square idea* [signed chi-statistic]*; I like the idea of comparison between…expected and observed. What we thought would happen and what actually happened is particularly interesting. I'm thinking about how we kind of do that 'expected'" (C1)*

> *" But this is a brilliant idea, I think, of looking from the level of three hour slots up to, like, a year, and being able to do that in one place, it would be a fantastically useful thing to do. Combined with the spatial element as well…" (C1)*

"to be honest - now you have reminded my memory - I looked at those [the glyphs] a fortnight ago [at the geovisualisation lecture] and I hated them…I really hated them. I thought they were inelegant, and I thought that they were hard to interpret. But…I mean, [now] I really do like it, because you've got the interaction of it here, I do like it. But it is kind of… you are trusting in your eye, like you are saying." (C2)

" being able to explore it up to a point where you have used all of these great tools to do that, and ultimately to be able to deliver that to somebody else and say. "We have done all of this exploration, and we have done it in a way that we have never done it before…" … but ultimately, you'll be telling them something and to be able to describe it in a way…Yeah. I like that." (C3)

"[speaking about placing glyphs on crime attribute treemap]: well, not necessarily on each one. I like the fact that this is the whole crime, and it is beyond a histogram…you have got more stability in your data, and you can break it down further…" (C3)

" we have seen the parallel plot thing working before…[on a application produced by a previous student]… it's good because this is something completely different." (C3)

5.3.3 ADDITIONAL INFORMATION ON ITERATION OF WIREFRAME DESIGNS

There are a number of comments made by the CDR subject categorised solely under the "tools", "interactions", "data" or "other" that do not also appear in the "Subject" category (although the majority do). These carry additional information that could be useful input to the designer to iterate the wireframes to a more sophisticated level of prototyping, or which provides additional understanding of the subjects and their context. The most relevant are outlined here.

5.3.3.1 WIREFRAME 1 COMMENTS

"[speaking about choice of denominator for cartograms] If you looked at assault in city centres, then a lot of it is movement into the city centre where most people do not live. So it is a moving target on most of these [crime categories] And we are aware of that problem between the team, but outside of that, It could be problematic." (C2)

"[speaking about choice of crime hierarchy to use] we tend to use these ones now. I think we found that the police were using these [CIS Group] and it seemed more consistent to take that approach…" (C3)

"[speaking about chi-squared thematic map representations "I think the…difficult thing… I imagine, from a crime point of view, is what the "expected" is... and then looking at that against the "observed". C3 has used this sort of mapping before looking at change in terms of the blues and reds. So we would have something like [a normal thematic map] saying 'this is what the crime figures are' and one then 'here is one which shows change'. So these are always going to show Loughborough as having high crime, but this one might, interestingly, showed that Birstall, which never normally features on anyone's radar, has gone up 300%. Which might only be 10 offences, but for the people of Birstall is significant." (C1)

"[speaking about the level of detail required on the demographics [OAC system]] I am not sure about those [50-odd sub-groups]… it is the sort of thing that people think they want, but I'm not sure what they actually do with it …" (C1)

"[speaking about cartograms and the choice of denominator] Theft of vehicles is a funny one really…it's interesting in that … a lot of the work that is done around vehicle crime focuses on safer car parks and things like that. And when you do any hot spots then car parks come up. But two thirds of all vehicle crime is on the street. So there is more vehicle crime which doesn't take place in car parks, but because it clusters around car parks, we address that as the issue." (C1)

5.3.3.2 WIREFRAME 2 COMMENTS

"[speaking about being clear about the meaning of 'last 12 months'] I think you would have to be 'the last data I have' is the cut-off, because we would not be entirely confident when we updated…" (C1)

"[speaking about the display of other data like pub locations on the map] I was going to say 'places of interest' [would be useful to show]. [Data is limited but], do we want to show it - yes we do!….[especially for] assault on a Saturday night." (C2)

5.3.3.3 CHOICE OF WIREFRAME TO DEVELOP FURTHER

At the end of the individual sessions with the CDR subjects on the wireframes, they were asked which of the wireframes designs should be selected to take to the next stage of development. C1 and C3 chose Wireframe 2; C2 chose Wireframe 1. The split is indicative that both wireframes had merit. Comments from the two subjects that gave a commentary on their choice are:

"…from my own personal point of view… we have MapInfo [GIS] etc. etc., but I have never become totally au fait with using it. So in terms of usefulness for me, I would have to say the maps [Wireframe 1], because I would probably be tempted to do the time series in SPSS. Out of the two. Because I'm au fait with SPSS. That's the tool for me, for that reason…" (C2)

" I am more interested in this [Wireframe 2] because I have no idea how… without being rude about your capabilities to do these things, I can do cartograms, I can do thematic maps, and I can do that kind of exploration myself. Though it would take me a hell of a long time, I can do that myself. Whereas with this, you are getting onto things where I couldn't do it. And I think it looks at the data in a way I haven't looked at it before, using things I haven't done before. So that is why I would probably choose this" (C3)

Both of the subjects giving reasons provide ones that are rooted in their context and current tool use, illustrating the situated nature of such choices for geovisualization design.

Wireframe 2 was the design chosen for further development based on the majority decision.

5.3.4 DISCUSSION OF WIREFRAME DESIGN SESSIONS

The sessions with the subjects started slowly – all subjects were initially quiet as the concepts of the wireframes were explained. It was clearly hard for them at first to grasp the concepts involved and grapple with novel tools [the treemap and temporal glyphs] explained in detail. If the session had not included a sizeable section of time where the subjects were prompted to speak at length on the wireframes, then I might have concluded - erroneously - that the wireframes were not being communicated to the subjects. **The amount of time the subjects had to absorb the ideas and to comment on and query them was clearly a decisive factor in their ability to engage effectively with the wireframes.**

The richness of the subjects' eventual deep engagement with the wireframe designs and their success in generating ideas, improvement suggestions, criticism, approval and general opinion is clear from the extracts in sections 5.3.1 – 5.3.3. The breadth and quality of idea generation is particularly noteworthy with both wireframes, although Wireframe 2 generates twice as many ideas than Wireframe 1. This may be because the order of presentation was the same (Wireframe 1 followed by Wireframe 2) for all subjects meaning they would have gained greater familiarity with the novel tools and their possible states by the time they encountered Wireframe 2, or it may genuinely reflect the potential in that wireframe to extract creative thinking from the subjects. In retrospect, the wireframe designs should have been introduced in a different order for one (randomly selected) subject of the three subjects.

The subjects' verbal engagement is in contrast to their physical engagement with the wireframes. Despite encouragement to write on the wireframes and the provision of pencils 'for scribbling', none of the subjects availed themselves of the facility.

The wireframe sessions were flexible enough for a wide range of topics to emerge, including a few not directly related to an individual wireframe design such as C1's thoughts on the use of textual information held by the police, and C2's exploration of the possibility of applying treemaps to fear of crime questionnaire results. The most significant results from the work with the CDR subjects with wireframes of a geovisualization application design are **the crucial importance of real data** and **the situated nature of design** in working with these crime domain experts.

After the sessions were completed, I produced a more developed design for Wireframe 2 to consolidate many of the comments and suggestions made by the CDR subjects – Figure 5.14. This is not intended to be the design of an actual interface, merely its components. It includes time icons for sequential selection with green and red dots to indicate selection state, "Friday plus Saturday" time and "racial" attribute selection boxes, and a text display panel showing what is selected (reflecting the 'command history' pattern suggested by Tidwell (2005)). While Figure 5.14 can be criticised for being overly 'finished' and for reflecting too much attachment to the design than is inappropriate at this stage in the development, it serves both as a record of the wireframing process and a prompt for further design work.

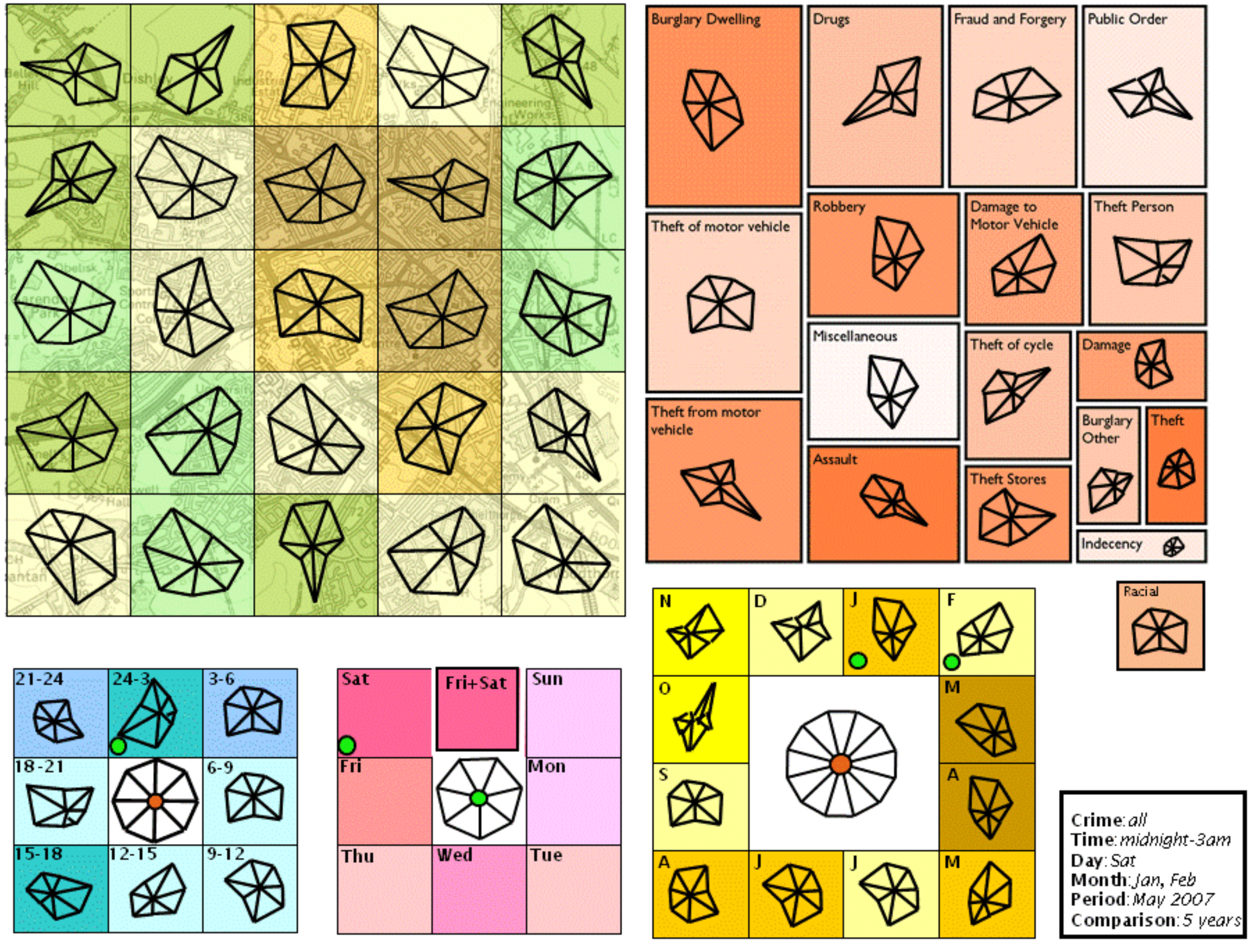

Figure 5.14: Iterated design for wireframe 2 with time icons used for selection "Friday plus Saturday" time and "racial" attribute selection boxes; display panel showing selection status with red and green dots (Background map© Crown Copyright/database right 2008. An Ordnance Survey/EDINA supplied service).

5.4 CONCLUSIONS

Research question 4 asks: **RQ4: How well do human-centered approaches concerned with design work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of design of geovisualization applications with prospective users?**

RQ4.1: How well do human-centered approaches concerned with design work in an applied geovisualization context?

The breadth and multi-disciplinary nature of both the human-centred and geovisualization domains makes design guidance hard to assimilate and to apply (section 5.2.2)

There is **strong evidence** that the CDR subjects interacted effectively with the wireframes given the quantitative (section 5.3) and qualitative (sections 5.3.1 – 5.3.3) evidence of their verbal commentaries containing approving remarks, ideas, limitations identified, opinions about, and queries on, the wireframes.

Another indicator of how CDR subjects could interact with the wireframes might be the extent to which they made amendments, additional sketches, or the like when encouraged to do so on the paper wireframes, as this is indicative of the 'preliminary' and 'throw away' nature of wireframe prototypes. While subjects were encouraged to do this verbally and by the provision of pencils 'for scribbling', there is **good evidence** (section 5.3.4) that they did not interact with the wireframes in this way as not one of them wrote anything on the wireframes at any time during the sessions. This indicates that perhaps the wireframes were 'too finished' and their production values discouraged emendation, or perhaps the CDR team may be similar to some of the geovisualization experts of section 4.4 who prefer to communicate their ideas exclusively verbally, and not like those who prefer to sketch their ideas. Certainly, the CDR subjects found the sketching exercise they undertook themselves (section 4.5.4) difficult and fatiguing.

When choosing which wireframe design they wished to pursue, two of the CDR subjects gave reasons for their choices that indicated how strongly their choices were rooted in their context and current tool use. Hence there is **good evidence** that geovisualization design is situated firmly in potential user context of use and data in context (see section 5.3.3.3).

Wireframe 2 generated twice as many ideas from the CDR subjects as Wireframe 1. While this could be a learning effect (Wireframe 2 sessions followed Wireframe 1 sessions), some other aspects of Wireframe 2 may account for this large difference. These could be that it:

- employed a means of exploring data temporally using a novel tool in the form of the time glyphs
- enabled exploration of a wider range of data, spatially, temporally and by crime attribute
- integrated tools for space, time and attribute more densely by superimposing these elements within a strong spatial framework

These are all plausible factors that contribute a number of different, confounding aspects. It would be possible to conceive of experiments that could tease out which individual factors – such as data density, strong spatiality, inclusion of novel tools, inclusion of temporal data - are more important in eliciting engagement and response from domain experts. **I commend** this work for future researchers to pursue.

RQ4.2: How might human-centered approaches concerned with design in an applied geovisualization context be changed?

I found it necessary to modify the wireframe design concept as outlined from the typical human-centred approach to create a 'geovisualization-modified' wireframe design, comprising a typical state for a design in an initial wireframe on a large sheet of paper, supplemented by adding additional sheets containing stand-alone multiples of tool components and of possible tool states.

I commend this 'geovisualization-modified' wireframe design approach to other researchers. However**, I caution** that the 'finished' look of such adapted wireframes may be an inhibiting factor in getting subjects to fully critique designs, evidenced by the reluctance of the CDR subjects to draw/scribble on the wireframe prototype (section 5.3.4). Consequently, additional effort should be expended with subjects to emphasise the provisional and 'throw away' nature of the wireframes.

However, the need for real data in a geovisualization context leads to contradictions in some of the characteristics of wireframes. Real data wireframes take longer to produce than simulated data wireframes, contradicting their 'quick production' nature. Longer production times contradict their 'throw away' and 'unfinished' natures. A wireframe with higher production values may mislead a subject as to its 'finished' state and discourage criticism and interaction. Such a wireframe may lead to a greater degree of attachment in the designer, who may be reluctant to discard it. Clearly, a 'geovisualization-modified' wireframe is different from its unmodified cousin. Yet for all of those differences, there is copious **strong evidence** from many parts of section 5.3 that it nevertheless succeeds in eliciting a rich body of information, of creativity and of understanding, from a group of subjects who have not engaged substantially with the geovisualization possibilities they have been exposed to up to this point in the geovisualization lecture session. Wireframes *do* work in a geovisualization context. However, **I commend that** more work is done in other domains with other assemblages of tools to refine 'geovisualization-modified' wireframes and determine what works well, and what does not.

It is questionable whether the success of the sessions is wholly due to the changes made to the wireframes to reflect the nature of geovisualization. It is likely that a large part is down to the nature of wireframes in general. From the subjects' point of view, they had a small numbers of tools and their possible states explained to them in an interactive, and hopefully supportive, environment. The context of use was their own (crime and disorder reduction), the setting was a familiar spatial area (Loughborough) and they were afforded a long period of time (nearly two hours) to understand and comment. This 'wireframe experience' is a distinct contrast to the 'geovisualization lecture' approach to communication (section 4.2.3) where the same subjects had a very short time to understand an individual tool or interaction, and the context was more abstract. **Some evidence** of the importance of longer exposure to geovisualization within a context that is domain-specific comes from subject C2's complete change of mind on the use of glyphs between the lecture and the wireframe sessions (section 5.3.2.5):

> *"to be honest - now you have reminded my memory - I looked at those [the glyphs] a fortnight ago [at the geovisualisation lecture] and I hated them…I really hated them. I thought they were inelegant, and I thought that they were hard to interpret. But…I mean, [now] I really do like it, because you've got the interaction of it here, I do like it." (C2)*

The comparative success of 'geovisualization-modified' wireframes with subjects suggests that some form of focus on specific tools in the form of early designs and envisaged interactions may be appropriate even earlier in the process of engagement with domain experts – in the requirements phase - given the general failure of the methods used to elicit geovisualization requirements (templating, and a lecture on geovisualization) in this research (see Chapter 4).

By extension, the success of 'geovisualization-modified' wireframes bodes well for other collaborative and artefact-rich processes such as different forms of prototyping, which are explored in Chapter 6.

RQ4.3: How does the nature of geovisualization affect the process of design of geovisualization applications with prospective users?

Consideration of the process of creating an outline design for a geovisualization application (section 5.2.3) leads me to conclude that It would be advantageous to the visualization community if application designers were to expose more of the process that led to the final design to help the learning of others. **I commend** this course of action to them.

Good evidence from section 5.3.4 states that CDR subjects took time to listen to and to understand the tools and their possibilities within each of the wireframes before commenting freely about them. **I recommend** that wireframe sessions with prospective users of an eventual application be of sufficient length to overcome the initial novelty and complexity of geovisualization tools and possible tool states, and permit subjects to query, engage, ideate and criticise the design fully.

Good evidence from two CDR subjects (section 5.3.2.4) reveals the crucial importance of using real data. I found that geovisualization wireframes need to represent the spatial correlation inherent in real data to subjects, who otherwise experience confusion, are puzzled by the absence of known patterns in the data, and as a consequence do not engage well with designs if they are presented with dummy data, as this important quote shows:

> *" one of the things that is perhaps hampering my limited imagination is because it is random data…I immediately try and make sense of it, kind of thing. 'Ah, theft from vehicles is very similar to…oh no it isn't - it's just random'. I immediately start to try to interpret it instead of just trying to leave it at the level of [an example]… (C1)*

It is not clear from this current research whether data has to be the subjects' own real data, or simply real data from the domain in general (for example crime data from another part of the UK). But it is clear it must be real data. Only real data carries the subtle but important spatial correlation artefacts of the First Law of Geography (Tobler, 1970) that these subjects expect to find in thematic maps of real data, and, by extension, the spatial patterns they expect to see that reflect temporal correlations in the glyphs of real data.

A **key finding** is therefore that the use of real user data is important to attract user engagement in geovisualization wireframe prototyping and **I strongly recommend** that researchers use real and not dummy data in their interactions with subjects from the earliest possible point. This implies gaining access to subject data as close to the beginning of the relationship between geovisualization designers and domain experts (see also section 3.5.3).

The striking difference in response from subjects between the geovisualization lecture (section 4.5) and the wireframing raises the question of which factors are responsible. For example, whether it is because the wireframes had more detail, less abstraction, more spatiality or presented fewer but more relevant images to subjects. **I commend** this as **useful work for future researchers to pursue**.

5.5 DISCUSSION

The nature of visualization adds a further layer of complexity to the existing plethora of design guidance from the human-centred tradition (like visualization, a composite domain). Geovisualization adds yet another layer of complexity from its own composite nature and inheritance from the cartographic tradition. This is summarised in section 5.2.2. While this design guidance corpus is extensive, its very breadth and multi-disciplinary nature makes it difficult to assimilate and apply effectively by a solus designer. Working in a group with mutual criticism as advanced by (Greenberg and Buxton, 2008) may be a better approach. An alternative may be to improve visualizations through the use of graphic and visual design experts, as suggested by Tory and Moller (2005) and Acevedo et al (2008) but at as early a stage as possible in their development.

In section 5.2.3, I outline in detail the approach I adopte to create the initial designs for an application for the CDR subjects based, as far as possible, on the HC and (geo)visualization design corpus with the input from the geovisualization experts (section 4.4) and the CDR subjects' elicited requirements (section 4.5). The starting point for two designs is led by the particular structures of the available CDR subjects' data. After an abortive design attempt using an analogue lightbox, I create two initial sketch designs on paper, and after critiquing them, iterate both. These second stage designs images of geovisualization tools are created from a range of existing applications such as a GIS, a treemap programme and PowerPoint and assembled in Visio, taking a significant time to construct. These designs are again critiqued, and iterated into wireframe prototypes.

In this next iteration, I make modifications to the wireframe design concept to account for the particular complex nature of geovisualization. These consist of a typical state for a design in an initial wireframe on an A3 sheet of paper, with additional sheets containing stand-alone multiples of tool components and of tool states. These are shown to subjects. These 'geovisualization-modified' wireframes prove successful in communicating an understanding of the design to the CDR subjects as strongly evidenced by the richness of the subjects' subsequent engagement with the wireframes and their narratives of generating ideas, suggesting improvements, criticism, approval and general opinions of the designs (section 5.3). However, subjects needed time to absorb the novelty of the geovisualization wireframes and to make their opinions, queries, opinions and ideas known. There is evidence from one instance (section 5.3.2.5) where seeing a tool (temporal glyph) in a wireframe completely changes a subject's mind about it from having seen it presented in a lecture.

> *"I looked at those [the glyphs] a fortnight ago [at the geovisualisation lecture] and I hated them…I really hated them. I thought they were inelegant, and I thought that they were hard to interpret. But…I mean, [now] I really do like it, because you've got the interaction of it here, I do like it. But it is kind of… you are trusting in your eye, like you are saying." (C2)*

The most significant result from the work with the CDR subjects with wireframes is the crucial importance of real domain data. A key piece of evidence comes from C1 (section 5.3.2.4), who despite being told the data is simulated, cannot hold back from attempting to interpret it:

> *" one of the things that is perhaps hampering my limited imagination is because it is random data…I immediately try and make sense of it, kind of thing. 'Ah, theft from vehicles is very similar to…oh no it isn't - it's just random'. I immediately start to try to interpret it instead of just trying to leave it at the level of [an example]… (C1)*

The final wireframes are simple and only scratch the surface of what geovisualization can deliver. This is in one sense disappointing in that more advanced tools and interactions are not communicated to users. Nevertheless, it is also pragmatic. The information on geovisualization provided by way of a lecture described in Chapter 4 was unsuccessful in communicating geovisualization to CDR subjects, and their needs, goals and outlook are constrained by the nature of their work. One could conceive of more complex geovisualization tools and interactions to explore other possibilities, but interesting though that might be, these are not mainstream concerns of the CDR team. van Wijk (2006) makes the point that "novelty is relative" in visualization, and reports a case where what a visualization researcher considered "standard information visualization concepts… more or less straightforward" were to the domain experts "highly effective and the most effective tool for the purpose they knew."

The key nature of real subject data is clear from the results. In order to create wireframes with this, employing one or other of the following might be a way forward:

- Scavenging existing applications of all kinds for elements that can produce relevant visual representations of subject data quickly. These might include:
    - presentation software such as PowerPoint, Visio,
    - dashboard software (Few, 2006)
    - spreadsheets (like Excel), and useful Excel plug-ins (like Treemapper (Microsoft Research, 2006) and the Tufte-inspired sparklines (Rimlinger, 2009)), possibly connected to databases (like Access and MySQL) giving access to subject data,
    - geographic information systems,
    - internet-scale, static, visualization tools (such as Many Eyes (Viégas et al., 2007) and Swivel (Dimov and Mulloy, 2005)),
    - single focus visualization and geovisualization tools created by practitioners and made freely available to academics (for example Mondrian (Theus, 2002), SomVis (Guo, 2005) and Estat (Robinson, 2005)),
    - visualization and geovisualization toolkits created by practitioners and made freely available to academics (such as GeoVista Studio (Gahegan et al., 2000), Prefuse (Heer, Card and Landay, 2005), Improvise (Weaver, 2006b) and GAV (Jern et al., 2007))
- Employing advances in programming such as the Processing language (Reas and Fry, 2003) to create code that can be assembled quickly for "making responsive images" and "sophisticated visual and responsive structures" for displaying subject data. (Dykes (2005b) highlights the general approach of removing barriers to entry for those wishing to create geovisualization applications by means of "increasing efficiencies, sharing software components and reusing resources".
- Extending the approaches adopted by some human-centred researchers to produce design tool software such as DENIM (Newman et al., 2003) that allow sketch-based inputs and various levels of refinement.

This concludes Chapter 5 on design and wireframes. The next chapter sees Wireframe 2 developed into paper and digital interactive prototypes that are communicated to the CDR subjects using simple tasks from a geovisualization task taxonomy to determine how these more advanced prototyping techniques need to change as a consequence of the nature of geovisualization. In a further round of evaluation, a CDR subject operates the digital interface to the digital interactive prototype to freely explore crime data. To provide a contrasting case for crime 'free exploration', a pre-existing geovisualization application (SomVis) is explained to the LCC Library subjects who then use it in a 'free exploration' way to cluster library borrowers using a combination of thematic map, self-organising map (SOM) and a parallel coordinate plot (PCP).


DOMAIN
like
patterns
GEOVISUALIZATION
might
process
centre
something
looking
subjects
Table
square
ALOUD
IMPROVEMENTS
got
clusters
interesting
assault
see
THINK
resolution
suggestions
shows
number
borrowing
quite
CDR
real
PROTOTYPES
things
EXPLORATION
DIGITAL
C3
section
new
also
FREE
INTERACTIVE
tasks
within
PAPER
using
well
PROTOCOL
PROTOTYPING
kind
QUESTIONS
able
day
go
L2
subject
way
time
PROTOTYPE
get
area
L3
use
theft
TESTING
first
two
C2
C1
one
information
just
case
active
three
context
evidence
USER
work
town
session
CRIME
data
going
SUMMATIVE
map
spatial
areas
Loughborough
intervention
know
L1
SOMVIS
LIBRARY
different
Figure
application
INDIVIDUAL
similar
good
LIBRARIES
pattern
RESULTS
sessions

6 PROTOTYPING

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ABSTRACT

I evaluate two different geovisualization prototypes – paper and digital interactive - with two different protocols – user testing with active intervention and free exploration - with two different sets of users from separate parts of LCC (crime and disorder reduction, and libraries). This is to establish to what extent they are able to support visual exploration of spatial and attribute subject data and how effective they are at eliciting suggested improvements to iterate the development of the prototype.

In all cases, think aloud records subjects' reactions to their interactions with the prototypes, and is recorded, transcribed and coded to highlight instances of exploratory behaviour and implicit and explicit suggestions for improvement. This material is supplemented by individual summative questioning.

Both prototypes effectively elicit significant exploration activity. The paper prototype is better for generating suggested improvement and produces more than twice as many suggestions for improvement that related to 'new' features (a category that includes novel geovisualization elements). The free exploration protocol with the digital interactive prototype generates more suggested improvements and more implicit suggestions. Exploratory activity is not significantly different from user testing with active intervention.

LCC Library subjects are introduced to aspects of the multivariate and spatial aspects of their data and the existing tools and techniques available. They undertake a free exploration with a geovisualization application regarded as a 'prototype' to explore their data and establish clusters of library borrowing, thought to be spatial in nature. The library subjects interact collaboratively with the 'prototype' and engage in a broad quantity of exploratory activity. Understanding context and explaining tailored geovisualization tool approaches in the context of subjects' data is sufficient for these subjects to use even sophisticated visualization tools in a free exploration environment, given adequate support.

The importance of real subject data, domain knowledge and subject context is reinforced in the sessions with both sets of subjects and with both prototypes and both protocols. This reinforces the importance of using a HC prototyping approach.

6.1 INTRODUCTION

RQ5: How well do human-centered approaches concerned with prototyping work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of prototyping of geovisualization applications with prospective users?

Working with CDR subjects has successfully communicated a design for a geovisualization application. Human-centred approaches that refine a design with prospective users, include a range of increasingly sophisticated prototyping techniques that differ in "audience, stage of development, speed, longevity, expression, style, medium and fidelity" (Arnowitz, Argent, Berger, 2007). This chapter looks at the ways in which different forms of prototype, with different ways of communicating to subjects, contribute to an understanding of the extent to which standard HC approaches work in a geovisualization context.

Two major methods of prototyping are paper and digital interactive, and CDR designs are developed in these media and exposed to the CDR subjects in usability testing with an active intervention protocol (Dumas and Redish, 1999), with relative simple spatial, temporal and attribute tasks based on using task types from the taxonomy of Koua, MacEachren and Kraak (2006), employing the subjects' own data. Usability testing is the human-centred evaluation approach Arnowitz, Argent, Berger (2007) consider "very appropriate" for both paper and digital interactive prototyping. But North (2006) has criticised user tests as a means of refining applications in a *visualization context*, where the primary aim is insight into domain data, and proposes "an open-ended protocol, (where) users explore the data in a way that they choose." Such an open-ended protocol ('free exploration') is used with CDR subjects as a contrast with the usability testing approach. To provide a comparison of the open-ended protocol with a different case, the Library subjects use a pre-existing geovisualization *application*, SomVis (Guo, 2005), to explore their data, as if it were a digital interactive *prototype*.

The usability testing and open-ended sessions lasted approximately two to three hours and subjects' think-aloud comments were recorded for later transcription and analysis, and were supplemented by questions asked verbally or with a questionnaire. Coding was based on the kinds of subjects' interactions with the prototypes, such as exploratory activity, hypothesis forming, ideation/insights, confirmation of known facts, and instances of confounded expectations, to understand how a prototype performed in a geovisualization context. This is a more detailed coding scheme than was used for the wireframes, anticipating richer feedback from these more sophisticated prototypes. Feedback from subjects about their approach to tasks and about the process was gathered using think aloud. Data was also coding to record specific and implicit suggestions for improvements to a the CDR prototype - the usual reason for conducting prototyping with prospective users - and which drives the development forward. Figure 1.1 makes clear the contributions of these different kinds of information.

6.2 METHODS

<table>
<tr><th>Case No.</th><th>ISO 13407 methods</th><th>Population</th><th>Sample</th><th>Units</th><th>Objective</th><th>Research Design</th></tr>
<tr><td>8</td><td rowspan="7">Prototyping (paper and digital interactive prototypes, with users tests with active intervention protocol and free exploration protocol, using observation, interviews, questionnaires and transcribed and coded think aloud)</td><td rowspan="5">Prospective geovis application users in LCC Research and Planning department</td><td rowspan="5">Crime & Disorder reduction (CDR) Team</td><td rowspan="5">CDR team members</td><td>Evaluate reactions to conducting tasks using a paper prototype using user testing with active intervention</td><td rowspan="2">(b) Case Study II</td></tr>
<tr><td>9</td><td>Evaluate reactions to conducting tasks using a digital prototype using user testing with active intervention</td></tr>
<tr><td>10</td><td>Compare CDR subject reactions to conducting tasks using paper and digital prototypes using user testing with active intervention</td><td>(d) Cross-sectional</td></tr>
<tr><td>11</td><td>Evaluate reactions to with free exploration protocol using a digital prototype</td><td>(b) Case Study II</td></tr>
<tr><td>12</td><td>Compare CDR subjects' experiences of conducting tasks using user testing with active intervention and free exploration protocols using a digital prototype</td><td>(d) Cross-sectional</td></tr>
<tr><td>13</td><td>Prospective geovis application users in LCC Libraries</td><td>Libraries Team</td><td>Libraries team members</td><td>Evaluate Library subject reactions to conducting free exploration using a digital 'prototype'</td><td>(b) Case Study II</td></tr>
<tr><td>14</td><td>Leicestershire County Council (LCC) departments</td><td>Libraries and Research & Planning departments</td><td>Libraries and CDR teams</td><td>Compare CDR and Library subjects' experiences of conducting free exploration using digital prototypes</td><td>(d) Cross-sectional</td></tr>
</table>

Extract from Table 2.2: Prototyping (Research Question 5) - the sections of this research showing case study details by type according to (Gerring 2004).

The case study scheme reproduced above outlines the framework for the research in this chapter.

6.2.1 PROTOTYPING METHODS, PROTOCOLS AND DOMAIN CASES

The aim is to evaluate appropriate prototyping approaches as suggested by the human-centred domain in a geovisualization context, using different **prototyping methods** (paper and digital interactive prototyping – case numbers 8, 9 and 10), different subject **protocols** (usability testing and free exploration – case numbers 11 and 12) and with subjects from different **domains** (crime and disorder reduction and public libraries – cases numbers 13 and 14). Prototyping is concerned with iterating a prospective application and garnering possible improvements. While this is of interest, from the point of view of this research, of primary concern is the extent to which different prototypes, different protocols and different domains affect the processes of subject exploration, hypothesis forming and insight/ideation.

6.2.1.1 PROTOTYPING METHODS

Typically, a more realistic prototype is developed from a wireframe before committing resource and emotion to writing code (Cohen et al., 2004). Researchers have compared the effectiveness of low-fidelity and high-fidelity prototypes. In an article about paper prototyping, Rettig (1994) "highlights some of the problems with hi-fi prototyping - the time it takes, the fact the users tend to focus on the gloss and the understandable resistance on the part of developers to change them." Rudd, Stern and Isensee (1996) discuss "arguments for and against low-and high-fidelity prototypes, guidelines for the use of rapid user interface prototyping, and the implications for user-interface designers.”

Virzi, Sokolov and Karis (1996) found "…substantially the same sets of usability problems in the low- and high fidelity conditions" and concluded that "the use of low-fidelity prototypes can be effective throughout the product development cycle, not just during the initial stages of design.” Catani and Biers (1998) investigated "the effect of prototype fidelity…(low = paper; medium = screen shots, high = interactive Visual Basic prototype)" and found "there were no significant differences as a function of prototype in the number and severity of problems encountered nor in the subjective evaluation of the product….[and] there was a high degree of commonality in the specific problems uncovered by users using the three prototypes". Walker, Takayama and Landay (2002) compared user testing with low- and high-fidelity prototypes in both computer and paper media and found that "low- and high-fidelity prototypes are equally good at uncovering usability issues". They concluded that "Usability testing results were also found to be independent of medium, despite differences in interaction style. Designers should choose whichever medium and level of fidelity suit their practical needs and design goal…" Lim et al (2006) support this general conclusion when they compare paper, computer-based and fully functional prototypes and conclude that "major usability issues...were identified by all the three types of prototypes." However when Liu and Khooshabeh (2003) studied the effects of varying the fidelity and automation levels of a prototype, their results showed a different result, that an "interactive prototype captured the same usability issues that the paper prototype studies did and more."

Houde and Hill (1997) are critical of the low level/high level prototyping taxonomy believing that "such characterizations can be misleading because the capabilities and possible uses of tools are often misunderstood and the significance of the level of finish is often unclear, particularly to non-designers."

Snyder (2003), in her comprehensive book on paper prototyping states “complex or subtle interaction usually can’t be simulated perfectly” with paper prototyping – an intimation that this approach may be limited for geovisualization. However, the approach does have the potential to show a wide range of functionality (simply by adding pieces of paper) that is not possible in a higher-level prototype (such as a digital interactive prototype). Geovisualizations typically comprise an assembly of different tools, each of which might be complex to create, let alone integrate with other tools, and here paper prototyping appears to offer a significant advantage.

The boundary between paper and digital techniques has become blurred over the last decade as researchers propose increasingly sophisticated computerised aids to prototyping. Uceta (1998) describe "the design, implementation and evaluation of an interactive sketching technique for usability testing" that adds limited interactivity to paper based sketching using PowerPoint by "hyperlinking various areas of the screen to simulate dynamic behaviors.” Other developments include SILK (Landay and Myers, 2001), DENIM (Newman et al., 2003) and MONET (Yang and James, 2005). Coyette, Kieffer and Vanderdonckt (2007) review the literature on these digital sketching tools for user interface prototyping, and propose their own multi-fidelity tool, SketchiXML.

In the field of geovisualization, the work of Ahonen-Rainio and Kraak (2005) and Ahonen-Rainio (2006) uses a digital interactive prototype to study the selection of maps by subjects from map metadata using maps themselves plus multivariate visualization tools such as parallel coordinate plots, scatterplot matrix and star glyphs. Subjects conducted comparison tasks in a user testing approach.

More recently, Floyd et al (2007) describe 'patchwork prototyping' and "explore novel practices of user-driven innovation…[illustrating] how users and developers are exploiting the proliferation of open APIs and open source systems…[to] rapidly create proofs of concept that are robust enough for actual use by combining pre-existing software components." Jones, Floyd and Twidale (2007) compare and contrast "patchwork prototyping with other prototyping methods including paper prototyping and the use of commercial off the shelf software."

Arnowitz, Arent, Berger (2007) devote a chapter of their book to the choice of a particular prototyping method, and their guidance was followed. For the midterm stage of the process to build an application, they suggest three approaches that offer both a low to medium fidelity (beyond the fidelity of a wireframe) and an interactive style that can used to probe subjects' reactions. It should be noted that 'interactive' here is in the sense of 'human-computer interaction' – the term does not imply the geovisualization sense of interactions as in 'combined multiple visualizations', for example. These three approaches are paper prototyping, Wizard of Oz prototyping, and digital interactive prototyping. Wizard of Oz prototyping is essentially a variant in the way that digital interactive prototypes may be deployed; another variant is 'chauffeured' prototyping. The Wizard of Oz approach uses "studies where subjects are told that they are interacting with a computer system through a natural-language interface, though in fact they are not. Instead the interaction is controlled by a human operator, the wizard, with the consequence that the subject can be given more freedom of expression, or be constrained in more systematic ways" (Dahlback, Jonsson and Ahrenberg, 1993). The Wizard of Oz approach demands an unnecessary subterfuge and technical constraints (two computers networked together in different rooms) and is not easily achieved in the field. In the 'chauffeured' variant "…only one person uses the [computer], either a group member or the meeting leader/facilitator" in order to free up the other participants (Nunamaker et al., 1991). In the context of geovisualization where subjects are dealing with a complex application, the **chauffeured approach** has advantages in not burdening the subject with manipulating the interface and is selected for use with the subjects when they are not given control of the interface.

The two prototyping methods employed here are **paper prototyping** and **digital interactive prototyping**. A paper prototype (Rettig, 1994) is manipulated by someone 'playing computer' (Snyder, 2003) and "consists of a paper mockup of the user interface. The interface is usually fully functional, even if all the functionality is mocked up on paper". A digital interactive prototype is "almost a digital version of the paper prototype…[and] shares the same objectives as paper prototyping." They can "range from a more narrative style…to a fully interactive high fidelity coded prototype" (Arnowitz, Arent, Berger, 2007). The evaluation of paper prototyping and digital interactive prototyping comprise case numbers 8 and 9, respectively, and the comparison, case number 10.

6.2.1.2 PROTOTYPING - USER TESTING AND FREE EXPLORATION

The canonical human-centred approach to this is **user testing/usability testing:** "user testing with real users is the most fundamental usability method and is in some sense irreplaceable, since it provides direct information about how people use computers and what their exact problems are with the concrete interface being tested." (Nielsen, 1993)

Dumas and Redish (1999) state that:

> "Every usability test shares these five characteristics:
> 1 The primary goal is to improve the usability of the product.
> 2 The participants represent real users.
> 3 The participants do real tasks.
> 4 You observe and record what participants do and say.
> 5 You analyze the data, diagnose the real problems, and recommend changes to fix those problems."

However they emphasise that "Nothing in our definition of a usability test limits it to a single, summative test at the end of a project...Usability testing is appropriate iteratively from predesign (test a similar product or earlier version), through early design (test prototype) and throughout development (test different aspects, retest changes)."

Maguire (2001) includes user testing under "Evaluation" in his overview of human-centred approaches for ISO13407, but makes it clear that user testing is appropriate "during the early stages of prototype development, continuing to the more formal summative testing as the prototype develops through usability work." Indeed Maguire suggests a form of evaluation, **participatory evaluation**, where "users employ a prototype as they work through task scenarios. They explain what they are doing by talking or 'thinking-aloud'. This information is recorded on tape and/or captured by an observer. The observer also prompts users when they are quiet and actively questions them with respect to their intentions and expectations." Dumas and Redish (1999) refer to a similar process as **active intervention**:

> "Active intervention is a technique in which a member of the [research] team sits in the room with the participant and actively probes the participant's understanding of what is

> being tested. For example, you might ask participants to explain what they would do next and why as they work through a task...By asking probing questions throughout the test, rather than in one interview at the end, you can get insights into participants' evolving mental model of the product. You can get a better understanding of problems that participants having than by just watching them and hoping they'll think out loud. Active intervention is particularly useful early in design. It is an excellent technique to use with prototypes, because it provides a wealth of diagnostic information. It is not the technique to use, however, if your primary concern is to measure time to complete tasks..."

Results so far from establishing context of use (Chapter 3), requirements (Chapter 4), and early design (Chapter 5) have covered the varying successes and failures of communicating understanding to and from subjects through a succession of different HC approaches. I see the use of user tasks and tests in an active intervention context as another one of a sequence of communicating evolving design to potential users in the context of geovisualization. It is a dialogue, heavily weighted towards to the subject, in the presence of a prototype, with a pre-built structure in the form of tasks. The tasks and the prototype are there to give a required focus to the conversation - the 'tests' themselves are a means to an end – the study, using an 'active intervention' protocol, of the success or otherwise of the prototypes in eliciting behaviour (and suggestions for improvement) that would be of use in the development of an eventual geovisualization application. User testing is not seen as an activity to be completed as an 'add-on' to the application creation process, but as part of the on-going communication between geovisualization researcher and domain expert. The **subject matter is constrained** within the user-testing protocol to provide a focus on an increasingly tangible representation of the final geovisualization representation, **but the dialogue is kept open** by using 'active intervention'.

Some researchers indicate that the use on tasks in a visualization context may be limited. Wilson et al (2008) state:

> "…researchers have created lower-level task taxonomies to identify the set of general user tasks in both visualization and geovisualization…While these taxonomies identify the variety of tasks for a user, they still do not provide significant detail on how users meet those goals within an interactive visualization."

North (2006), in an information visualization context, considers:

> "… tasks are troublesome for several reasons. They force users into a line of thought that they might not otherwise take. They place an undo burden on evaluation designers…The choice of tasks and the phrasing of task questions can introduce bias. Benchmark tasks lack completeness. Finally, because the tasks must be predefined, the experiment's results are limited to only the tasks that evaluators chose."

North (2006) promotes the notion that user tests do not have to be task based:

> "A more radical step is to eliminate the pesky benchmark tasks from the protocol entirely. This method's fundamental concept is to change the benchmark tasks from an independent to a dependent variable. Hence, instead of instructing users in exactly what insights to gain, researchers observe what insights users gain on their own. This method involves the following key innovations:
>
> - an open-ended protocol,
> - a qualitative insight analysis, and
> - an emphasis on domain relevance.
>
> With an open-ended protocol, users explore the data in a way that they choose."

North foresees the difficulties with such an approach as including "potentially long training and trial times…more effort …to capture and code results; motivated, [and] domain knowledgeable users who will not merely follow instructions but generate insight in a self-directed manner…"

In a geovisualization context, a protocol based on North's principles would allow subjects to operate the interface to the prototype themselves and explore whatever data they wished, in a free manner. I call this form of open-ended protocol **free exploration**. The evaluation of a free exploration protocol within LCC CDR comprises case number 11, and its comparison with user testing, case number 12.

6.2.1.3 DOMAIN CASES

So far, the design focus has been on developing an application for the crime and disorder reduction team, and producing paper and digital interactive prototypes is an obvious next iteration of the communication and feedback process. Providing a second case study in the form of the LCC public libraries team provides additional evidence and a domain case comparison.

As seen in Chapter 5, geovisualization wireframe prototypes are time- and resource-consuming to produce, let alone more involved paper and digital interactive prototypes. One way to modify the process for a more-closely defined subject set of requirements might be to use a pre-existing application as a surrogate prototype. This dovetails with Maguire (2001): "evaluating an existing or competitor version of the system can provide valuable information about the extent to which current systems meet user needs." Clearly, an existing application is 'pre-designed', but it could be represented to subjects as a digital interactive prototype. From section 3.3.1.3, the library team's requirements are known to be narrow – to cluster library borrowers in such a way as to permit tailored marketing messages to be produced – so this modified approach may be possible.

But such an approach will limit the research questions that can be addressed. Using an extant application means that paper prototyping cannot be employed. Subjects could however be asked to undertake exploration with either, or both, of user testing or free exploration protocols with the 'prototype'. To progress this modification, I consider which, if any, extant applications could manage the library team's requirement to cluster their borrowers, and this is described in section 6.2.2.3.

6.2.2 PROTOTYPE BUILDING

6.2.2.1 CRIME DIGITAL INTERACTIVE PROTOTYPE

It may seem perverse to discuss the construction of the CDR digital interactive prototype in advance of the paper prototype, which at first sight would appear to be the simpler proposition. For geovisualization prototypes, this is not necessarily the case as the complex, multi-tool, data-dense nature of a typical geovisualization combines with the need established throughout this research for subjects to see and work with their own, real data. In this situation, a 'real data' paper prototype can only be machine generated – the experience of creating dummy data representations of an application during the wireframes process demonstrates this abundantly.

The digital interactive prototype had its genesis in a conversation with a geovisualization expert who had developed applications in the past (henceforth the 'developer'). The designs that made up Wireframe 2 (Figures 5.11, 5.12 and 5.14) and the abortive 'analogue lightbox' concept were used to communicate the ideas behind the design concept to the developer. From this dialogue the developer was able to create what became known as the 'digital lightbox' – a digital interactive prototype to explore crime attribute data in time and space.

LCC CDR had provided an sizeable extract from their database, containing over 250,000 crimes over a six year period. The extract contains only data on crime incidents and no details of offenders or victims; the spatial details of crime locations are limited by data aggregation to 100-metre squares (see section 3.3.5.1). Following discussion with the CDR subjects, the 42,000 crimes over six years for the 5km square urban area of Loughborough was used as the basis for the digital lightbox. This data was 'cleaned' and provided to the developer.

The developer was time-constrained and able to produce a digital lightbox that only had some of the fully-envisaged functionality of the wireframe. The digital lightbox consisted of an internet browser with scalable vector graphics (SVG) (W3C, 2003) plug-in (Adobe, 2008) that linked via the browser URL string to about 400 lines of PHP code that took a text string to query a database stored in MySQL (on a University server). It was able to render a spatial grid of 100m2 squares or aggregates of such squares in SVG, coloured according to the value of a crime attribute relative to all the other squares in the display. Thematic colour styles were selected from ColorBrewer (Brewer, Hatchard and Harrower, 2003) and a range of background maps of Loughborough at different scales could be toggled to appear under the thematic colouring for navigation and orientation (Figure 6.1). In free exploration sessions, subjects accessed the prototype by inputting text strings directly. In user testing sessions, subjects interfaced through a paper input sheet that permitted multiple changes of screen in one operation. These input mechanisms are discussed further in section 6.3.2. The digital lightbox contained glyphs of hours of the day, hours grouped into three hour bands (midday to 3pm etc), days of the week (with day starting at midnight or at 6am), and months of the year (Figure 6.2). These were shown as simple 'spiders' and not the more elaborate versions shown in Wireframe 2. All spider arms were coloured dark grey apart from the start times (midnight, Sunday, January etc.) which were coloured black as a check by the developer on the accuracy of the translation between code and screen. A maximum of 25 glyphs, corresponding to the 25 spatial areas with the highest crime, was shown at any one time to reduce processing overheads (with the incidental benefit of focusing attention on the highest crime areas (Figure 6.3)).

Crime attribute values could also be displayed coloured according to a bivariate Brewer colour scheme relative to a long term aggregated value for that geographic location using a signed chi-statistic (Figure 6.4). The developer decided to add a visual clue of absolute value in the form of a circle sized to crime volumes in the signed chi-statistic view.

Figures 6.5 to 6.8 show, respectively, the effect of a change of crime attribute (theft from a motor vehicle is replaced by assault – the latter is a much more spatially concentrated crime) (Figure 6.5); zooming in (Figure 6.6); zooming out (Figure 6.7); a change of resolution from 500m squares to 100m squares (Figure 6.8). In each of these screen shots, the browser URL string defines what is shown. For example in Figure 6.3, the URL string reads:
…/v6.php?i=25bx&cb=yob&res=10&o=TFV&T=M

This 'translates' as 'set a 1:25,000 map as the background image (code: i=25bx); set the thematic colouring to conform to ColorBrewer yellow-orange-brown scheme (code cb=yob); the resolution at 10 (res=10; this corresponds to 500m squares); offence to 'theft from motor vehicle' (o=TFV); and the glyphs to show months of the year (T=M)'. By using these and similar code strings, a huge range of different screens is possible giving different views into the data. Omitting one or more code strings result in that feature being 'toggled off', allowing the removal of elements and reducing the amount of data displayed.

The developer took two full days of coding to produce the digital lightbox prototype but was not able to implement a number of elements present in the wireframes. These include:

- the filters that would eliminate glyphs or 'grey out' the thematic colouring once the aggregated value dropped below a predetermined number of crimes.
- the treemap of crime attributes from Wireframe 2 (although the developer subsequently collaborated to create a stand-alone treemap application, Treemappa (Wood and Dykes, 2008)).
- the system of progressive temporal filtering envisaged in the final Wireframe2

The constraint on developer time, and consequently on developing what is possible, is realistic, and shows a practical limitation to producing complex digital interactive prototypes.

Inevitably, the choices made by the developer of how to implement the digital prototype (rendering SVG in a browser in response to text strings submitted to a remote database) has consequences for the ease and complexity of adding additional functionality in subsequent iterations, and for its operation. One of the more notable is the decision to host the data remotely rather than locally, trading the power of a remote server to calculate new SVG against the latency and vulnerability inherent in requiring a communications link for the digital interactive prototype to function.

6.2.2.2 CRIME PAPER PROTOTYPE

The crime paper prototype consisted of two main components. Firstly, screen shots taken from the crime digital prototype that incorporated a background map, thematic shading and temporal glyphs (see, for example, Figures 6.3 – 6.8). Secondly, treemaps of the crime hierarchy with the size of the treemap rectangles proportional to the all-Loughborough long term (2001-6) crime numbers, and thematic colouring related either to crime numbers for a selected spatial area and/or a selected year. Treemap rectangles can also be thematically colouring with a bivariate scheme of signed chi-statistics for temporal comparisons. Temporal glyphs (at a variety of scales – hours, days, months) are superimposed on individual crime rectangles within the treemap to provide combined crime attribute and temporal visualization. See Figure 6.9 for an example of a treemap of this kind.

The treemaps are created using an existing application, a plug-in to Excel, Treemapper (Microsoft Research, 2006). The superimposing glyphs are produced using the 'digital lightbox' by suppressing background map and thematic colouring (similar to Figure 6.2) and setting the resolution to produce a single glyph for an individual crime type (Figure 6.9).

Clearly, use of real data in machine-produced paper prototypes in this way is time-consuming and does not scale well to include many different possible displays. It entails additional work by the designer and runs the risk that its creator holds the finished product with greater attachment than would be normal for a paper prototype (see quotations from (Cooper, 1999) and (Cohen et al., 2004) from section 1.3.1), so designers need to be aware of this factor.

Only 32 different views (combined thematic map + treemap) were created to produce the material for tightly-focused paper prototyping user testing sessions. Approximately the same amount of time was taken to develop the CDR paper prototype as the CDR digital interactive prototype.

On the paper prototype, subjects selected single choices by pressing a 'key' on a paper interface (Figure 6.10) and a researcher (the 'Computer') acted as a 'chauffeur' (section 6.2.1.1) to manipulate the pieces of paper to create a new display of thematic map + treemap. The paper interface had paper strips that could be lifted and replaced to alternately reveal and conceal options. This was necessary to constrain the choices available to the pre-prepared paper prototypes available at each stage of the session. On the digital interactive prototype, because the same multiple changes were possible throughout, the input mechanism was a piece of paper on which subjects circled their choice(s) (Figure 6.11), with a researcher 'chauffeur' entering the correct URL string. Each input method was tailored to the nature of each prototype, and it was not possible to have a uniform approach. On the digital interactive prototype, subjects were given a 'time glyph' crib (Figure 6.12) to help them with glyph options and orientation.

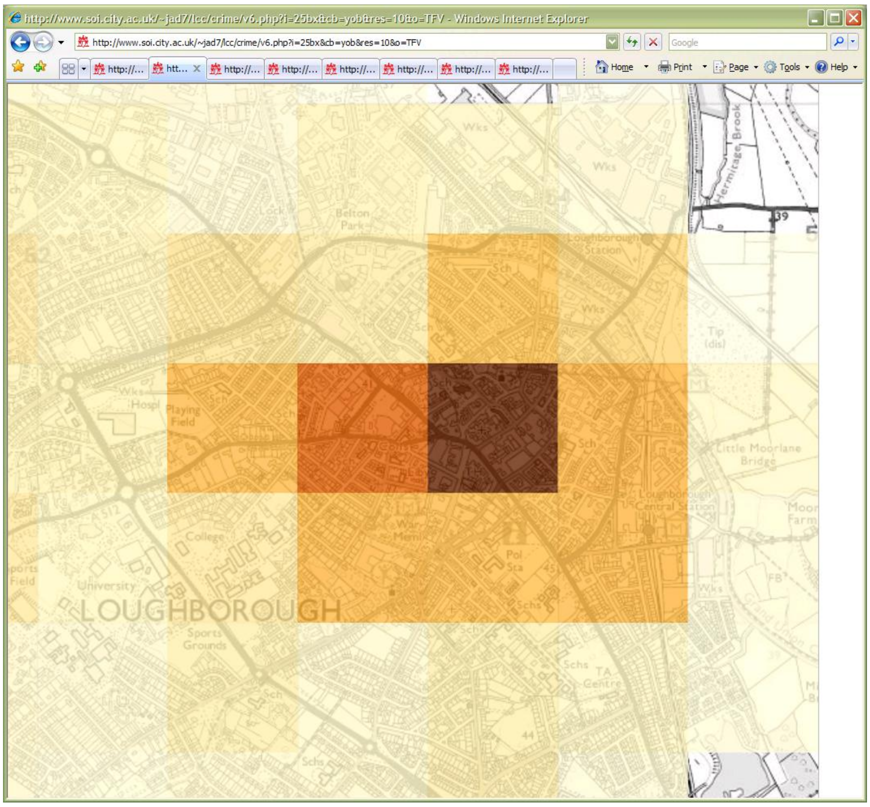

Figure 6.1: Thematic map of absolute crime numbers for theft from vehicles (TFV) overlain on a greyscale 1:25,000 map of Loughborough

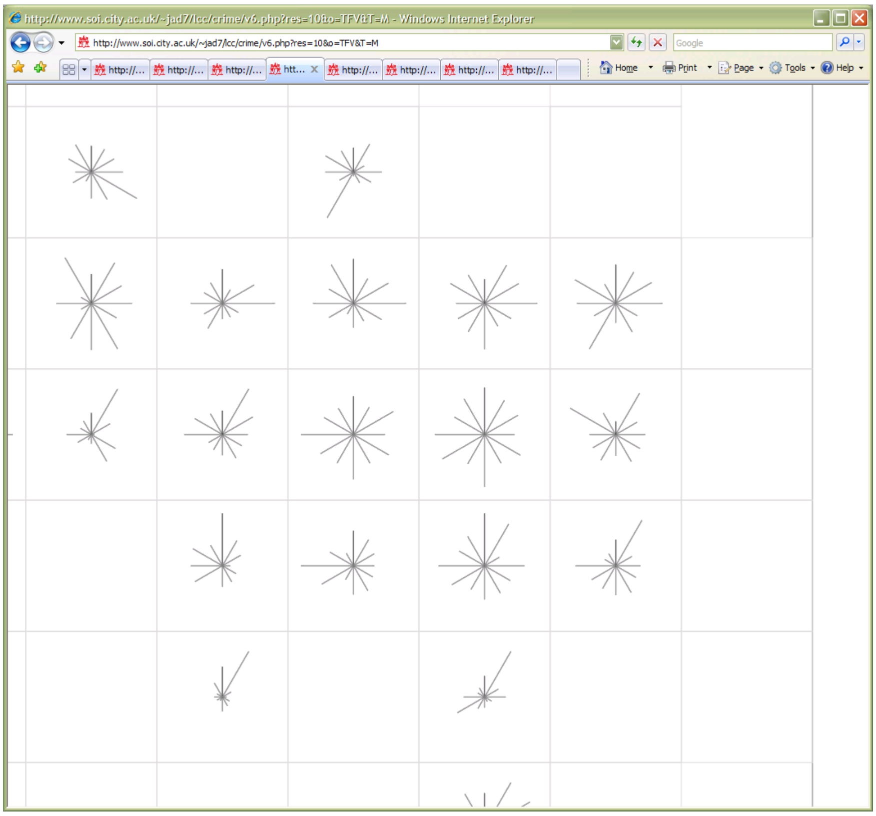

Figure 6.2: Temporal glyphs of TFV by month with January at the top and months proceeding clockwise

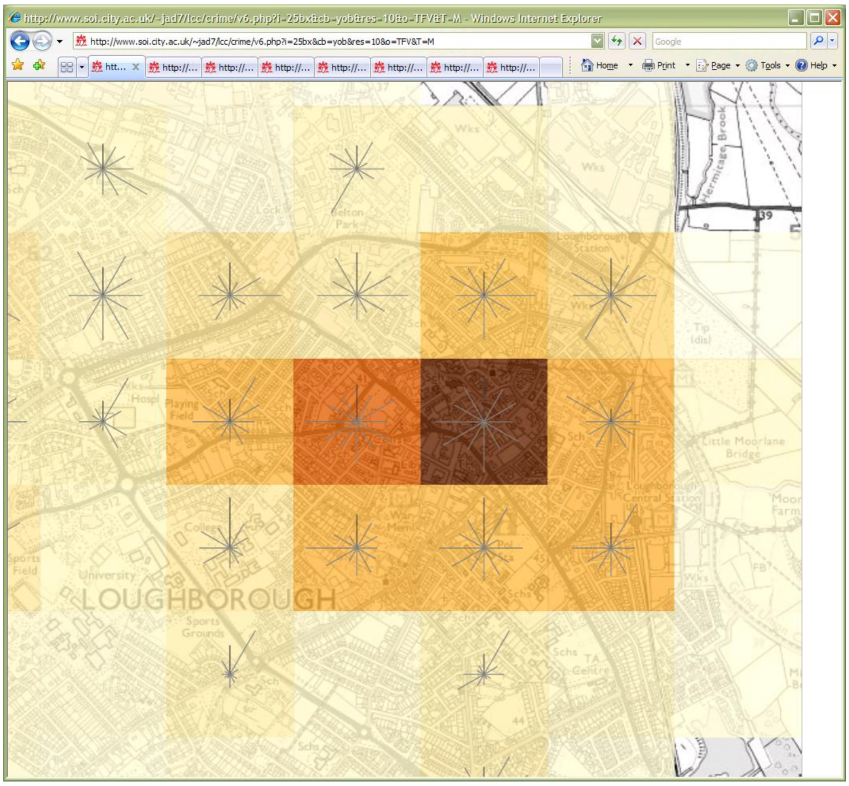

Figure 6.3: Thematic map of absolute crime numbers for theft from vehicles (TFV) with monthly time glyphs and background map

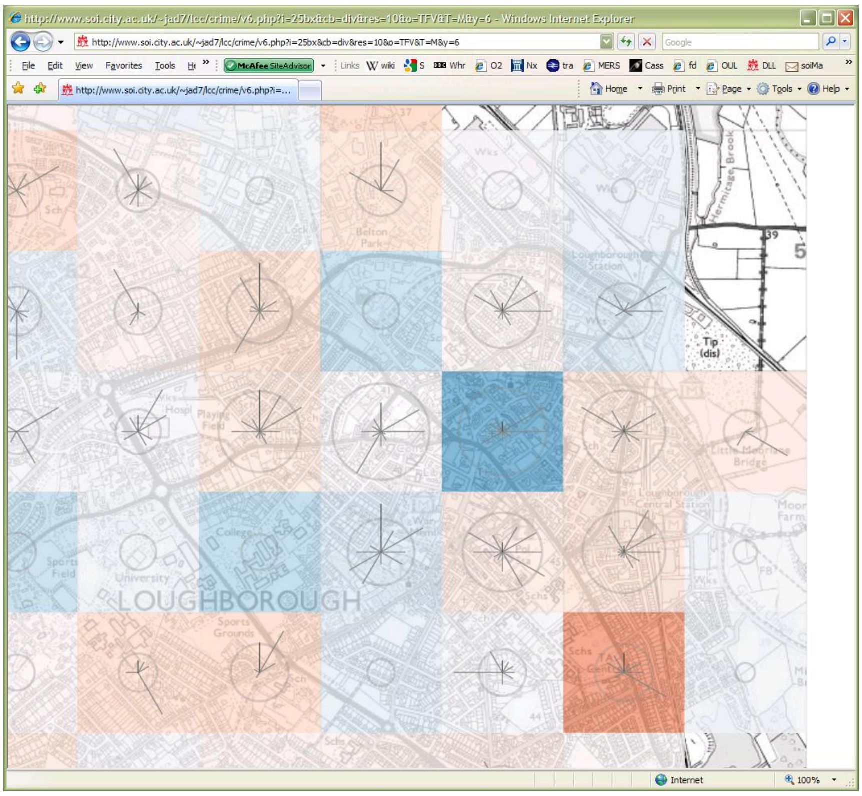

Figure 6.4: 2006 Theft from vehicles (TFV) crimes compared to 2001-6 TFV crimes shown as a bivariate thematic colouring of signed chi-statistic values, with absolute 2006 TFV numbers shown as circles, overlaid with temporal glyphs of TFV by month

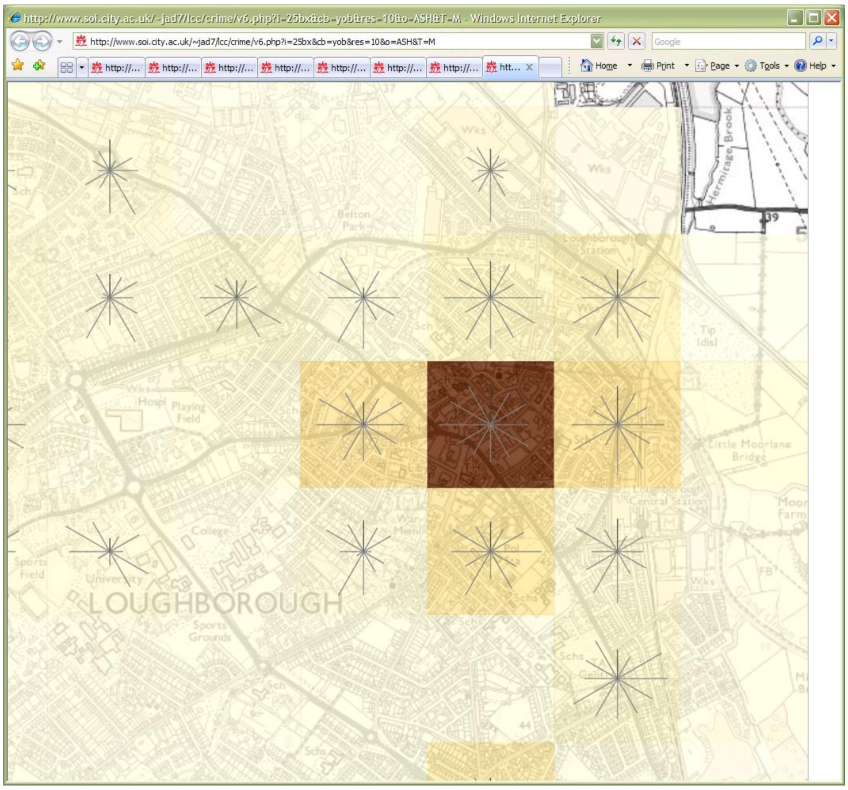

Figure 6.5: Thematic map of absolute numbers for Assault, a differently distributed crime, with monthly time glyphs and background map

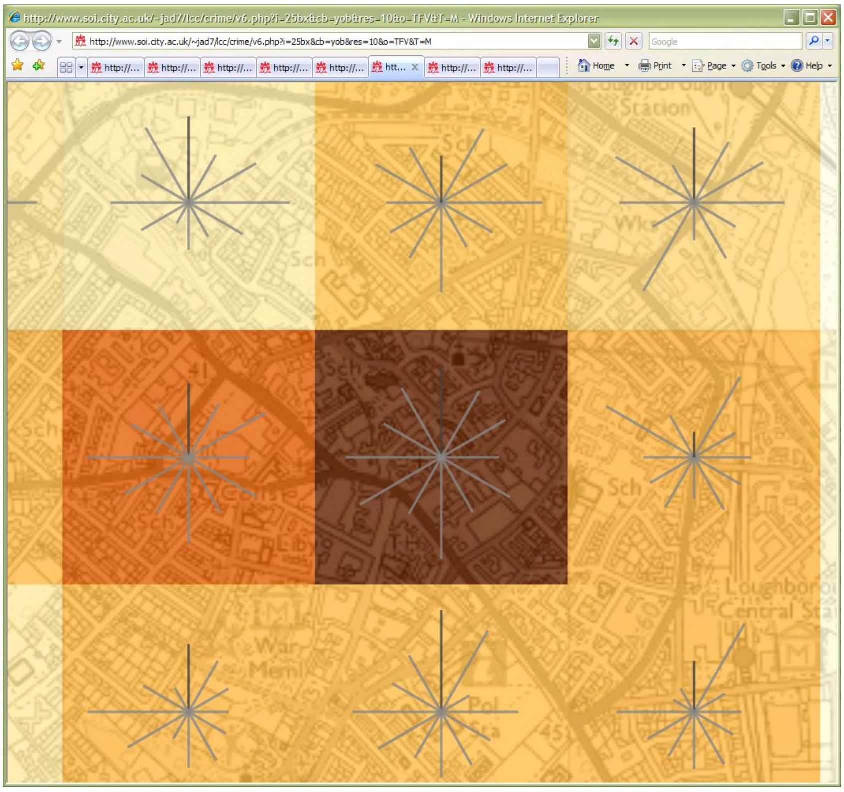

Figure 6.6: Thematic map of absolute numbers for zoomed in thematic map of absolute crime numbers for theft from vehicles (TFV) with monthly time glyphs and background map

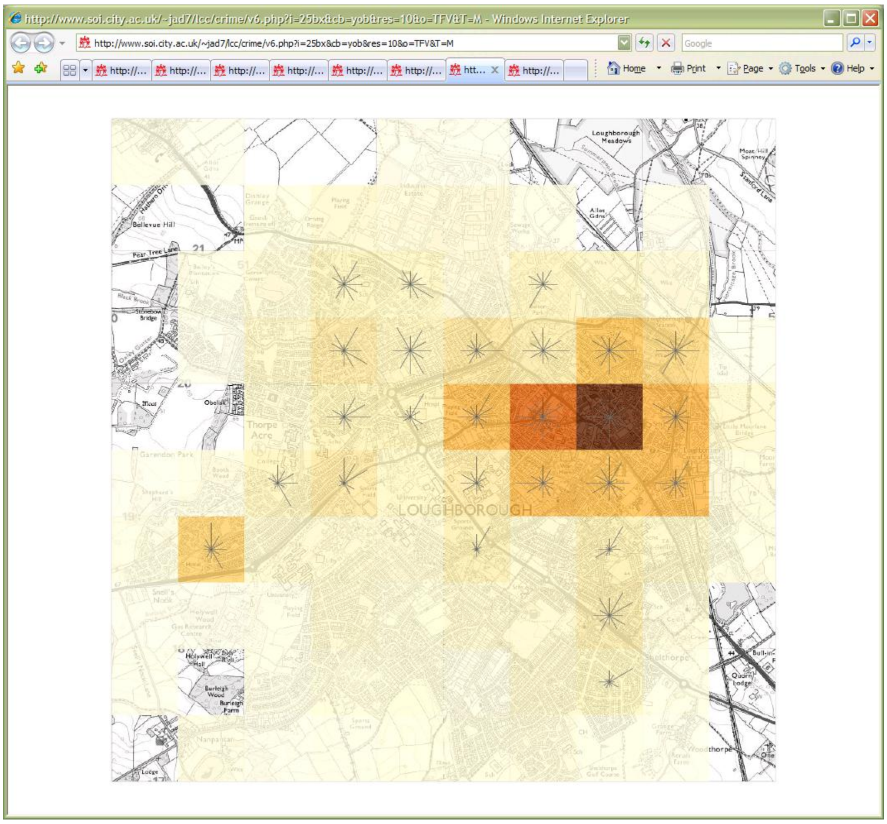

Figure 6.7: Zoomed out thematic map of absolute crime numbers for theft from vehicles (TFV) with monthly time glyphs and background map

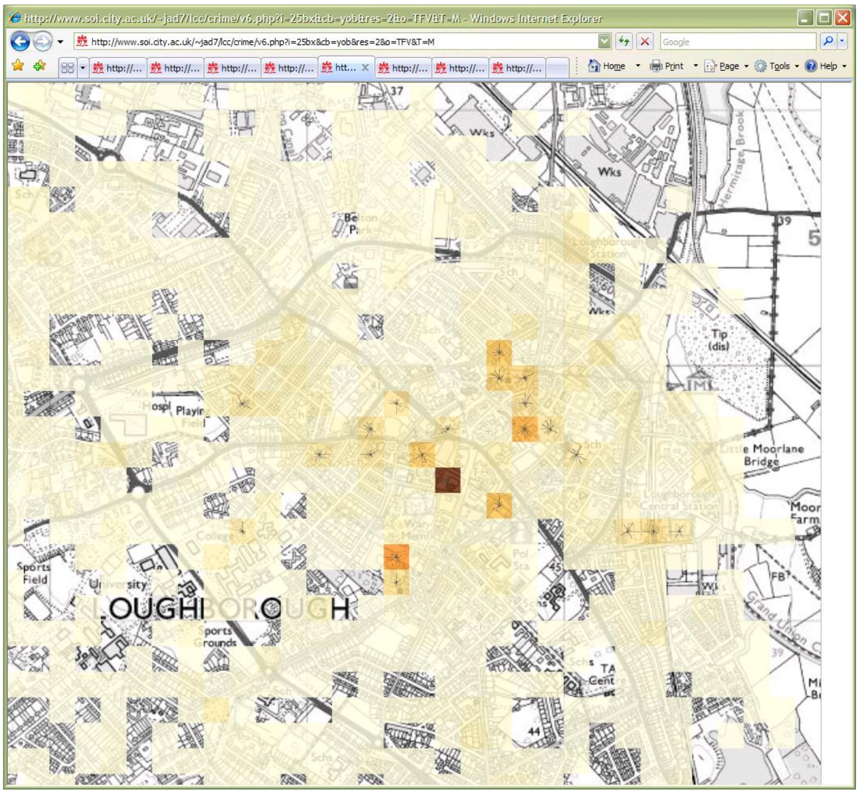

Figure 6.8: Thematic map of absolute crime numbers for theft from vehicles (TFV) with changed resolution (100m instead of 500m squares) with monthly time glyphs and background

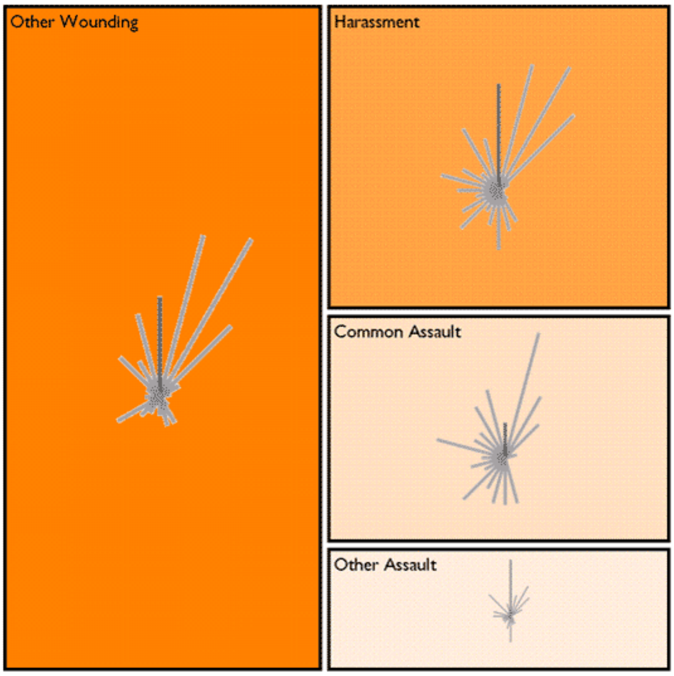

Figure 6.9: Treemap component of crime paper prototype showing crime hierarchy for the four sub-categories of Assault with hour-of-the-day temporal glyphs superimposed Midnight is at the top and hours are read clockwise. Colours represent crime numbers for the 'town centre' square kilometre of Loughborough. Rectangle sizes correspond to the long term all-Loughborough numbers for these crimes.

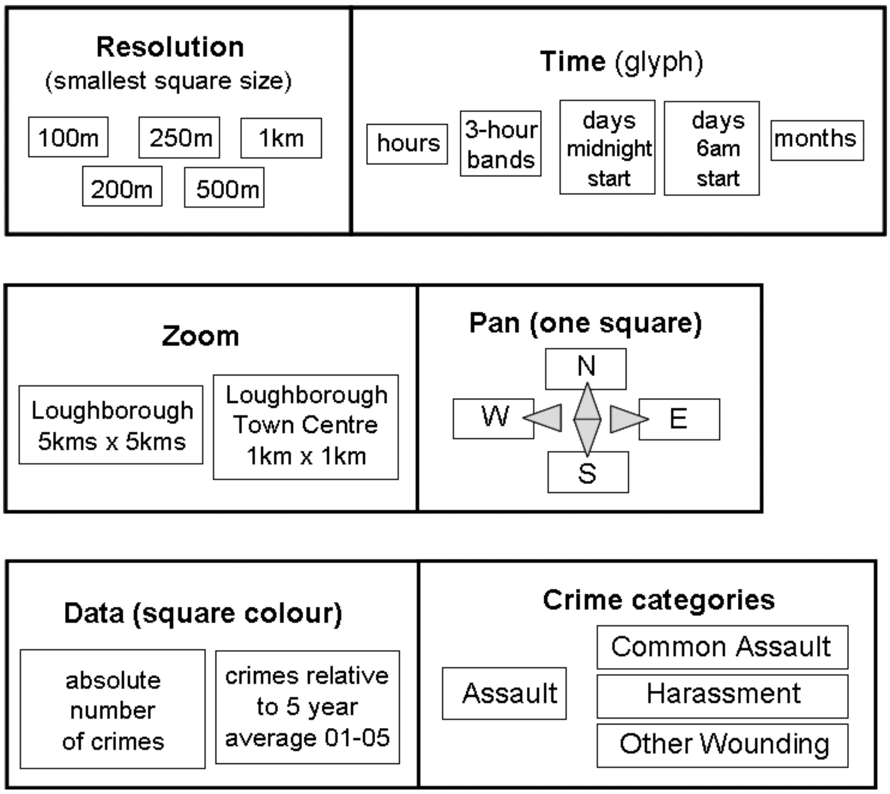

Figure 6.10: Paper prototype input interface. Options were covered over with paper strips and revealed only when paper prototypes with those values were available to show the subject

Spatial resolution (smallest square size)	**100m** **200m** **250m** **500m** **1km** **5km**
Spatial zoom (size whole screen)	**100m** **200m** **250m** **500m** **1km** **5km**
Spatial pan (point to screen to indicate if not adjacent)	**Up one square** **Left one square** **Right one square** **Down one square**
Time (glyphs	**Hours** **Bands of 3 hours** **Day (start at midnight)** **Day(start at 6am)** **Month**
Crime category	**AOT** (Theft) **ASH** (Assault) **BDW** (Burglary Dwelling) **BOT** (Burglary Other) **CDM** (Damage) **DRG** (Drugs) **ROB** (Robbery) **TFV** (Theft from a motor vehicle) **THC** (Theft of a cycle) **TOV** (Theft of a motor vehicle)
Crime sub-category (ASH (Assault) only)	**Common Assault** (ASHCA) **Harrassment** (ASHHA) **Other Wounding** (ASHOW) **All other Assault** (ASHOA)
Year	**2001** **2002** **2003** **2004** **2005** **2006** (Apr–Dec) (all these years from January to December)
Data (colour of square)	**Absolute number of crimes** **Crime relative to five year average of 2001-05**
Items visible	Background map **ON** **OFF** Glyphs **ON** **OFF** Coloured squares **ON** **OFF**
Colour of squares	**yellow-green** **white-red** **yellow-orange-brown** **greys**

Figure 6.11: Paper input for digital interactive prototype. Choices made by circling element(s)

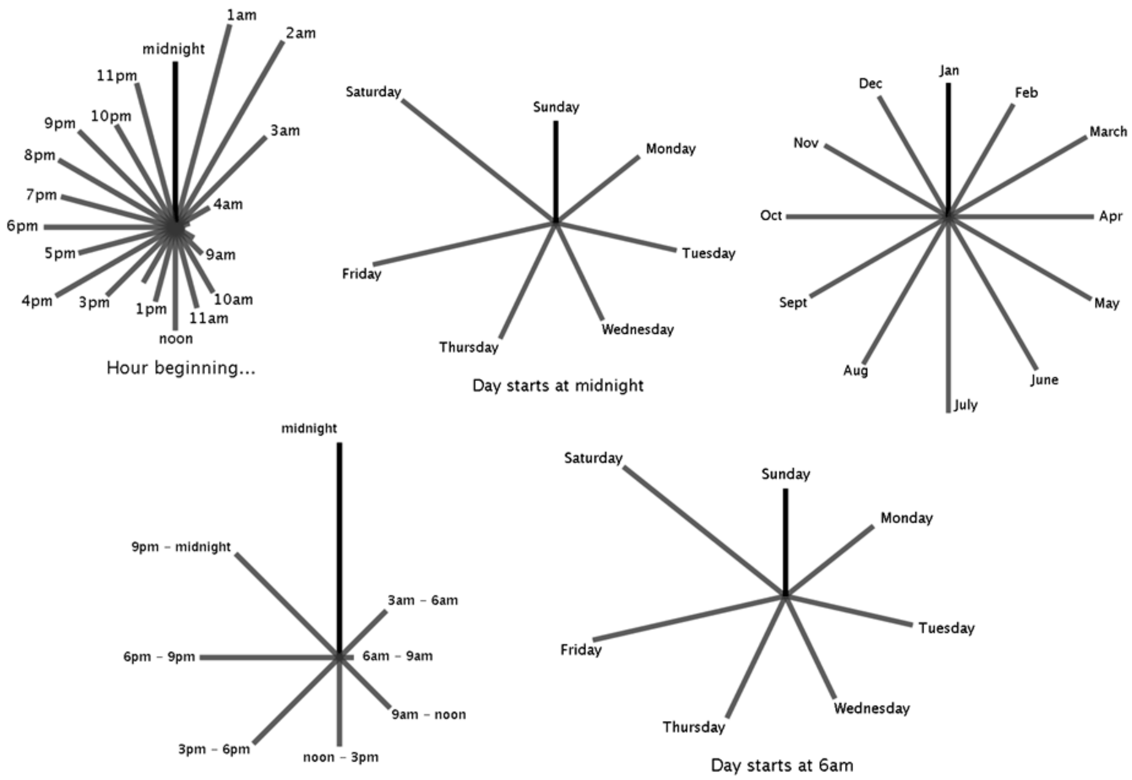

Figure 6.12: Temporal glyph 'crib sheet' provided to subjects for prototype sessions

6.2.2.3 LIBRARIES DIGITAL INTERACTIVE 'PROTOTYPE'

The Libraries digital interactive prototype is born from a process of selection from existing applications rather than creation from scratch. As van Wijk (2006) points out, "we aren't certain we really need new visualization methods to solve [a domain expert's] problem; possibly a combination of more traditional approaches will do, supplemented with an easy-to-use interface tailored to [the expert's] domain." This is clearly the right methodology where LCC Libraries is concerned. From the work to understand their context of use, there is a clear focus to be able to segment library borrowers in order to market effectively to them. A number of possible applications that perform clustering are available, and the task is to choose among them to find a 'prototype' candidate.

The need is for visual, exploratory, dimension-reducing clustering tools that feature a spatial component, because Libraries believe that there is a spatial component to their borrowers' behaviour, and pragmatically, because this is *geo*visualization research. This rules out statistical approaches such as factor analysis or principal component analysis. There is only very weak temporal variation in aggregate library borrowing and therefore applications that permit examining temporal patterns will not be of primary interest.

Tan, Steinbach and Kumar (2005) describe the basic concepts of cluster analysis; Berkhin (2002) surveys data mining clustering techniques; and Johansson et al (2005) look at ways to reveal structure within clustered parallel coordinates plots. Visual methods of exploring clustering are limited. Seo and Shneiderman (2006) describe their Hierarchical Clustering Explorer that uses non-spatial techniques, built initially to explore genomic datasets. While containing interesting tools, the Libraries' data requires a spatial aspect and a partitional clustering rather than hierarchical. A geovisualization approach to classification using k-means is available in the Pixelex application (Dykes, 2005c).

The self-organising map is "part of a large group of techniques known as artificial neural networks" (Skupin and Agrawal, 2008), and the canonical text is Kohonen (1995). Skupin and Fabrikant (2003) outline a cartographic research agenda for non-geographic information visualization, while Koua and Kraak (2004) and Skupin and Fabrikant (2003) use a SOM to provide an alternative visualization of large geospatial datasets. Most interestingly, Flexer (2001) demonstrates the use of self-organising maps for "clustering or visualization separately, for simultaneous clustering and visualization, and even for clustering via visualization." This is a highly useful approach, and a more detailed survey of available SOM applications is in order.

The original application for self-organising maps is SOM_PAK (Kohonen et al., 1992-5). A number of applications have been written to make access to the application easier, such as Vesanto et al (1999) via a Matlab toolbox, and the ongoing (but unfinished at the time of writing) work of Lacayo and Skupin (2007) to integrate a SOM into ESRI ArcMap via an add-in module, SOM Analyst (Lacayo, 2007-9). Others have written their own SOM applications such as Geo-SOM (Bacao, Lobo and Painho, 2005) and Carto-SOM (Henriques, Bacao and Victor, 2005). A SOM is part of the larger geovisualization toolkit, GeoVista Studio (Gahegan et al., 2002), and a SOM appears in its off-shoot VIS-STAMP (A Visual Inquiry System for Space-Time and Multivariate Patterns) (Guo et al., 2006), and SomVis (Guo and Gahegan, 2006). The last of these - SomVis - shows promise. Guo and Gahegan (2006) describe the use of the SomVis application (Guo, 2005) to:

> "summarize a large number of input data items in a moderate number of clusters with the Self-Organizing Map (SOM); encode the SOM result with a systematically designed color scheme; visualize the multivariate patterns with a modified Parallel Coordinate Plot (PCP) display and a geographic map (GeoMap); and support human interactions to explore and examine patterns."

In choosing an application from amongst academic software, there is always an element of the pragmatic - issues like availability, transparency and the ability to get an application running with one's own data. SomVis passes on all counts and selected as the Libraries' digital interactive 'prototype' candidate. The final test was to see whether SomVis could cope with the volume of Library data.

The available Libraries data is described in section 3.3.5.2 and covers borrowing from four South Leicestershire libraries over a two year period, aggregated by week. 'Cleaning' and temporally aggregating reduced a near gigabyte dataset to 16,932 complete records of active individual borrowers with one of the four libraries as their 'home library'. Library data is available at the individual borrower level aggregated for confidentiality reasons to full postcode. Individual borrower data is problematic to link to aggregated datasets of possible interest such as demographic datasets available only at output area level, like the output area classification, OAC (Vickers and Rees, 2007). Personal data on borrowers is limited to age and sex. Borrowing data is available for books, talking books, music (CDs) and film (DVDs), with book borrowing split into a number of fiction and non-fiction genres or classifications.

SomVis is stable with this dataset up to about 10,000 records and is unpredictably unstable at the full 16,932. However, by carefully selecting sub-sets of the full database – for example, by geography, by demographics or by borrowing characteristics - SomVis is serviceable for the task in hand. The basic functionality of a self-organising map is to reduce multi-dimensiona data and display it in a two-dimensional matrix with data values clustered at regular nodes. Nodes are typically differentially coloured and situated within a unified distance matrix (U-matrix) (Ultsch and Siemon, 1990) where "the distance between the adjacent neurons is calculated and presented with different colorings between the adjacent nodes….Light areas can be thought as clusters and dark areas as cluster separators." (Hollmén, 1996)

SomVis consists of a 'Control' screen , the self-organising map (SOM), a parallel coordinate plot (PCP) (Inselberg, 1985) and a map. The last three tools are linked so that a selection in one selects the corresponding data in the other two tools. The 'Control' screen loads data and an associated shapefile, the selection and weighting of variables from within the dataset and the size of self-organising map to generate. The SOM displays with coloured nodes, sized according to the number of data points allocated to each node which is embedded in a U-matrix. Node pattern sizes of 3 x 3, 5 x 5, 7 x 7 or 9 x 9 are possible. The PCP shows the individual clustered nodes arranged as a series of parallel plots. A typical SomVis display is shown in Figure 6.13. The map displays cluster membership represented by different colours; it is *not* a choropleth.

The application as it stands needs to be tailored for the LCC Libraries subjects in one important respect. The Libraries marketing subjects believe that there is a spatial component to borrowing (not least because borrowing derives from stock – if DVDs are not stocked in a particular library, then DVD borrowings will be zero), but this may be strong. Aggregated spatial units such as postcodes are highly unlikely to contain predominantly borrowing of a one type, and the level of spatial focus must be that of the individual borrower. The SomVis application can only handle spatial data as polygons. The library data contains the full postcodes of borrowers, and while postcode shapefile polygons are available, the problem of multiple borrowers in each polygon leads to representational problems. Ideally a transformation of individual borrower 'points' to individual borrower 'polygons' is desirable.

The TreeMappa application (Wood and Dykes, 2008) makes possible the representation of each borrower as a single rectangle within a spatial treemap that could be used as the framework for thematic mapping in SomVis. The rectangular treemap is produced by TreeMappa and preserves the original geographical correspondences between borrowers as far as possible. Effectively the generated treemap is used to produce a hierarchical rectangular cartogram – see Figure 6.14.

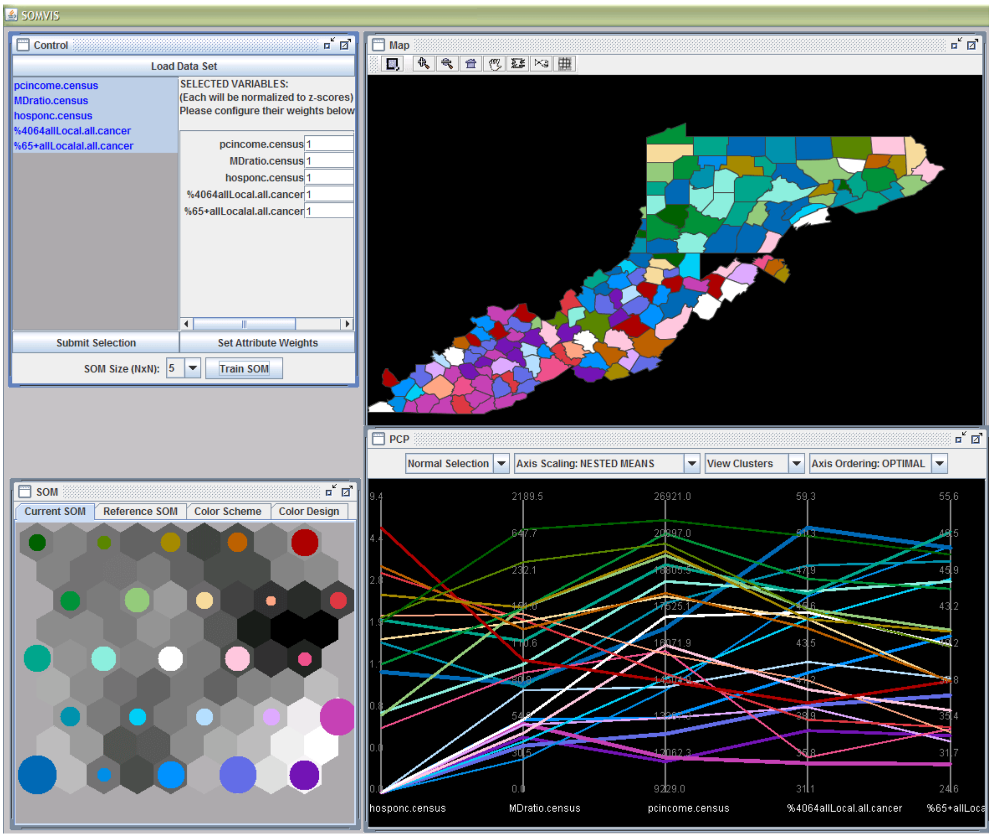

Figure 6.13: SomVis showing (clockwise from top right) control panel, thematic map, parallel coordinate plot and self-organising map with application-provided sample data (Guo, 2005)

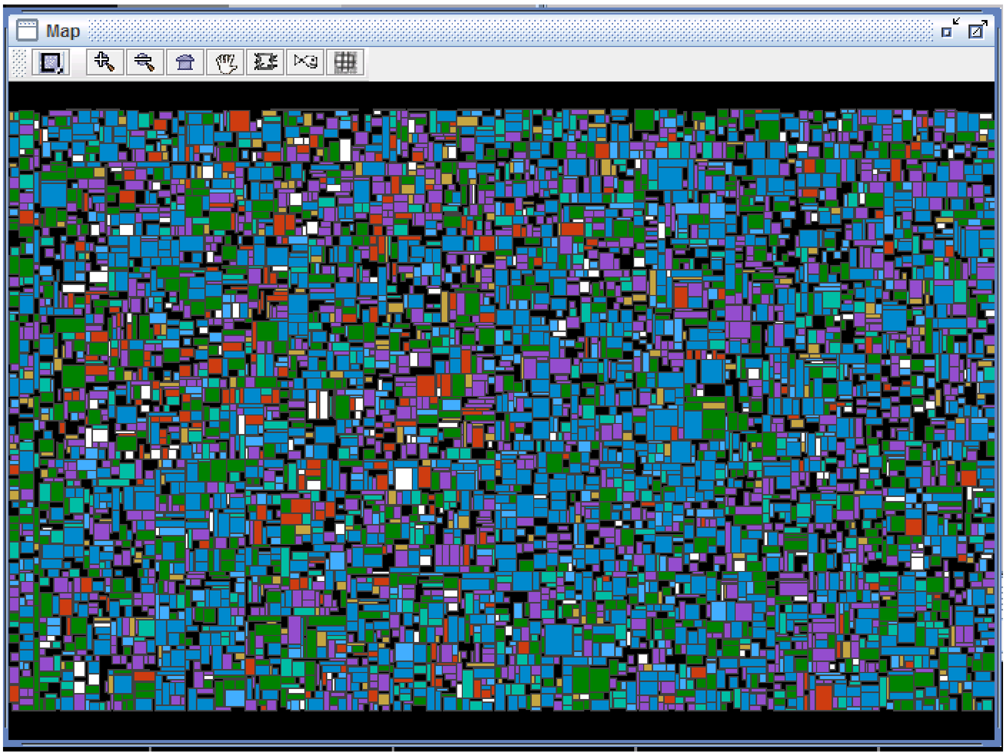

Figure 6.14: Thematic display of a sample from the Libraries database coloured by SOM cluster with each rectangle representing a borrower and sized by borrowings. Rectangles are produced using TreeMappa and largely conserve spatial correspondences

An advantage of this form of representation is the ability to select an appropriate aspect ratio for the resulting treemap (overcoming the problem identified in 'Critique of initial wireframe designs' in section 5.2.3) and yielding a data-dense display. Its obvious disadvantages for subjects are the removal of clear location and navigational clues, and the unfamiliar and abstract nature of its representation. However, the problematic spatial instability of treemaps is not an issue, as once the treemap is calculated it can be used for all visualizations as a 'container' for thematically coloured representations. In order to deal with the problem of multiple borrowers at a single postcode, postcode centroids were converted into their equivalent (x,y) coordinates and a 'geographical perturbation' applied by adding a small random amount to both x and y. This generated unique coordinates for each borrower (while retaining the spatial correspondence).

In spite of the advantages of the treemap view, there will be confounding effects that would not be present if a standard map were able to convey the data. Such confounding effects are inevitable. To ameliorate the problems associated with the unfamiliarity of the TreeMappa representation of the spatial data, a paper map that identified borrowers according to their 'home library' was produced in a GIS as a 'crib' for the library subjects– see Figure 6.15. The spatial representation of the home libraries depends on the hierarchical nature of the postcode numbering. A problem arises when a library's' catchment area spans postcode sector boundaries that, although spatially adjacent, have postcodes whose numerical codes indicate separation – in Figure 6.15 the borrowers with the 'red' home library are shown spatially separated, an artefact that does not reflect the reality. Nevertheless the issue can be partially addressed by providing Figure 6.15 as a 'crib'. Another approach would have been use the ability of TreeMappa to show the spatial extent within each of the four 'home libraries' – that is, placing 'home library' at the top of the treemap hierarchy. This would show the four home libraries as distinct rectangles, but complicate the explanation of the (now replicated) spatiality to the library subjects.

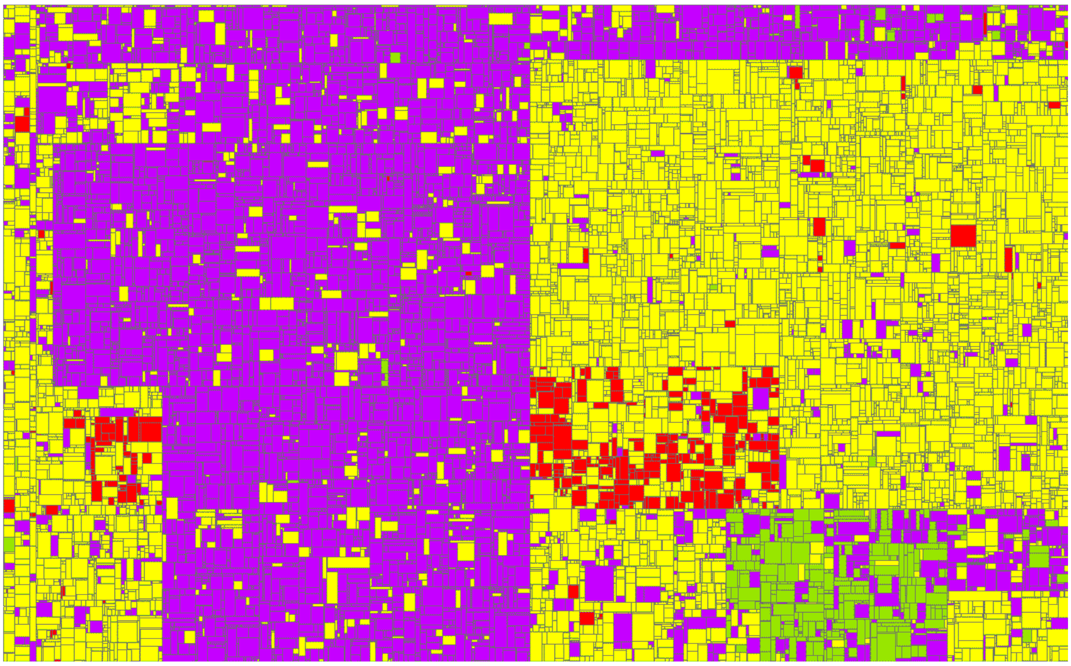

Figure 6.15: TreeMappa representation of borrowers' spatial location where each of the four colours represents one of four 'home libraries'. Each rectangle represents a single borrower and rectangle size is proportional to borrowing

6.2.3 PROTOTYPING PROTOCOLS

6.2.3.1 USER TESTING WITH CRIME PAPER AND DIGITAL INTERACTIVE PROTOTYPES

The construction of the digital interactive and paper crime prototypes is described in section 6.2.1. This section deals with the nature of the user tasks and the protocol used to explore the CDR subjects' interaction with these prototypes. The tasks were selected to explore different spatial, temporal, and crime attribute aspects of the prototypes. These aspects were: spatial resolution; crime attribute as temporal glyph (single); crime attribute as temporal glyphs (multiple); spatial zoom; spatial pan; absolute and relative data representations; and crime sub-attributes. The tasks themselves use the taxonomy described by Koua, MacEachren and Kraak (2006) and comprise categorise, compare, correlate, distinguish, distribution and locate task types. The tasks start with reasonably simple ones and finished with ones that were more complex, and this dictated the order in which the different aspects of the prototypes (spatial resolution to crime sub-attributes) and their associated tasks were exposed to the subjects.

The interaction with the CDR subjects was via a series of questions (Table 6.1 and Figure 6.16) designed to elicit information about both the usability of the prototype to inform its future development, and also the process of the prototype itself, to explore how a particular kind of prototyping (paper or digital interactive) works in a geovisualization context. Information was gathered from a mixture of 'think-aloud' (audio recorded with consent) as subjects completed the tasks, followed immediately by verbal questions about task/prototype or the prototyping process itself. At the end of both paper and digital interactive prototyping sessions, a set of summative questions (Figure 6.17) were asked about the overall prototyping experience. Separate paper and digital interactive prototype sessions were conducted with individual CDR subjects, typically lasted two hours per prototype. The exceptions to this were the first sessions, which involved C1. These lasted nearly three hours each and were clearly too lengthy for C1 who commented on the fatigue experienced. Therefore, subsequent paper and digital interactive sessions with C2 and C3 were shortened by removing two non-spatial task areas – 'crime attribute as temporal glyph (multiple)' and 'crime sub-types'.

Snyder (2003) advises that "in addition to users, there are three roles in a paper prototype usability test: the facilitator, the Computer, and the note taking observers" and gives guidance on combining these roles in fewer than three persons. Because of the demands of facilitating the subject sessions, operating the prototypes in 'chauffeur' mode, keeping to time, and operating the recording equipment, a small team was necessary, consisting of a facilitator (a geovisualization expert) and a 'Computer' (me). Snyder (2003) suggests that "it's difficult to test your own design…it's best to let someone else facilitate", hence the allocation of roles. I decided the role of the Observer was likely to be exceptionally complex given the detail and novelty of data to be collected, and was unlikely to be performed competently in real time with untrained personnel. Though R was present during the sessions, the Observer role was taken 'off line' for later audio transcription of 'think aloud' and summative question responses.

The facilitator's roles in the user testing is to:

- make the subject as comfortable as possible during the sessions, get consent forms signed, explain purpose of different roles, timetable and what to do if help is needed
- explain the prototype, how to interface with it, and its functionality
- check subject's understanding; emphasise that subject should 'think aloud' in tasks
- pose task(s) (repeating if necessary); remind subject to think aloud if the flow dries up
- elicit results from subject using the 'active intervention' approach suggested by (Dumas and Redish, 1999), prompting for supplementary information
- ask summative questions about the tasks/prototypes and the process
- prompt the subject for any other feedback before ending every stage of the session.

The "Computer's" role in the user testing is to supply the piece of paper (paper prototype) or the URL string (digital interactive prototype) necessary to comply with the subject's inputs in a slick but unobtrusive manner, resetting the prototype to the state it needs to be in after each stage. The Computer remains as silent as possible except to offer a brief 'Help' service to the subject when requested, and is the only operator of the prototype.

Different crimes, but with a similar pattern of concentration in town centres, were chosen for the paper and digital interactive prototypes to avoid a learning effect. One subject, chosen at random, was exposed to the digital interactive prototype first – the other CDR subjects had the paper prototype first. The paper prototype was based on Assault – a crime that has two major components - domestic violence, and assault relating to the night-time economy (the latter has the greater incidence). The digital interactive prototype was based on 'All Other Theft' (AOT), a 'catch-all' theft category that excludes the crimes of theft of and from a motor vehicle, and whose major components are theft from the person (for example, purse and wallet snatching) and theft from shops (for example, shoplifting). Both crimes have components that produce concentrated spatial patterns linked to town centres, but different temporal patterns.

One issue with the digital interactive prototype was the availability of the functionality to zoom and pan the thematic map using the SVG plug-in capabilities, a functionality clearly not possible in the paper prototype. Permitting SVG zoom and pan would have given a considerable *interaction* advantage in functionality to the digital interactive prototype over the paper version, and would almost certainly have influenced the subjects in their comparisons between the two. Nor could such functionality be implemented via a 'chauffeured' method with paper input. For these reasons, the SVG zoom and pan functionality was not made available to subjects in order to maintain as much commonality as possible with the paper prototype, and enabling the control of this variable.

Table 6.1 shows the questions for paper prototype against the task taxonomy derived from Koua, MacEachren and Kraak (2006). Figure 6.16 gives the setup, task(s), questions and task/prototype summative questions and the process summative questions for the paper prototype. The corresponding one for the digital interactive prototype is almost identical (they differ, for example, in respect of the presence of the treemap in the paper prototype and its absence in the digital interactive prototype). Figure 6.17 shows overall summative questions used when both user testing sessions were completed.

QUESTION	TASK TYPE: categorise	compare	correlate	distinguish	distribution	locate
1 SPATIAL RESOLUTION						
Tell me where you think are the areas of high assault as you change resolution	x	✓	x	✓	x	✓
2 ATTRIBUTE GLYPH (HOURS)						
2a How does the hourly pattern of assault in the square with the most assaults compare with the other squares?	x	✓	x	x	x	x
2b Are there any squares that have a similar hourly distribution of assault with each other? Which are they? Are there any other squares that share a similar time pattern?	✓	x	x	x	x	x
2c Are there any underlying reasons for this/these clusters of patterns you've observed do you think? If so, what are they?	x	x	x	✓	x	x
3 ATTRIBUTE GLYPHS (TIME - ALL)						
3a How does the spatial 'hours grouped in three hours bands' view differ from the 'by hour' view of assault? Does the grouping into three hour bands make any pattern clearer? Whereabouts on the map? Are any patterns visible on the hourly glyph lost when	x	✓	x	x	x	x
3b Do the two 'days of the week' glyphs (the one that starts at midnight and the one at 6am) give different spatial patterns anywhere? Where? What underlies these different patterns do you think?	x	✓	x	x	x	x
3c Are there any underlying spatial patterns in the monthly pattern of assault you can see? If so, where are they? What underlies these do you think?	x	x	x	✓	x	x
4 SPATIAL ZOOM						
4a How does the spatial pattern of assault by hour of day differ between the whole of Loughborough and the town centre area?	x	✓	x	x	x	x
4b For the town centre of Loughborough (1km square), how does the hourly pattern of assault in the square with the most assaults compare with the other squares?	x	✓	x	x	x	x
4c For the town centre of Loughborough, are there any squares that have a similar hourly distribution of assault? Which are they? Are there any other squares that share a similar time pattern?	✓	x	x	x	x	x
4d For the town centre of Loughborough, are there any underlying reasons for this/these clusters of patterns you've observed do you think? If so, what are they?	x	x	x	x	✓	x
5 SPATIAL PAN						
5a How does the spatial pattern of assault by hour of day differ between Loughborough town centre area and the areas bordering it? What reasons are there for these patterns, do you think?	x	✓	x	x	x	x
5b How does the spatial pattern of assault by hour of day compare for areas of high assault on the approaches to Loughborough's two railway stations (they are north and east of the town centre)?	x	✓	x	x	x	✓
6 ABSOLUTE AND RELATIVE DATA REPRESENTATIONS						
Is there any link as far as you can see between areas of Loughborough town centre that have high levels of assault in 2006 with those areas whose level of assault is above the five year average? What lies behind these links (or lack of them) do you think	x	✓	✓	x	x	✓
7 CRIME SUB-ATTRIBUTES						
7a How does the spatial pattern of Common Assault by hour of day differ from Harassment and from Other Wounding for the town centre of Loughborough?	x	✓	x	x	✓	x
7b How does the spatial pattern of Common Assault by hour of day differ from Harassment and from Other Wounding for areas where there is a medium to high absolute incidence of these three crimes? What reasons are there for these patterns, do you think?	x	✓	x	x	✓	x
7c How does the spatial pattern of Common Assault by hour of day differ from Harassment and from Other Wounding for areas where there is a medium to high absolute incidence of these three crimes? What reasons are there for these patterns, do you think?	x	✓	x	x	✓	✓
7d Looking at the components of Assault in the town centre of Loughborough for 2006 and seeing both absolute and relative levels of crime, where would you advise your constituents to place their funding?	x	✓	x	x	✓	✓

Table 6.1: Task questions for paper prototype user testing related to task type

1 SPATIAL RESOLUTION

Set up

"The first aspect of this prototype I want to show you is the ability to look at data at a number of different *<u>spatial resolutions</u>. This map shows a 5km x 5km area of Loughborough and colours – going from light yellow to dark green – show the absolute number of assaults in 2006. All the data we are going to show relates to 2006. We are using the crime classification system "CIS Group", so this is "ASH" Assault. This control allows you to change the spatial resolution – you touch the control on the paper and we'll do the rest. Currently it shows 1km squares."*

Task *"Tell me where you think are the areas of high assault as you change resolution."*

Task/prototype summative questions

"Is the ability to change resolution like this useful to you in exploring data?"
"Which resolution or resolutions is/are the most useful? Why? What things would you be able to get from one resolution rather than another?"

Process summative questions

"Did you feel that changing resolution using pieces of paper gave you a realistic sense of exploring the data?"
If so, *"what aspects worked particularly well?* If not, *"why not?"*
"What could have improved things, given that we are using paper?"

2 ATTRIBUTE GLYPH (HOURS OF DAY GLYPH)

Set up

"Another aspect of this prototype is the ability to show time aspects of crime data in the form of a spider diagram or glyph. This glyph, for example, shows the distribution of assault by hours of the day. There are 24 lines each corresponding to one hour of the day. The vertical one at the top corresponds to the hour beginning midnight, for example. When we have an area on the map with 5 or fewer squares per side, glyphs appear for those areas. So each line represents the absolute number of assault crimes committed in that 1km square in 2006 for that particular one hour period."

Tasks

2a *"How does the hourly pattern of assault in the square with the most assaults compare with the other squares?"*
2b *"Are there any squares that have a similar hourly distribution of assault? Which are they? Are there any other squares that share a similar time pattern?"*
2c *"Are there any underlying reasons for this/these clusters of patterns you've observed do you think? If so, what are they?"*

Task/prototype summative questions

"Are hourly glyphs like this useful to you in exploring data?"
"Did you know the time clusters you identified would be there before you looked at the prototype? Were any time clusters you identified new to you?"
"Is it easy to see the glyphs against the coloured background? Is there a better way to represent time in hours?"

Process summative questions

"What worked and what didn't work doing this with paper?"
"What could have improved things, given that we are using paper?"

3 ATTRIBUTE GLYPH (TIME - ALL)
Set up *"We've now explored the hours of the day using an hours glyph. We have four other glyphs to show you. One groups the hours of the day into eight three-hour bands – midnight to 3am is the vertical at the top. There are two glyph designs show the seven days of the week – on one the day starts at midnight, the other at 6am – Sunday is at the top vertical. Finally there's a glyph showing the twelve months of the year; January at the top vertical. They all go clockwise. As you select a different glyph, both the overall area (the right hand piece of paper) and the glyphs on the map change Each glyph line represents the absolute number of assault crimes committed in that 1km square in 2006 for either hours, three-hour bands, days of the week or months."*

Tasks
3a "*How does the spatial 'hours grouped in three hours bands' view differ from the 'by hour' view of assault? Does the grouping into three hour bands make any pattern clearer? Whereabouts on the map? Are any patterns visible on the hourly glyph lost when the hours are grouped? Whereabouts on the map?"*
3b "*Do the two 'days of the week' glyphs (the one that starts at midnight and the one at 6am) give different spatial patterns anywhere? Where? What underlies these different patterns do you think?"*
3c *"Are there any underlying spatial patterns in the monthly pattern of assault you can see? If so, where are they? What underlies these do you think?"*

Task/prototype summative questions
"Are these other time-based glyphs like this useful to you in exploring data? Which ones? Why? Are any not useful?"
"Were any time patterns you identified new to you?"

Process summative questions
"What worked and what didn't work doing this with paper?"
"What could have improved things?"

4 SPATIAL ZOOM
Set up
"We have so far looked at Loughborough at a size of 5km square. The prototype has a facility to zoom into smaller areas (and zoom out again). On this prototype we are able to zoom into the town centre of Loughborough – an area 1km square. We are back to looking at just hours of the day now. Remember this is all assault for 2006."

Tasks
4a *"How does the spatial pattern of assault by hour of day differ between the whole of Loughborough and the town centre area?"*
4b *"For the town centre of Loughborough (1km square), how does the hourly pattern of assault in the square with the most assaults compare with the other squares?"*
4c *"For the town centre of Loughborough, are there any squares that have a similar hourly distribution of assault? Which are they? Are there any other squares that share a similar time pattern?"*
4d *"For the town centre of Loughborough, are there any underlying reasons for this/these clusters of patterns you've observed do you think? If so, what are they?"*

Task/prototype summative questions
"Did you know the time clusters you identified would be there before you looked at the prototype? Were any time clusters you identified new to you?"
"Would you want to zoom in further?"
"Would it be difficult to distinguish between glyphs if they were shown 10 x 10 instead of 5 x 5?"

Process summative questions
"What worked and what didn't work doing this with paper?"
"What could have improved things, given that we are using paper?"

5 SPATIAL PAN
Set up
"The other basic spatial operation apart from zooming is panning – moving around within the area - up, down, right and left. The prototype allows us to explore the four areas immediately north, south, west and east of the town centre square. We are still looking at just the hours of the day, and all assault happening in 2006."

Tasks
5a *"How does the spatial pattern of assault by hour of day differ between Loughborough town centre area and the areas bordering it? What reasons are there for these patterns, do you think?"*
5b *"How does the spatial pattern of assault by hour of day compare for <u>areas of high assault</u> on the <u>approaches</u> to Loughborough's two railway stations (they are north and east of the town centre)?"*

Task/prototype summative questions
"Did you know the time clusters you identified would be there before you looked at the prototype? Were any time clusters you identified new to you?"
"Would you want to zoom in further? Would it be difficult to distinguish between glyphs if the they were shown 10 x 10 instead of 5 x 5?"

Process summative questions
"What worked and what didn't work doing this with paper?"
"What could have improved things, given that we are using paper?"

6 ABSOLUTE AND RELATIVE DATA REPRESENTATIONS
Set up
"So far we have looked at 2006 crime data as an absolute number of crimes represented by the colour of the squares on the prototypes. Another way is to show 2006 assault in relation to the average over the previous five years or so. (Computer: reveal absolute/relative options). We are still looking at just the hours of the day. The colours here run from dark blue to lighter blue to white to light red to dark red. The blue colours represent areas for which 2006 is below the 5-year average; red represents above the 5-year average. There is an additional feature on the map and that's the presence of a circle whose size is related – approximately – to the absolute level of assault. So, small circle on this map equals a light yellow colour on the other map; and a big circle represents a dark green colour on the other map."

Task *"Is there any link as far as you can see between areas of Loughborough town centre that have high levels of assault in 2006 with those areas whose level of assault is above the five year average? What lies behind these links (or lack of them) do you think?"*

Task/prototype summative questions
"Is this "relative" view something you might use in exploring data?"
"What other comparison – other than 'average of last 5 years' would be useful?"
"Would you see a role for this "relative" way of looking at data in your role of presenting data?"
"Did the "circle" on the "relative" display help or hinder you? Please expand."
"Would "visual cues" like the circle be useful in other parts of the prototype to add another aspect of the data? What kind of cues? Where in the prototype?"
"Are the blue-white-red colours right for the "relative" view of the data? How about the yellow-green" scheme for the absolute values?"

Process summative questions
"What worked and what didn't work doing this with paper?"
"What could have improved things, given that we are using paper?"

7 CRIME SUB-ATTRIBUTES
Set up *"We have confined our attention to just one crime category – assault. The prototype is capable of showing this crime in more detail in both map and treemap form by giving information on some components of assault – Common Assault, Harrassment, Other Wounding and the remainder - Assault minus these three sub-categories We are still looking at just the hours of the day and 2006. We also have both absolute and relative data view available."*

Tasks
7a "*How does the spatial pattern of Common Assault by hour of day differ from Harassment and from Other Wounding for the town centre of Loughborough?"*
7b *"How does the spatial pattern of Common Assault by hour of day differ from Harassment and from Other Wounding for areas where there is a medium to high absolute incidence of these three crimes? What reasons are there for these patterns, do you think?"*
7c "*How does the spatial pattern of Common Assault by hour of day differ from Harassment and from Other Wounding for areas where there is a medium to high absolute incidence of these three crimes? What reasons are there for these patterns, do you think?"*
7d "*Looking at the components of Assault in the town centre of Loughborough for 2006 and seeing both absolute and relative levels of crime, where would you advise your constituents to place their funding?"*

Task/prototype summative questions
"Does the exploration of the hourly distribution of assault sub-categories give any additional insight into Assault generally? If so, what insights does it provide?"
"How useful was the treemap with glyphs? Does the fact that the treemap shows the relatives sizes of the sub-categories of Assault add anything, or could they have just as well been shown in boxes of the same size?"
"What it be useful to provide any other information – for example pub locations?"

Process summative questions
"What worked and what didn't work doing this with paper? What could have improved things, given that we are using paper?"

Figure 6.16: Setup, task(s), questions and task/prototype summative questions and the process summative questions for the paper prototype

1 Overall, how did the digital interactive prototype compare to the paper prototype?
2a Are we on the "right track" with what we are doing? 2b Should we be doing something different?
2c Is what we are doing relevant to your needs?
2d Can you see yourself using an application that does these kinds of things?
3a Were the task sensible? 3b Which weren't? Why?
4 Do you believe we are making progress towards a working application by the succession of prototyping we have been doing over the last two months?
5a How have the last two hours been? 5b Did you learn anything new? If so, what was that?
6 Is there anything else you would like to say about ANY aspect of what we've done today or so far?

Figure 6.17: Overall summative questions used when both user testing sessions completed

Figure 6.18 shows the paper prototype during user testing and Figures 6.19a and 6.19b two views of the digital interactive prototype. User testing took place over three days. C1 was tested first on both prototypes (paper first in the morning; digital interactive in the afternoon, taking a whole day) at LCC in a room away from C1's normal place of work. A large laptop was used as the display screen for the digital interactive prototype. The user testing of C2 took place at a conference facility in Leicester, away from C2's normal place of work and both paper (first) and digital interactive (second) were completed in a (long) morning session. For C3, the user testing of the digital interactive protototype took place at the same conference facility in the afternoon, and the paper session was completed the next day in a room away from C3's normal place of work.

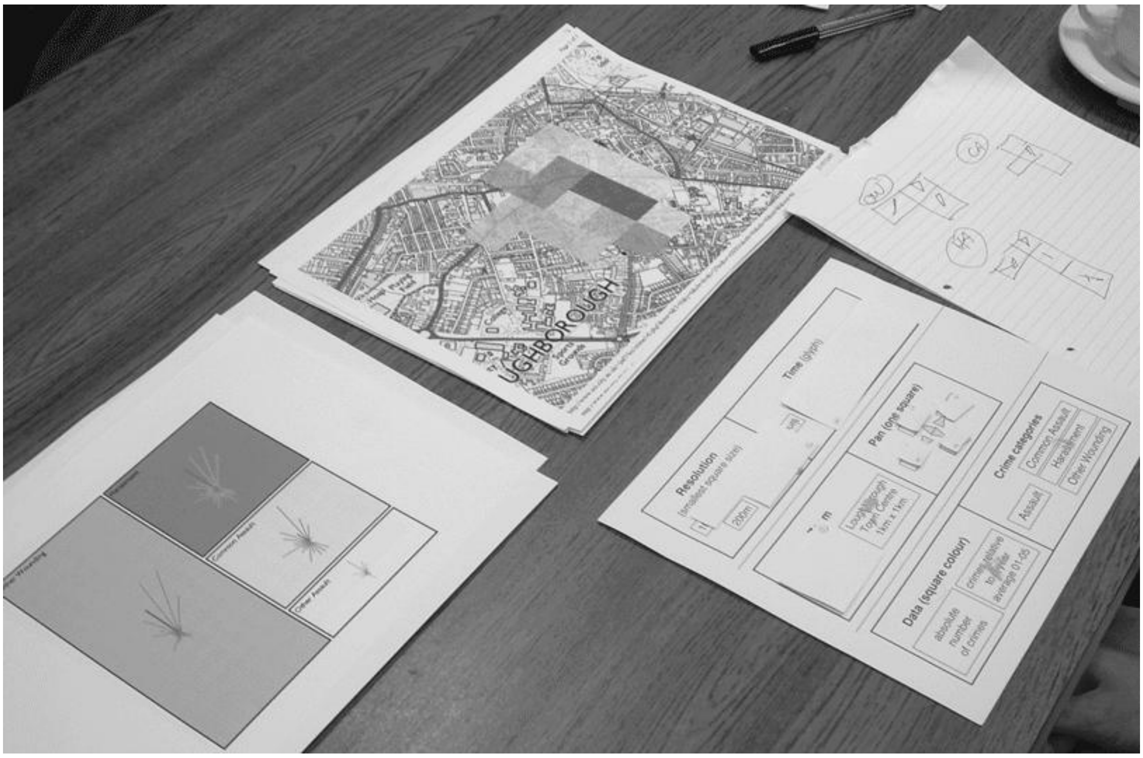

Figure 6.18: Paper prototype during user testing showing (left to right) treemap and thematic map (both with temporal glyphs) and input sheet for the user interface

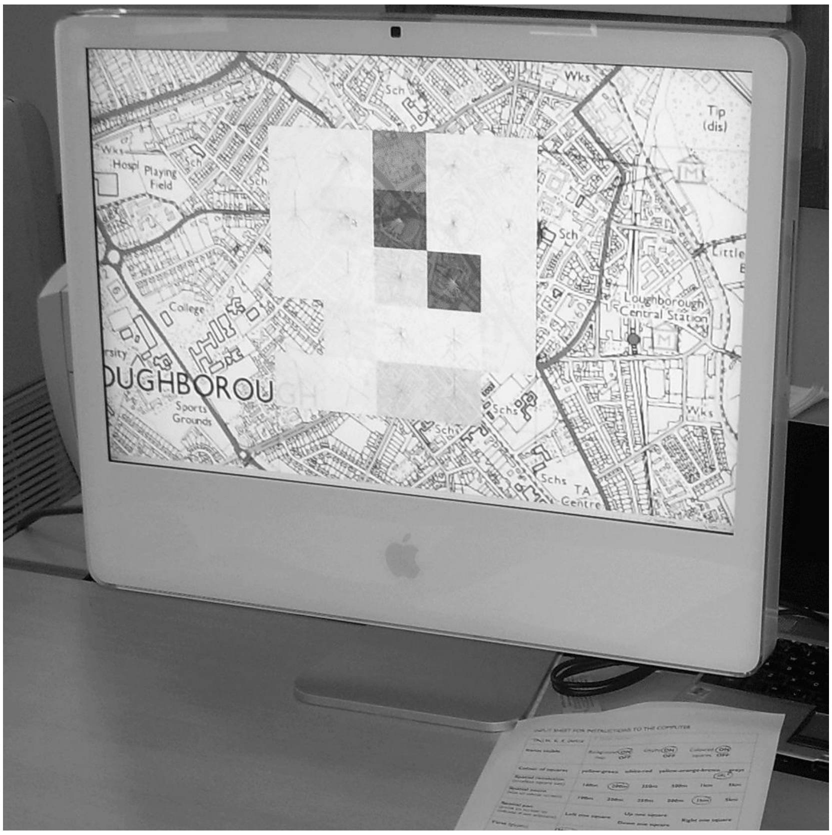

Figure 6.19: (a) and (b) Two images of digital interactive prototype being used in 'user testing' protocol with 'chauffeured' selection of the display.
Screens show thematic map and temporal glyphs; the paper input sheet can be seen to the left of the top picture and the right of the bottom picture.

6.2.3.2 FREE EXPLORATION WITH THE CRIME DIGITAL INTERACTIVE PROTOTYPE

The digital interactive prototype was used with a CDR subject, C3, with a different protocol from user testing – that of free exploration. Only C3 was available to undertake this as C1 had left LCC and C2 was unavailable on the day scheduled for the free exploration. C3 was asked a week in advance of the session to select some exploratory work C3 would like to perform with the digital interactive prototype that was non-trivial, suited to the prototype and that was likely to lead to engagement with the prototype for period of about an hour. C3 chose to explore the 'criminal damage' crime category:

> *"The reason I've picked [criminal damage] is because I feel that there's going to be multi[ple] dimensions to the kind of behaviours behind it. I'm expecting at least two different parts of the day when there is going to be different things happening, 'cos when you look at it traditionally over the day you normally get a peak at after school, and a peak late at night. And the fact that you've got the town centre itself with the pubs, nightclubs and Night-time Economy in it, but it's also - it's Loughborough - it's got some big schools and the schools all tend to be together as well, so it's kind of to test out a theory that you've got a set of data that [I] can explain spatially and temporally…" [C3]*

In order for C3 to be able to explore the dataset freely, C3 should interact with the data directly and not through an intermediary. But the user interface of the digital interactive prototype is highly functional – strings entered into a browser that permit php code to access a MySQL database and return the desired graphics in SVG form for display in a browser. The first stage of the free exploration was therefore to give C3 a tutorial on how to operate the interface. This was in the form of a PowerPoint presentation and covered all the various possibilities offered by the prototype – images; coloured backgrounds; resolutions; offences; time glyphs; signed chi-statistic display; zooming and panning (using SVG in-browser controls). It consisted of about 40 slides and took 30 minutes to deliver. To support this, a "crib sheet" showing the main interface components was given to C3 to refer to throughout the session. C3 was allowed to try out the interface to the prototype before the session began and expressed confidence in operating it effectively.

The session was conducted in a room away from C3's normal place of work. The prototype - covering the same geographical area as before (Loughborough) - was set up with a start string www.soi.city.ac.uk/~jad7/lcc/crime/v6.php?, and C3 given about one hour to explore the dataset. I offered to provide help with the interface at any time, asked C3 to 'think aloud' for the duration of the session (which was audio recorded with consent). C3 was asked to examine the data with the prototype "until you feel you would not gain any more insight", and in particular should articulate through 'think aloud':

- the reasons why screens are changed,
- whenever something is seen in the data that is interesting to them – "observations, inferences, conclusions" (Saraiya, North et al, 2006),
- whether a finding that is interesting is something new that has been learned, or something already known, or something else entirely (these are categories corresponding to "unexpected finding", "confirmed knowledge" and "additional finding" as suggested by Flood (2007)),
- whenever there is any problem with the prototype,
- whenever there is a wish that the prototype did something it can't do currently.

At the conclusion of the session, summative questions were asked to gain information on:

- the positive and negative aspects of the process;
- the perceived strengths and weaknesses of the prototype;
- summative views on what had been learned (Flood, 2007)) that was:
    - new
    - already known
    - something else entirely
- the conduct of the session
- specific questions considered in advance to be of interest such as the adequacy of the interface, prototype speed, and the importance of real data.

The detailed questions were as follows. Whenever C3 was unable to offer responses, prompts were used.

- Could you give me some adjectives to describe the positive aspects of the last hour or so? How about some negative ones?
- What were the strengths of the prototype in this "exploratory mode"?
- What were the weaknesses of the prototype in this "exploratory mode"?
- Did you learn anything new from exploring the data today? If yes, what did you learn that was new?
- Did you find out anything that confirmed something you already knew from exploring the data? If yes, what was that?
- How well did the tutorial on the interface help you operate the prototype?
- How well did the "crib sheet" help you operate the prototype?

- How acceptable would it be to you to operate the prototype long term with the interface it has at the moment?
- Did the speed at which things happened change the way you interacted with prototype?
- Can you see yourself using an application that does these kinds of things?
- How important to you is being able to see your own, real, data in the prototype?
- Is there anything else you would like to say about any aspect of what we've done in this session today?

The evaluation of the free exploration protocol within LCC CDR comprises case number 11, and its comparison with user testing case number 12.

6.2.3.3 FREE RANGE EXPLORATION WITH LIBRARY DIGITAL INTERACTIVE 'PROTOTYPE'

Of the two cases within LCC, one – crime and disorder reduction – represents subjects who have a good knowledge of their data, use a GIS, spreadsheet and statistical tools, and who explore the details of their data as part of their roles. The other - public libraries marketing - represents subjects whose knowledge of their data is poor, who do not employ GIS tools, and who do not explore details of their data as part of their everyday roles. (see sections 3.3.1.1, 3.3.1.3, 3.3.2, 3.3.3.1 and 3.3.3.2).

In approaching prototyping with LCC public libraries, I bore in mind their strong desire to be able to identify customer segments within their data in order to market subsequently to those segments, expressed in interviews (section 3.3.1.3). Clearly, tasks had to be related to that end in order to engage the subjects. Experience from the use of the free exploration protocol within LCC CDR by this time had indicated that results were at least as good as from user testing with an active intervention protocol, and sessions were easier to manage. Using a free exploration protocol with public libraries would enable an important comparison to be drawn between its use in two domains (case number 14). 'Free exploration' was chosen as the protocol to evaluate how the libraries subjects conduct exploration with a digital interactive 'prototype', and this comprises case number 13. See the Table 2.2 extract at start of this chapter for details of these case studies.

Clearly, the applications in these domain cases are very different, as are the goals and motivations of the two sets of subjects. And, given the difficulties communicating geovisualization to the CDR team, it is clearly a difficult proposition to use SomVis with its novel tools within LCC public libraries.

Subject L1 expressed a strong desire to involve two colleagues (L2 and L3) from the LCC Community Services management information team who had spreadsheet and statistical skills, and so the work was structured as a 'co-discovery' exercise with all three present at once. This represents a further difference from the CDR free exploration session that features a single individual. But it also represents the practical reality of conducting fieldwork with real users. A 'co-discovery' session has a number of benefits. Snyder (2003) lists co-discovery as:

- more comfortable for the users
- easier for the facilitator
- generates more data

Dumas and Redish (1999) state that "talking to another person is more natural than thinking out loud alone. Thus co-discovery tests often yield more information about what the users are thinking and what strategies they are using to solve their problems than you get by asking individual participants to think out loud."

In the case of free exploration, the three-role team of facilitator, 'Computer' and observer (Snyder, 2003), is reduced to two roles as the subject is now adopting the 'Computer' role. If observing is 'off lined' by way of audio recording and later transcription, then a single role, that of facilitator, remains.

Because of the library subjects' relative lack of knowledge about their data (compared to CDR), their relative lack of skills and their complete unfamiliarity with geovisualization, or the notion of data exploration, I decided that the free exploration session with SomVis would need to be preceded by another, equally substantial session. This would examine firstly their available data and metadata, consider ways to derive meaning from it such as exploratory data analysis, simple statistical measures and plots, and introduce spatial analysis with a GIS. Secondly, the representation of borrowers as a rectangular cartogram would be shown with a variety of variables. Finally, SomVis itself would be introduced via its individual component tools – the parallel coordinate plot and the SOM (with the map). This approach was influenced by the results from Chapter 5 where I suggested that **scavenging existing applications** for elements that can produce relevant visual representations of subject data as a way to achieve subject engagement. A day was scheduled for this preliminary session which was audio recorded with consent and took place in a room away from the library subjects' main place of work.

The preliminary session lasted three and a half hours in total (excluding a break) and contained:

- An introduction that reprised my understanding of LCC libraries marketing, the state of their data, and their desire to cluster their customer base, before introducing the rest of the session; signing of consent forms.
- A presentation on the extent of the data available for four libraries in south Leicestershire (see section 3.3.5.2) looking at the contents of the dataset and its metadata. Conveying an understanding of the data 'cleaning' process this data has undergone and the decisions I made to L1-L3 (definitional issues; exclusions were due to: 'home library' listed as other than Oadby, Wigston, South Wigston and Great Glen ('study libraries'); no borrowing in the period; missing data (eg postcode, gender); borrowing at one of the four study libraries by people whose home library was elsewhere)
- An exploration of extracted data with a range of spreadsheet tools - some numerical (mean, quartiles, variance), some graphical (box and whisker plot for 1D data; histogram for 1D data; scatter plot to explore 2D data) so that L1-L3 get a feel for the data and understand the strengths and limitations of this approach.
- A spatial exploration of the extracted data using a GIS conveying the limitations of the data (explanation of how data is referenced by postcode and the problems of multiple borrowers per postcode; getting L1-L3 familiar and comfortable with TreeMappa cartogram representation).
- Using of GIS to introduce TreeMappa rectangular cartogram (Figure 6.15) for visualising individual borrowers.
- Showing L1-L3 the available library variables in a GIS displayed within the cartogram in order to see which variables were of most interest to L1-L3, and to demonstrate possibilities offered by changing colours; flipping symbolisation; changing number of breaks; changing classification method. Showed how spatial representations can be supplemented by graphical representations by adding a histogram within GIS.
- Discussing with L1-L3 the notion of increasing and decreasing the relative importance of variables by weighting them differently.

- A simple explanation of how SomVis works and the role of the different tools (PCP, SOM and map) one at a time (SomVis up on screen but static, no interaction)
- Running SomVis using a sample of real library data to demonstrate its linking capabilities (taking L1-L3 through the process of selecting variables, applying a weight, selecting size of SOM and visualizing result on PCP and cartogram map, with linking and brushing and showing save options so borrowers in each cluster can be subsequently identified).

At the end of the preliminary session, L1-L3 agreed to a further session where they would filter their choice of data to create sub-sets to input into SomVis (mindful of its inability to handle all 16,932 records at once), and 'drive' SomVis themselves to explore the clusters that emerged.

In advance of that subsequent session, L1-3 discussed what sub-sets of their data they wanted to use and decided on 'aged 45 to 54'; 'aged 55 to 64'; 'males'; 'borrowers responsible for the top 80% of borrowings of issues of all kinds'. I subsequently produced these in a standardised form, with log transforms (except for recency and number of library visits), statistical normalization, and with range adjusted to run from zero to 1000, and 'ready to run' in SomVis. I produced a pre-generated record sheets for the exploratory session, both to save time on the day and to ensure that all essential information was easy to record by a library 'scribe'. I also created a series of colour charts for all possible SOM sizes with a number allocated to each colour, anticipating that referencing SOM clusters this way would minimise possible ambiguity.

Also in advance of this session, lead roles were allocated between the subjects. They decided L1 would take the lead in deciding the direction of the exploration; L2 would act as 'scribe', recording insights the subjects found useful and keeping track of where particular 'runs' of SomVis were recorded; and L3 would operate SomVis.

The main exploratory session of the library subjects with SomVis took place in a room away from their main place of work (but not wholly isolated from external interruption) and lasted four and a half hours in total, excluding two breaks. The session was audio recorded with consent for later transcription.

At the start of the session, I outlined the plan for the day with timing, confirmed the roles the subjects were adopting, distributed a list of their chosen sub-sets for examination with instructions for loading each file, gave the 'scribe' the pre-prepared recording forms for each data sub-set, and provided the SOM-numbering colour charts.

I recapitulated the use of SomVis covering how to load the various data sub-sets, variable selection and weighting, initialising the SOM and selecting its size, how to save a particular run (with a suggested naming convention scheme to make recording easier), how to interact with the SOM, PCP and map of the rectangular cartogram, and explained some of the more advanced options the application offers.

I requested the subjects 'think aloud' during the session, and I used an 'active intervention' protocol (Dumas and Redish, 1999) in a facilitating role. Guidance was provided verbally as well as in writing for the think aloud (substantially the same guidance as given to C3 for the free exploration session) as follows:

> Please "think aloud"…externalise your thoughts… about what is going on, what your feelings are, if you gain a particular insight, if something doesn't make sense or if you need help. In particular. please say:
>
> * Why you have selected the variables you have
> * Why you have selected the weightings you have
> * Why you have selected the SOM size you have
> * Whenever you see something in the data that is interesting to you
> * Whether a finding that interests you is something new you have learned, or something you already knew, or something else entirely
> * Whenever you have any problems with SomVis
> * Whenever you think of something you want SomVis to do that it can't do

Subjects were asked to explore the data for clusters and examine the data with the prototype until they feel they would not gain any more insight. Figure 6.20 shows SomVis in use by subjects to explore LCC library data. After the natural end of the first SOM exploration (including any iterations), the subjects were offered the opportunity to use a rectangular cartogram based on total issues by borrower instead of the one based on equal area per borrower. This opportunity was taken up for the rest of the session.

After several hours spent exploring the data, the exploratory sessions were concluded, a summative questionnaire was given to each subject to complete (to determine individual responses to the session, taking 10 minutes to complete) – see Table 6.2.

	Likert scale	
Question	"1" means:	"5" means:
1 How good an understanding do you have of how to do clustering of library variables using	*very good*	*very poor*
2 How good was the instruction you received in how to use SomVis?	*very good*	*very poor*
3 How good was the supporting materials for the day (record sheets, map pictures, prompt sheets on "thinking aloud" etc)?	*very good*	*very poor*
4 Overall, how easy did you find SomVis to learn?	*very easy*	*very hard*
5 Overall, how easy did you find SomVis to use?	*very easy*	*very hard*
6 Did you prefer the map of borrowers based on 'total issues' or the 'equal size' one?	*strong preference for 'total issues' map*	*strong preference for 'equal area' map*
7 How easy was it to select variables in SomVis?	*very easy*	*very hard*
8 How easy was it to select weightings in SomVis?	*very easy*	*very hard*
9 How easy was it to select SOM size in SomVis?	*very easy*	*very hard*
10 How easy was it to interpret the parallel coordinates plot ('PCP') in SomVis?	*very easy*	*very hard*
11 How easy was it to interpret the map of borrowers ('map') when it showed "equal area" rectangles in SomVis?	*very easy*	*very hard*
12 How easy was it to interpret the map of borrowers ('map') when it showed "total issues" rectangles in SomVis?	*very easy*	*very hard*
13 How easy was it to interpret the SOM ('SOM') in SomVis?	*very easy*	*very hard*
14 How easy was it to select different areas on the parallel coordinates plot ('PCP') in SomVis?	*very easy*	*very hard*
15 How easy was it to select different areas on the map of borrowers ('map') when it showed "equal area" rectangles in SomVis?	*very easy*	*very hard*
16 How easy was it to select different areas on the map of borrowers ('map') when it showed "total issues" rectangles in SomVis?	*very easy*	*very hard*
17 How easy was it to select different parts on the SOM ('SOM') in SomVis?	*very easy*	*very hard*
18 How easy was it to work with different representations of the data (parallel coordinates plot, map of borrowers and SOM) simultaneously in SomVis?	*very easy*	*very hard*
19 How important was it for you that you used real LCC Library data in SomVis?	*very important*	*very unimportant*
20 How good was the speed at which SomVis produced the SOM and other graphics?	*very good*	*very poor*
21 How useful would it be for LCC Libraries to acquire SomVis?	*very useful*	*useless*
training)?	*very well*	*very poorly*

23 Please write down three positive adjectives that describe your work with SomVis
24 Please write down three negative adjectives that describe your work with SomVis

Table 6.2: Individual summative questionnaire for libraries subjects. Questions 1-22 have responses based on Likert scales, the extreme values of which are shown

This was followed by a series of verbal questions asked of the group (with replies recorded for later transcription) that covered issues not answered in the individual summative questions, and which together correspond to the summative questions asked of C3 at the end of the CDR free exploration (due allowance being made for specific 'prototype' differences):

- What were the strengths of SomVis in helping you find clusters of borrowers?
- What were the weaknesses of SomVis in helping you find clusters of borrowers?
- Did you learn or discover anything new from exploring the data with SomVis today?
- If yes, what did you learn that was new?
- What was it that led to this discovery?

- Did you find out anything from exploring the data with SomVis that confirmed something you already knew?
- If yes, what was that?
- What was it that led to this confirmation?
- Was there anything else that exploring the data with SomVis led you to think about?
- If yes, what was that?
- What was it that led to this?
- Is there any change or addition to the SomVis software that you would make as a result of your experience? What changes? Why?

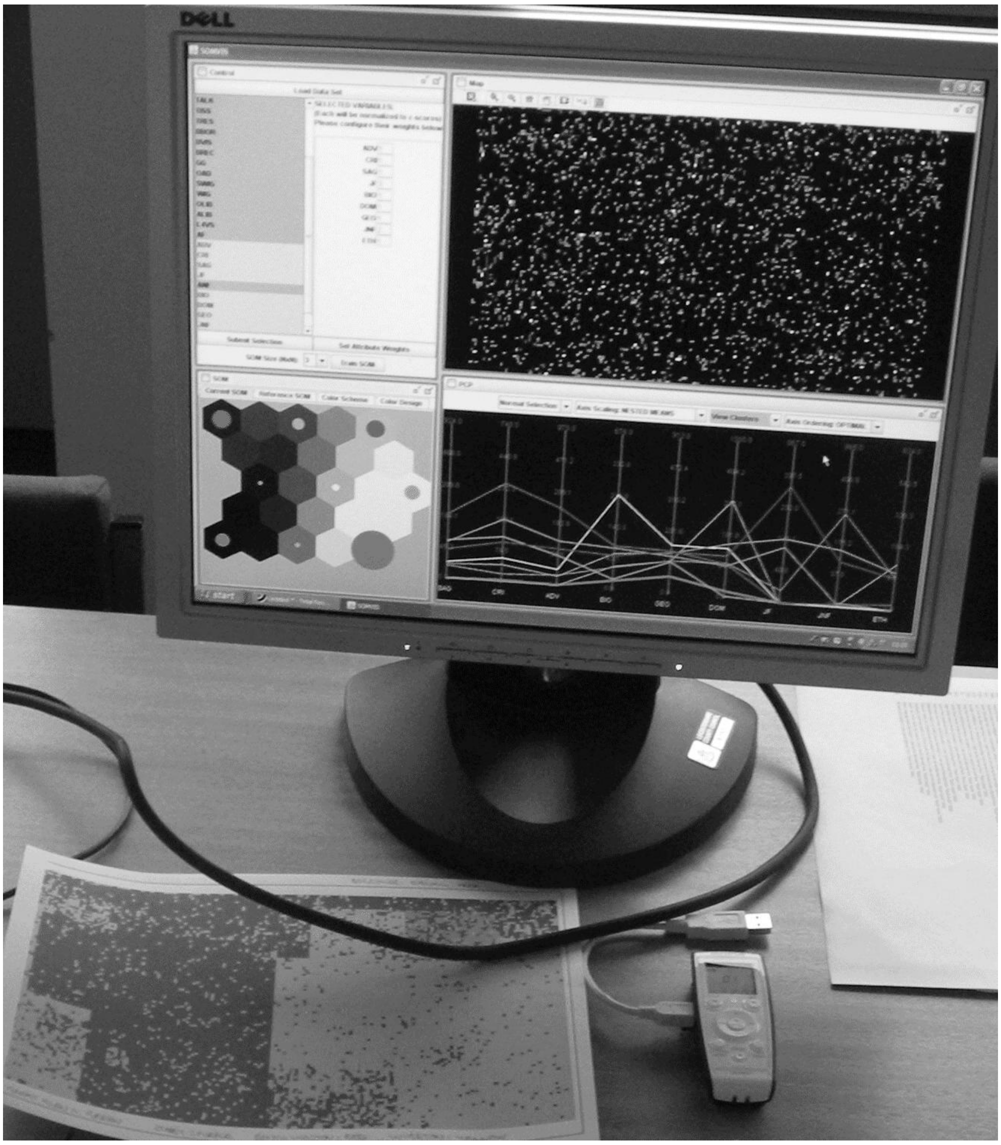

Figure 6.20: SomVis in use by library subjects showing SOM, PCP and cartogram map. Also shown is paper 'crib' of home library locations that relates to SomVis map (with each borrower given an equal area rectangle).

6.2.4 CODING AND ANALYSIS

The transcriptions of the paper/digital user testing/free exploration prototyping for CDR and Libraries cover twenty hours of 'think aloud' and total 150,000 words. The same scheme is used to code user testing and free exploration transcriptions for both CDR and libraries, although the library coding omits a number of codes included in CDR scheme to avoid coding areas with low incidence (as seen in the CDR results) or due to the particular nature of the SomVis session. Complete subject sessions (user testing and free exploration) were coded for both CDR and libraries, as many insightful 'think aloud' verbalisations by subjects occurred between user testing sessions, during summative questions sessions or even in 'winding down' after formal testing or free exploration had finished.

The overall scheme emerged from a skeletal framework worked out in advance that then was iterated and enhanced as the data was transcribed (see section 2.1 4 and the references to Lewins and Silver (2007) and Robinson (2007)). The scheme was designed to record the key elements of interest in their context. These are:

- categories that give an insight into the extent of subject geovisualization using the prototypes. This records instances of subjects undertaking **exploratory activity**, **hypothesising**, having **ideas or insights**, **confirming known facts**, or having their **expectations about received facts confounded**. Insights are defined as "an individual observation about the data by the user, a unit of discovery." (Saraiya, North and Duca, 2004)
- aspects of the prototype that need improvement, and thus form the basis of on-going iteration towards a final application. These were initially coded as **'explicit'** and **'implicit' suggestions for improvement,** and subsequently recoded in greater detail to determine which kinds of suggested improvement are generated by each prototype, whether there are differences, and to provide the material for iterating the design of the digital interactive prototype through prioritising the suggested improvements. The recoding details are given in a separate part of this section.
- filters to discern the key **contexts** of these:
    - **task taxonomies** (categorise, compare, contrast, distinguish, distribution and locate);
    - prototype **task types** for the user tests (spatial resolution, single glyph, multiple glyphs, spatial zoom, spatial pan, absolute and relative representation and crime sub-types);

    - **prototype/protocol** (paper user testing, digital interactive user testing and digital interactive free exploration).

The scheme also coded for a range of other 'subject' elements that give additional context and the potential to locate quickly information about:

- subjects' state – when they are confused, disengaged, misunderstand, have no insight into a task; plus when they mention their physical state (for example, tiredness) or their current feelings (for example, bored, interested or excited).
- specific subject verbalisations: negative comments/disagreements; positive comments/agreements; hesitation; uncertainty; inability to articulate (the last three recorded to see whether any geovisualization-related issues caused these).
- subjects requesting help: clarifying requests; seeking help with the prototype; requesting repetition of something said by the facilitator; seeking confirmation; and other help requests.
- certain miscellaneous topics such as terminology issues.

The scheme also coded for a number of 'application' elements that give flexibility to acquire supplementary contextual information about:

- the experiment, such as when prompting occurs (useful to ensure that prompted replies from subjects are given less weight or are eliminated as evidence); contain 'think aloud' that is noted as important to the research; indicate a departure from protocol or the facilitator repeating statements (indicative of a difficulty in communicating); or that identified a summative session.
- tools within the prototypes – SOM, cartogram map (in the library sessions), thematic map and glyph/treemap (in the CDR sessions); to the interface; to data; to comparisons between prototypes; and other miscellaneous items.

The full code scheme is given in Table 6.3, and Figure 6.21 shows it in network form.

category	sub-category	code
TASK	prototype	paper (user test)
		digital interactive (user test)
		digital interactive (free exploration)
TASK	taxonomy	categorise
		compare
		contrast
		distinguish
		distribution
		locate
TASK	type	spatial resolution
		single glyph
		multiple glyphs
		spatial zoom
		spatial pan
		absolute/relative
		crime sub-attribute
SUBJECT	explore	**exploratory activity**
		hypothesising
		insight/ideation
		confirmation
		expectations confounded
SUBJECT	verbal	hesitation
		negative comment/disagreement
		positive comment/agreement
		user cannot articulate thought/desire
		user uncertain/equivocal
SUBJECT	help	clarify request
		help with application
		repetition request
		seeks confirmation
		other request
SUBJECT	state	expresses feelings
		physical state
		user confused
		user disengaged
		user has no insight
		user misunderstands
SUBJECT	miscellaneous	argues from map to pattern
		"task is hard"
		terminology issue
SUBJECT	Crime & Disorder	C1
		C2
		C3
SUBJECT	Libraries	L1, L2, L3
APPLICATION	improvements/limitations	**explicit improvement**
		inplicit improvement
APPLICATION	experiment	error in protocol/off protocol
		"important"
		interviewer repetition
		prompt
		summative questions
APPLICATION	other	cartogram map
		glyph/treemap
		thematic map
		SOM/clustering
		data needs/issues
		input sheet/interface
		learning effect
		paper/digital comparison
		prototype insight
		thoughts on prototype

Table 6.3: Coding scheme for prototyping analysis

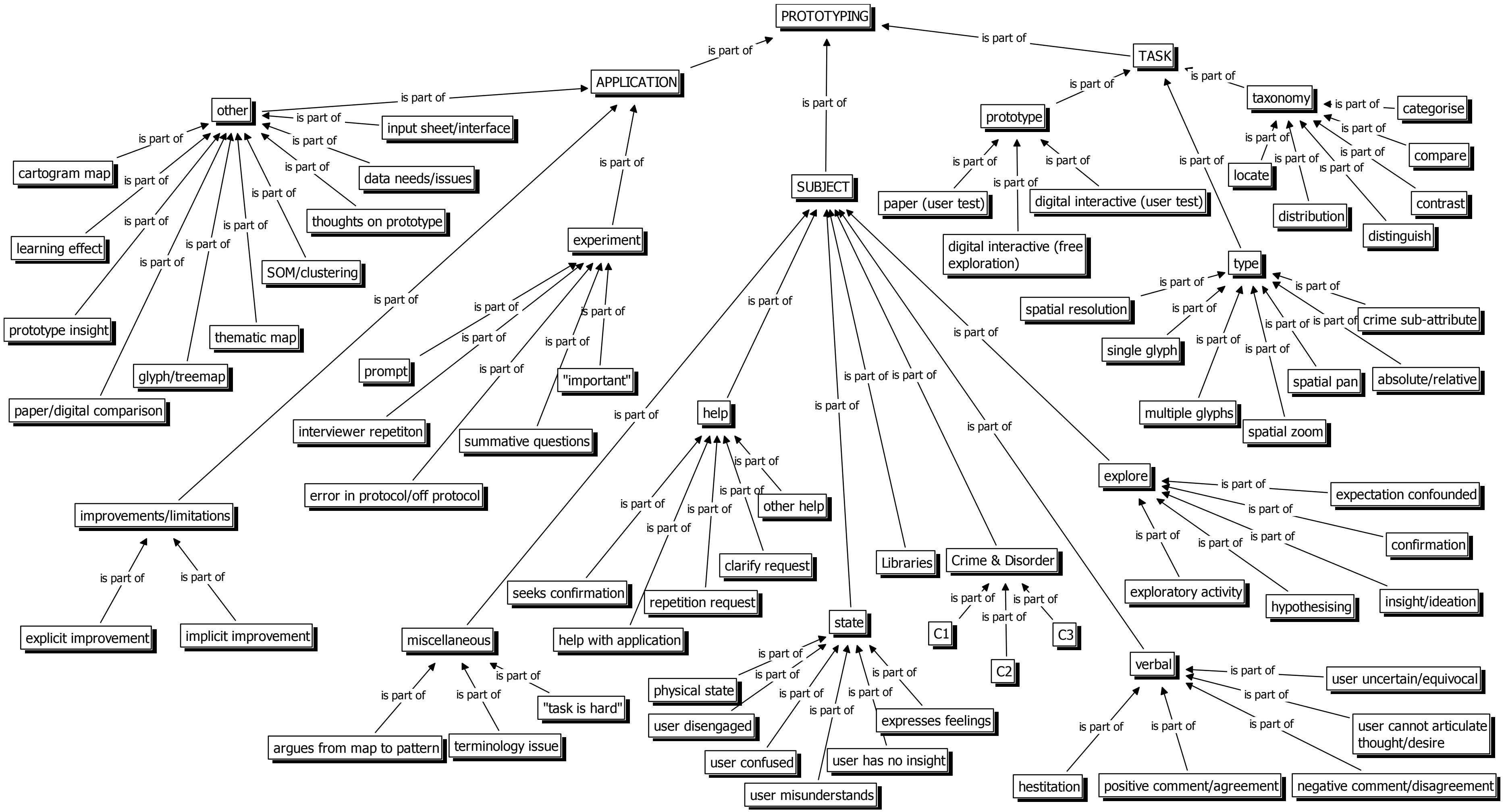

Figure 6.21: Network diagram of coding scheme for prototyping analysiss

6.2.4.1 RECODING OF SUGGESTED IMPROVEMENTS FROM CDR PROTOTYPES

A recoding of the information on the implicit and explicit suggestions for improvement that emerged during the CDR paper and digital interactive prototyping provides additional detail. The complete text blocks coded as implicit or explicit suggestions cover 332 suggested improvements and over 50 A4 pages of narrative. An iterated emergent initial coding scheme created after examining this corpus –Table 6.4.

Code	Explanation
AGG	need to aggregate
BIG	need to see 'big picture'
CIR	circle describing another attribute
DOD	want details on demand
FIL	want to filter data (either by time, space or attribute)
FSC	want flexible scale for different elements
HIG	system should highlight for user
KEY	key, text, legend or grid needed
LOG	system logic related/expectation that system does not follow
MOV	moveable window wanted
MUL	multiple views wanted
NAV	navigation/orientation related
OAD	other data attribute needed
OVL	cognitive issues; overload; complexity
REB	want to rebase data
RNK	want to rank data
RVL	want ability to selectively reveal
SGM	want scaleogram facility
SIZ	size issue
SPD	speed of application
SUB	sub-attribute
TOG	toggle wanted
TRE	treemap related
VIS	visibilty improvement needed

Table 6.4: initial emergent recoding scheme for CDR prototypes suggested improvement data

A second pass through the corpus results in merging/splitting suggestions into 35 coherent statements of improvement that could be 'costed' in terms of hours of development to incorporate each into the digital prototype by a geovisualization developer. However this coherence is relative – the journey from 332 suggestions to the final 35 is not straightforward - very few suggestions say exactly the same thing and the final 35 are simplified and composite. They represent perhaps the centre of a 'fuzzy' cloud of similar suggestions.

The 35 possible improvements are in Table 6.5. They are grouped together into four categories corresponding to “data related” (nos 1-10); “interface-related” (nos 11-16); “interaction-related” (nos 17-23); and “new” (nos 24-35). **The 'new' group includes novel geovisualization tools that could be included to achieve the possible improvements**. The final list of 35 possible improvements is intended to be shown to, and prioritised by, the CDR subjects. This part of the research is the subject of Chapter 7.

No	Possible Improvement	Description
1	Aggregate selected areas together	Geographic areas are selected on some basis and their contents aggregated together for the purpose of analysis and comparison. Glyphs for aggregated areas would be available. Example might be the pre-existing CCTV coverage area. With even more development, this could be extended to multiple scales, or
2	Aggregate selected times on glyphs together into bands	Aggregate times into bands of the user's choice in order to create new temporal comparisons. Examples might be: to aggregate hours of the day into "day" and "night"; months into seasons; some days into "weekend". These would need to be preselected initially, but even more development would allow flexible
3	Aggregate selected historical time periods to act as the comparison with the current view	Aggregate selected historical time periods to act as the comparison with the'current view' on the "blue-white-pink relative" map. Examples might include comparisons with last year; last financial year; last three years, etc. These would need to be preselected initially, but even more development would allow flexible
4	Display the crime numbers associated with geography, times and crime categories as text	Display the crime numbers associated with geography, times and crime categories as text. This would include total crimes represented by each glyph and by each "arm" of each glyph, as well as crime sub-categories (on the treemap). Details would be available under user control and could be switched off entirely or only appear when a part of the screen was "brushed". Even more development could provide graphics as
5	Filter the data shown in the current view to include only certain areas	Filter the data shown in the current view to include only certain areas. Example might be "show only the CCTV area"
6	Filter the data shown in the current view to include only certain times	Filter the data shown in the current view to include only certain times. Example might be "show only the crimes between 10am and 5pm on Saturdays"
7	Filter the data shown in the current view to include only certain crimes or sub-crimes	Filter the data shown in the current view to include only certain crimes or sub-crimes. Example might be "show only the All Other Theft category 'theft from shop'"
8	Filter the data shown in the current view to include only crimes greater than a particular number	Filter the data shown in the current view to include only crimes greater than a particular number. Example might be "show only the crimes where crime numbers exceed 4 per day per 100m square"
9	Add contextual data to the map view	Add contextual data to the map view. Examples might include the location of retail premises such as shops, pubs, cinemas, gyms, schools, universities, car parks; location of designated "Safe Routes", "alcohol-ban zones, CCTV coverage areas; population, daytime population. This would be done by providing background
10	Add contextual policy data to map view	Add contextual policy data to map view. Examples might include areas where initiatives to reduce crime had taken place; areas of incresed policing; new areas brought within CCTV coverage. This would be done by providing background images (in .png format) and images would need to be provided by LCC CDR.
11	Allow comparison of current view with selected external comparisons.	Allow comparison of current view with selected external comparisons, not just with historical data. Examples might include comparisons with the county, force or borough average; average for market towns in county; average for other 'most similar' family group CDRPs in UK. The LCC CDR team would have to provide the
12	Base thematic map colours on something other than relativity to crimes in display area	Base thematic map colours on something other than relativity to crimes in display area ("local"). Example might be relative to the whole of Loughborough ("global"), or whole of borough or county. These would be predetermined (by LCC CDR), or selected from CDR provided options. Even more development work could
13	Retain the paning and zooming position when changing the display	When paning and zooming (using keyboard short cuts), changing the display via the PHP string will now show the current location where the pan/zoom occured. Even more development will retain the current
14	Reduce complexity of the system	Reduce complexity of the system. Design changed to hide complexity as much as possible.
15	Reduce difficult in comparing 25-odd glyphs	Reduce difficult in comparing 25-odd glyphs by providing a different view of the data
16	Current system to work 50% faster	Current system to work 50% faster (adding new functionality may, of course, slow system down)

Table 6.5: (1 of 2): 35 possible improvements from recoding of CDR prototyping think aloud. Numbers 1-10 are "data-related"; 11-16 are "interface-related"

No	Possible Improvement	Description
17	System to indicate the state of various components with text labels	System to indicate the state of various components with text labels. For example label map with crime (or sub-crime) type (e.g. "All Other Theft" or "Harrassment"), or data time period (e.g. "2005"). With even more development, the system could provide context specific advice. For example, where crime numbers were low (and where care should be taken in interpretation) system could produce a message to indicate this, or
18	Provide map grid with scale	Provide map grid with scale showing size of smallest square in grid and size of overall map
19	Provide legends to assist interpretation of application components	Provide legends to assist interpretation of application components, including map colours, circle sizes, various temporal glyphs and the lengths of glyph "arms". Even more development could provide glyph "arms" that were sized according to number of crimes (with an option to toggle this on/off). Yet more
20	Provide better background maps	Provide better background maps, for example by providing a high resolution version of OS Streetview (a 1:10k raster). Maps need to be provided as .png by LCC CDR - note that large maps carry a considerable penalty in terms of system performance. Even more development could produce a "GIS" like approach to
21	Provide orientation aid	Provide aid to assist orientation when looking at a zoomed-in map with a graphic to show current location
22	Make glyphs easier to see, retaining 25 or more per map	Make glyphs easier to see, by improving contrast. Even more development could allow selection from alternative colour schemes and transparency. Yet more development could select colour and transparency
23	Improve readability of map + glyphs + thematic colours	Improve readability of map + glyphs + thematic colours by incorporating a "halo on/halo/off" toggle. Even more development work could provide user control of number of glyphs (e.g. top 10, top 20 etc.)
24	Allow for aoristic crime taking account of time span of crime	Some crimes are aoristic - that is, their exact time is not known, only an earliest time and a latest time. Allocate such crime across the possible time span instead of using the convenient, but usually wrong,
25	Provide another view of the data that can see an individual crime in relation to all crime	Provide another view of the data that can see an individual crime in relation to all crime. An easy way to implement this is to run two versions of the application at once and "alt-tab" between them. With development, one could have an "all crime" view loaded alongside the "current" view with the latter colour-shaded according to the scheme used in the former. More development work could lead to a single view
26	Provide different views at different resolutions together	Provide different views at different resolutions together by showing numeric / graphical aggregates for the whole area under study and selected area. Even more development work would show values at current location at range of spatial scales (would slow down application). Yet more development could vary user-
27	Computer to assist the user by highlighting of interest, significance or similarity	Computer to assist the user by highlighting of interest, significance or similarity. Specifically, highlight all glyphs which have a maximum at the same time point (or within 1 time point).Even more development would highlight/lowlight glyphs according to a formula based on the root mean square difference between a
28	Make simultaneous comparison of different views easier	Make simultaneous comparison of different views easier. improvements made to interface will make it easier to move between views and running the application twice and using 'alt/tab' will allow comparisons. Even more development will record the system state for later recall. Yet more development work would
29	Show rank information away from map in a new tool	Show rank information away from map in a new tool. This encapsulates the notion that some information's spatiality may be unimportant in some contexts and that an aspatial way of looking at it might be preferable
30	Selectively build up information on map so that the highest crime areas appear first followed by a short delay	Selectively build up information on map so that the highest crime areas appear first followed by a short delay. Cut offs would be pre-set at absolute numbers (5, 10, 25 etc). Even more development could have cut offs pre-set to relative numbers (e.g. >10% then >mean then >mean + 1 standard deviation etc.). Yet more
31	Provide small multiple display of all resolutions at once	Provide small multiple display of all resolutions as non-interactive multiple (pre-determined) resolution static 'small multiples'. Even more development could yield interactive small multiples.
32	Add a scalogram	Add a scalogram. This would show crime rates at different resolutions at a selected location. Even more development work would show how rates vary with distance from any selected point. Yet more
33	Show pattern stability by moving base of grid	Show pattern stability by moving base of grid, for example by moving the basis for cells randomly. Even more development would allow selection from pre-selected alterantives. Yet more development would
34	Extend "circle" cue on maps	Extend "circle" cue on maps. Circles added to relate to differences from predetermined values as supplied by CDR team. Even more development would allow greater choice/complexity.
35	Introduce treemap of crime sub-categories into application	Introduce treemap of crime sub-categories into application which would be the interface for the selection of crime categories. Even more development work would allow the colours on the treemap to update to show

Table 6.5 (2 of 2): 35 possible improvements from recoding of CDR prototyping think aloud. Numbers 17-23 are "interaction-related"; 24-35 are "new-related"

6.3 RESULTS AND ANALYSIS

The results in sections 6.3.1 to 6.3.3 correspond to case numbers 8 and 9 on Table 2.2 (an extract of which is at the start of this chapter).

The results are presented initially as a series of counts of the number of times a particular code is used to tag a block of text (Table 6.6). This is a simple measure because it takes no account of the detail in the text and groups a range of different qualities (a small insight is coded the same way as a "Eureka!" moment, for example). However it is useful to examine broad trends. It should be borne in mind that multiple codes are tagged to a single block of transcribed text in this analysis, so the number of code instances greatly exceeds the numbers of text blocks. Analysis of the exploratory work of the subjects (undertaking exploratory activity, hypothesising, having ideas or insights, confirming known facts, or having their expectations about received facts confounded) and analysis of aspects of the prototype that need improvement embrace the vast bulk of the textual material.

There are differences in the codes recorded for the libraries free exploration, which followed the CDR coding. Many of the codes recorded in the CDR case (see Figure 6.21) and thought at that stage to be potentially useful, were unused in the final analysis. These were not recorded in the libraries case. While the issue of possible improvements was included in the summative questions asked of the library subjects, suggestions for improvement were not coded during the analysis of the library subjects' think aloud as so few were mentioned during the actual session. This is not surprising given that SomVis is a 'completed' application. The main focus for this research was centered on the exploratory activity of the library subjects, and this was fully coded in the same way as the CDR sessions.

The details of instances of subjects undertaking data exploration and their suggestions as to how prototypes can be improved are considered by prototype, by protocol and by domain case (CDR or libraries) with qualitative analysis of subject 'think aloud'. Summative question responses are considered separately, as are responses to libraries' individual questionnaires.

Table 6.7 contains counts of instances of geovisualization exploration, hypothesising, ideation/insight, expectations confirmed and expectations confounded, verbalised during the course of the paper and digital interactive prototyping sessions, by CDR subject and by task type (spatial resolution, spatial zoom, spatial pan, single glyph, multiple glyph, absolute/relative crime attributes and crime sub-categories.

Table 6.8 contains counts of instances of explicit and implicit suggestions for improvement to prototypes during the course of the paper and digital interactive prototyping sessions, by CDR subject and by task type (spatial resolution, etc.)

Table 6.9 contains the counts from the recoding of the count data of explicit and implicit suggestions for improvement to prototypes into data-related, interface related, interaction-related and new-related by CDR subject, 'simple' implicit and explicit suggestions (implicit = indirectly expressed; explicit=clearly expressed), prototype and protocol. From this table it is clear from inspection that the categories of possible improvement elicit different responses across the different CDR subjects and across many of the dimensions.

During the recoding of qualitative data there are inevitable reassessments and this is the case with the recoding of the suggestions data. From an original 332 (Table 6.6) this has become 303. There are 25 possible improvements that are specific to paper (as opposed to suggestions from the paper prototype that have applicability to the digital interactive version of the prototype), 40 additional suggestions created by allowing text blocks to be split into more than one suggestion, and 44 suggestions removed because they were already implemented (by way of the 'concealed' zoom and pan capabilities of the digital interactive prototype) or were inappropriately identified as true suggestions in the first place. This yielded 303 recoded suggestions (= 332 – 25 + 40 – 44).

category	sub-category	code	Paper User test C1	Digital User test C1	Paper User test C2	Digital User test C2	Paper User test C3	Digital User test C3	Digital Free explore C3	Digital Free explore L123
TASK	prototype	paper (user test)	1		1		1			
		digital interactive (user test)		1		1		1		
		digital interactive (free exploration)							1	1
TASK	taxonomy	categorise	1	1	1	1	1	0		
		compare	12	10	5	5	5	5		
		contrast	1	1	1	1	1	1		
		distinguish	1	1	1	1	1	1		
		distribution	5	4	0	1	1	0		
		locate	5	2	2	2	2	2		
TASK	type	spatial resolution	1	1	1	1	1	1		
		single glyph	1	1	1	1	1	1		
		multiple glyphs	1	1	0	0	0	0		
		spatial zoom	1	1	1	1	1	1		
		spatial pan	1	1	1	1	1	1		
		absolute/relative	1	1	1	1	1	1		
		crime sub-attribute	1	1	0	0	0	0		
SUBJECT	explore	exploratory activity	6	8	7	5	5	6	12	8
		hypothesising	17	10	9	9	5	0	10	21
		insight/ideation	31	23	18	20	10	9	22	45
		confirmation	6	3	3	7	1	7	1	8
		expectations confounded	4	0	5	0	2	0	5	4
SUBJECT	verbal	hesitation	4	0	0	0	0	1	0	
		negative comment/disagreement	7	8	3	5	4	3	1	
		positive comment/agreement	19	16	17	29	24	14	7	
		user cannot articulate thought/desire	3	1	0	0	0	0	0	
		user uncertain/equivocal	8	5	8	13	7	9	0	
SUBJECT	help	clarify request	6	2	8	2	6	4	0	
		help with application	1	3	0	0	0	3	5	
		repetition request	3	6	1	1	5	4	0	
		seeks confirmation	4	1	7	7	2	15	5	
		other request	0	0	0	0	3	0	1	
SUBJECT	state	expresses feelings	16	13	3	8	5	6	6	0
		physical state	0	5	0	1	2	2	0	1
		user confused	5	0	4	6	0	4	1	3
		user disengaged	0	2	1	0	4	0	0	0
		user has no insight	2	0	2	0	0	0	0	0
		user misunderstands	0	0	2	0	0	1	0	0
SUBJECT	miscellaneous	argues from map to pattern	4	1	1	0	1	0	0	
		"task is hard"	9	5	3	1	1	4	0	
		terminology issue	3	0	2	0	1	4	0	
SUBJECT	Crime & Disorder	C1	1	1						
		C2			1	1				
		C3					1	1	1	
SUBJECT	Libraries	L1, L2, L3								1
APPLICATION	improvements/limitations	explicit improvement	24	20	27	23	43	30	20	
		inplicit improvement	38	15	30	18	17	5	22	
APPLICATION	experiment	error in protocol/off protocol	8	9	4	8	3	4	4	
		"important"	13	27	13	29	45	19	28	
		interviewer repetition	13	6	4	6	6	3	1	
		prompt	14	15	16	29	13	10	7	20
		summative questions		1		1	1		1	1
APPLICATION	other	cartogram map								4
		glyph/treemap	6	2	6	4	11	0	1	
		thematic map	1	0	0	0	0	0	0	
		SOM/clustering								12
		data needs/issues	2	9	0	7	10	7	4	0
		input sheet/interface	0	0	1	6	3	2	3	0
		learning effect	0	1	0	2	4	0	0	
		paper/digital comparison	0	12	0	12	13	0	0	
		prototype insight	4	5	2	2	0	1	1	0
		thoughts on prototype	0	6	0	0	2	0	4	0

Table 6.6: Transcription codes showing instances by each of the eight prototyping sessions. Both C1 user testing sessions contained seven tasks; C2 & C3 user testing sessions five tasks

exploratory activity		spatial			temporal		attribute		Totals for sr, sz, sp, gs & ar				
		spatial resolution	spatial zoom	spatial pan	single glyph	multiple glyph	absolute + relative	crime sub-categories					
		sr	sz	sp	gs	gm	ar	sb	spatial	temporal	attribute	Total	Total
paper	C1	3	0	3	0	0	0	0	6	0	0	6	paper
	C2	5	1	1	0		0		7	0	0	7	18
	C3	1	2	1	0		1		4	0	1	5	
digital inter-active	C1	2	1	0	1	1	0	2	3	1	0	4	digital
	C2	1	0	3	0		1		4	0	1	5	16
	C3	3	0	0	1		3		3	1	3	7	

hypothesising		spatial			temporal		attribute		Totals for sr, sz, sp, gs & ar				
		spatial resolution	spatial zoom	spatial pan	single glyph	multiple glyph	absolute + relative	crime sub-categories					
		sr	sz	sp	gs	gm	ar	sb	spatial	temporal	attribute	Total	Total
paper	C1	0	0	4	4	3	4	2	4	4	4	12	paper
	C2	0	1	2	5		1		3	5	1	9	26
	C3	1	1	1	2		0		3	2	0	5	
digital inter-active	C1	1	1	0	0	0	0	3	2	0	0	2	digital
	C2	1	1	3	3		1		5	3	1	9	11
	C3	0	0	0	0		0		0	0	0	0	

ideation /insight		spatial			temporal		attribute		Totals for sr, sz, sp, gs & ar				
		spatial resolution	spatial zoom	spatial pan	single glyph	multiple glyph	absolute + relative	crime sub-categories					
		sr	sz	sp	gs	gm	ar	sb	spatial	temporal	attribute	Total	Total
paper	C1	2	3	3	3	6	4	5	8	9	9	26	paper
	C2	2	4	4	6		2		10	6	2	18	47
	C3	3	2	1	2		1		6	2	1	9	
digital inter-active	C1	4	1	1	1	1	1	5	6	2	6	14	digital
	C2	3	6	2	4		5		11	4	5	20	37
	C3	2	1	1	3		2		4	3	2	9	

confirmation		spatial			temporal		attribute		Totals for sr, sz, sp, gs & ar				
		spatial resolution	spatial zoom	spatial pan	single glyph	multiple glyph	absolute + relative	crime sub-categories					
		sr	sz	sp	gs	gm	ar	sb	spatial	temporal	attribute	Total	Total
paper	C1	0	0	0	4	2	0	0	0	4	0	4	paper
	C2	0	1	1	1		0		2	1	0	3	8
	C3	0	0	0	1		0		0	1	0	1	
digital inter-active	C1	0	1	0	0	1	0	0	1	0	0	1	digital
	C2	0	1	2	3		1		3	3	1	7	15
	C3	5	1	1	0		0		7	0	0	7	

expectation confounded		spatial			temporal		attribute		Totals for sr, sz, sp, gs & ar				
		spatial resolution	spatial zoom	spatial pan	single glyph	multiple glyph	absolute + relative	crime sub-categories					
		sr	sz	sp	gs	gm	ar	sb	spatial	temporal	attribute	Total	Total
paper	C1	1	0	0	0	3	0	0	1	0	0	1	paper
	C2	4	0	1	0		0		5	0	0	5	8
	C3	0	0	1	1		0		1	1	0	2	
digital inter-active	C1	0	0	0	0	0	0	0	0	0	0	0	digital
	C2	0	0	0	0		0		0	0	0	0	0
	C3	0	0	0	0		0		0	0	0	0	

Table 6.7: Counts of instances of geovisualization exploration, hypothesising, ideation/insight, expectations confirmed and expectations confounded during the course of the paper and digital interactive prototyping sessions, by CDR subject and by task type (spatial resolution, spatial zoom, spatial pan, single glyph, multiple glyph, absolute/relative crime attributes and crime sub-categories.

paper user test		spatial			temporal		attribute		Totals for sr, sz, sp, gs & ar				
		spatial resolution	spatial zoom	spatial pan	single glyph	multiple glyph	absolute + relative	crime sub-categories					
		sr	sz	sp	gs	gm	ar	sb	spatial	temporal	attribute	Total	Total
explicit improvement	C1	0	5	5	1	3	7	3	10	4	10	24	**explicit 92**
	C2	1	9	1	5		11		11	5	11	27	
	C3	0	12	5	12		12		17	12	12	41	
implicit improvement	C1	3	2	6	4	9	3	8	11	13	11	35	**implicit 78**
	C2	4	4	6	8		8		14	8	8	30	
	C3	0	6	2	4		1		8	4	1	13	

digital interactive user test		spatial			temporal		attribute		Totals for sr, sz, sp, gs & ar				
		spatial resolution	spatial zoom	spatial pan	single glyph	multiple glyph	absolute + relative	crime sub-categories					
		sr	sz	sp	gs	gm	ar	sb	spatial	temporal	attribute	Total	Total
explicit improvement	C1	0	1	0	0	1	1	3	1	1	4	6	**explicit 57**
	C2	1	5	6	4		5		12	4	5	21	
	C3	6	5	7	6		6		18	6	6	30	
implicit improvement	C1	2	0	0	1	1	0	1	2	2	1	5	**implicit 27**
	C2	2	7	5	3		0		14	3	0	17	
	C3	1	2	0	1		1		3	1	1	5	

Table 6.8: Counts of instances of explicit and implicit suggestions for improvement to prototypes during the course of the paper and digital interactive prototyping sessions, by CDR subject and by task type (spatial resolution, spatial zoom, spatial pan, single glyph, multiple glyph, absolute/relative crime attributes and crime sub-categories).

	subject			suggestion (C1, C2, C3)		user testing (C1, C2, C3)		free exploration (C3)
	C1	C2	C3	implicit	explicit	paper prototype	digital interactive prototype	digital interactive prototype
Data	47	32	44	48	75	70	43	10
Interface	12	4	17	16	17	10	20	3
Interaction	21	33	36	53	37	47	30	13
New	14	13	30	10	47	35	16	6

Table 6.9: Counts of instances of suggestions for improvement by category (data-related, interface-related, interaction-related, and new-related) to prototypes during the course of the paper and digital interactive prototyping sessions, by CDR subject, implicit or explicit suggestion, prototype and protocol (user testing or free exploration)

6.3.1 STATISTICAL ANALYSIS OF CODING RESULTS

In this analysis, large amounts of textual information are analysed to obtain quantitative evidence that is rooted in the particular subjects' context of use, and necessarily employs only the small number of subjects who are experts in the particular domain. Aggregating instances into counts yields data that is susceptible to quantitative analysis and this is carried out in this section. However, the limited numbers of subjects raises a valid question as to the extent to which these results may be generalised (even when the results of such tests are statistically significant). While suggestive, the statistical results below can be more widely generalised only when they form part of a broader consideration, set alongside the work of other researchers conducting similar studies of human-centered approaches for geovisualization (or information visualization) in conjunction with subjects from different domains.

6.3.1.1 GEOVISUALIZATION EXPLORATION - STATISTICAL ANALYSIS

Table 6.10 compares the different kinds of exploration recorded by CDR subjects in the paper and digital interactive prototyping sessions conditioned on possible improvement category.

A null hypothesis is that geovisualization exploration generation is independent of prototype type. The appropriate test is a non-parametric chi-squared test (Pearson, 1900). This yields a value of 1.73 (the categories 'confirmation' and expectations confounded' are merged due to low absolute numbers). The critical value for a chi-squared at the 0.05 significance level is 7.81 (DF=3), so the calculated value is less than the critical value.

> 1.73 < 7.81 (DF=3; sig=0.05). **I FAIL TO REJECT the null hypothesis that geovisualization exploration generation is independent of prototype type**, and conclude that the **level of geovisualization exploration generation obtained from the paper and digital interactive geovisualization prototypes cannot be distinguished**.

	paper	digital
exploratory activity	18	19
hypothesising	31	19
insight/ideation	59	52
confirmation	10	17

Table 6.10: Exploration recorded by CDR subjects in the paper and digital interactive prototyping user testing sessions

Because the order of presentation of the prototypes was different for the three CDR subjects (C1 and C2 encountered the paper prototype first; C3, the digital interactive), there is an opportunity to compare the different kinds of exploration based on 'first-' and 'second-encountered' – see Table 6.11. A null hypothesis is that geovisualization exploration generation is independent of the order of encounter of prototype. Using a chi-squared test yields a value of 2.44, and the critical value for a chi-squared at the 0.05 significance level is 7.81 (DF=3; the categories 'confirmation' and expectations confounded' are merged due to low absolute numbers). The calculated value is less than the critical value.

> 2.44 < 7.81 (DF=3; sig=0.05). **I FAIL TO REJECT the null hypothesis that geovisualization exploration generation is independent of the order of encounter of prototype**. I conclude that **order of encounter makes no significant difference to exploratory activity**.

	first user test	second user test
exploratory activity	19	18
hypothesising	26	24
insight/ideation	58	53
confirmation	16	11

Table 6.11: Exploration recorded by CDR subjects by 'first' and 'second' prototype encountered during user testing sessions

It is instructive to see whether the CDR subjects' exploration counts are similar or different. Table 6.12 gives the data. C3's recorded exploration count is marked lower than C1 and C2 for hypothesising and for insight/ideation. Based on a null hypothesis that geovisualization exploration generation is independent of CDR subject, a chi-square test yields a value of 7.6, while the critical value of chi-sq (DF=6) is 12.59 at 0.05 significance level.

> 7.6 < 12.59 (DF=6; sig=0.05). **I FAIL TO REJECT the null hypothesis**, and conclude that **the geovisualization exploration generation is independent of CDR subject.**

Repeating the test with data for paper and digital interactive prototypes separately yields the same result (paper chi-sq = 2.6; digital interactive = 11.8, both lower than the critical value of chi-sq (DF=6) of 12.59 at 0.05 level).

	C1*5/7	C2	C3
exploratory activity	10.0	12	11
hypothesising	19.3	18	5
insight/ideation	38.6	38	19
confirmation	6.4	10	8

Table 6.12: Exploration recorded by CDR subject for combined paper and digital interactive prototypes. Subject C1 had 7 user task testing sessions, C2 and C3 had 5 in the paper and digital interactive prototyping sessions. C1's count has been multiplied by 5/7

I wish to see if there is a significant difference in the exploration recorded between the two digital interactive prototype protocols – user testing and free exploration. Table 6.13 shows the data for C3 (C3's paper prototyping results are shown for completeness), who is the only CDR subjects to experience both protocols. The null hypothesis is that geovisualization exploration generation with the digital interactive prototype is independent of the prototype protocol. A chi-squared test on digital interactive user-test versus free exploration (combining 'confirmations' and 'expectations confounded' and exploratory activity and hypothesising, respectively, because of low values) for C3 results in a chi-squared result of 4.46 which is lower than the critical value of chi-sq (DF=2) of 5.99 at the 0.05 significance level.

> 4.46 < 5.99 (DF=2; sig=0.05). **I FAIL TO REJECT the null hypothesis that geovisualization exploration generation is independent of the prototype protocol**.

The overall level of exploration is over twice the level for free exploration as the user testing with active intervention session, in sessions that lasted about the same time. **I conclude that free exploration elicits significantly more overall exploratory activity than a user testing protocol with a digital interactive prototype.** However this must bear a caveat. The free exploration activity was preceded by earlier paper and digital interactive user testing sessions, and the result is for one CDR team member, C3, only.

	Digital - user test	Digital - Free exploration
exploratory activity/ hypothesising	6	22
insight/ideation	9	22
confirmations (all)	7	6

Table 6.13: Exploration recorded by CDR subject C3 for both prototypes and both protocols

Count information can be used to compare the exploration recorded by C3 with the CDR digital interactive prototype and the exploration recorded by the LCC Libraries subjects collectively with SomVis, both with a free exploration protocol (Table 6.14). Based on a null hypothesis that exploration activity is independent of domain within LCC, a chi-square test yields a value of 5.74, while the critical value of chi-sq (DF=3; the categories 'confirmation' and expectations confounded' are merged due to low absolute numbers) is 7.81 at 0.05 significance level.

> 5.74 < 7.81 (DF=3; sig=0.05). **I FAIL TO REJECT the null hypothesis** that exploration activity is independent of domain within LCC. I conclude that, **despite the differences in domain, in prototypes, in subjects and in tasks, the pattern of overall exploration cannot be statistically distinguished, indicating that there is a degree of robustness in eliciting the relative kinds of overall exploratory activity**. However this must bear a caveat. The comparison is between different sets of subjects and cover just two sessions, one with a single CDR subject, C3, the other the collaborative L123 libraries session.

	C3 Free exploration	L123 Free exploration
exploratory activity	12	8
hypothesising	10	21
insight/ideation	22	45
confirmation	1	8

Table 6.14: Exploration recorded by C3 with the CDR digital interactive prototype compared with that of the LCC Libraries subjects with SomVis, both with free exploration protocol

6.3.1.2 SUGGESTED IMPROVEMENTS TO PROTOTYPES - STATISTICAL ANALYSIS

Table 6.15 compares the explicit and implicit suggestions made to improve the prototype recorded by CDR subjects in the paper and digital interactive user testing sessions. A null hypothesis is that recorded suggested improvements are independent of prototype type. Using a chi-squared test with Yate's continuity correction (Yates, 1934) for a 2x2 table yields a value of 4.40. The critical value for a chi-squared at the 0.05 significance level is 3.84 (DF=1), so the calculated value is greater than the critical value.

> 4.40 **>** 3.84 (DF=1; sig=0.05). **I REJECT the null hypothesis that recorded suggested improvements are independent of prototype type**, and conclude that **recorded suggested improvements depend on prototype type**. The numbers in Table 6.13 show that **the paper prototype yields more suggestions for improvement than the digital interactive prototype**.

In particular, the digital interactive prototype appears to be poor at eliciting *implicit* improvements. It may be that the paper prototype format forces subjects to work harder in a geovisualization setting, and that issues are articulated more readily than with a digital interactive prototype where 'persevering with the computer' may be the default behaviour. Another explanation is that there may be an effect related to the first encountered prototype, regardless of type – this is tested below (table 6.15).

	Paper	Digital
explicit improvement	94	73
implicit improvement	85	38

Table 6.15: Explicit and implicit suggestions made to improve the prototype by CDR subjects in the paper and digital interactive user testing sessions

As with exploration (Table 6.11), there is an opportunity to compare the suggestions for improvement made based on 'first-' and 'second-encountered' where I do not control for individual subjects – see Table 6.16. A null hypothesis is that recorded suggested improvements are independent of the order of encounter of prototype. Using a chi-squared test with Yate's continuity correction (Yates, 1934) yields a value of 2.92, and the critical value for a chi-squared at the 0.05 significance level is 3.84 (DF=1). The calculated value is less than the critical value.

> 2.92 < 3.84 (DF=1; sig=0.05). **I FAIL TO REJECT the null hypothesis that recorded suggested improvements are independent of the order of encounter of prototype. There is no evidence for a 'order of encounter' effect.**

	First test	Second test
explicit improvement	81.0	86.0
implicit improvement	73.0	50.0

Table 6.16: Explicit and implicit suggestions made to improve the prototype by CDR subjects by 'first' and 'second' prototype encountered during user testing sessions

Table 6.17 shows the data for suggested improvements to both prototypes by CDR subject. Based on a null hypothesis that recorded suggested improvements are independent of individual CDR subjects , a chi-square test yields a value of 20.4, while the critical value of chi-sq (DF=2) is 5.99 at 0.05 significance level. Repeating the test with data for paper and digital interactive prototypes separately yields the same result (paper chi-sq = 12.72; digital interactive = 14.97, both lower than the critical value of chi-sq (DF=2) of 5.99 at 0.05 significance level).

12.72 **>** 5.99 (DF=2; sig=0.05). **I REJECT the null hypotheses that recorded suggested improvements are independent of individual CDR subjects for the paper prototype**
14.97 **>** 5.99 (DF=2; sig=0.05). **I REJECT the null hypotheses that recorded suggested improvements are independent of individual CDR subjects for the digital interactive prototype.**

These results contrast with the result obtained when considering the CDR subjects' exploration counts that are not statistically different. Examiniing the data shows C2 and C3 make a similar number of suggestions but the balance between explicit and implicit suggestions is different. C3 is far more likely to make explicit suggestions than C2. C1 makes fewer suggestions overall (about 70% of the level of C2 and C3), but C1's balance between explicit and implicit is far more similar to C2's than C3's. C3's suggested improvements ratio between explicit and implicit is also seen with both paper and digital interactive prototypes (paper: explicit/implicit = 43/17; digital interactive = 30/5). The implication of this finding is that the subjects exhibit individual characteristics, and that their individual roles within the CDR team, their different responsibilities, different expertise with tools, different experience, different geographical knowledge, and so forth, represents an ecological reality. In particular, it adds further weight to the caveats about results based on a single CDR subject (see text relating to Tables 6.13 and 6.14).

	C1 5/7	C2	C3
explicit improvement	31.4	50	73
implicit improvement	37.9	48	22

Table 6.17: Suggested improvements recorded by CDR subject for combined paper and digital interactive prototypes. Subject C1 had 7 user testing sessions, C2 and C3 had 5 in the paper and digital interactive prototyping sessions and so C1's count has been multiplied by 5/7

Table 6.18 shows that when only C3's results from both prototypes and both protocols are compared, the explicit/implicit suggestion ratio shows a marked decrease in the free exploration protocol results. A null hypothesis is that recorded suggested improvements are independent of prototype protocol for subject C3. A chi-squared test with Yate's continuity correction (Yates, 1934) on C3's digital interactive user-test versus free exploration, results in a chi-squared result of 20.1 which is higher than the critical value (DF=1) of 3.84 at the 0.05 significance level.

> 20.1 **>** 3.84 (DF=1; sig=0.05). **I REJECT a null hypothesis that recorded suggested improvements are independent of the prototype protocol used (user test v free exploration) for subject C3.** From Table 6.18 it is clear that the main difference is in the relative frequency of explicit and implicit suggestions and suggeststhat **user testing with active intervention is particularly poor at producing implicit suggestions for improvement**.

However, this must bear a **heavy caveat**. This is evidence from one individual. And Table 6.16 shows that this individual produces low numbers of implicit possible improvements compared to CDR C1 and C2, whose balance between explicit and implicit possible suggestions is very similar to C3's for the digital interactive prototype with a free exploration protocol. This result must be treated with scepticism until it can be replicated.

	Paper - user test	Digital - user test	Digital - Free exploration
explicit improvement	43	30	20
implicit improvement	17	5	22

Table 6.18: Suggested improvements recorded by C3 for both prototypes and both protocols

6.3.1.3 RECODED IMPROVEMENTS TO PROTOTYPES - STATISTICAL ANALYSIS

Where the suggested improvement type cannot be shown statistically to be independent of other variables – prototype type (paper or digital interactive), CDR subject, and (for C3) protocol (user testing or free exploration) – there is an opportunity to examine these further with respect to the category of the suggested improvement – data-related, interface-related, interaction-related, or new-related using the recoding of the data (Table 6.5).

Table 6.19 compares the category of suggestions made to improve the prototype recorded by CDR subjects in the paper and digital interactive user testing sessions. A null hypothesis is that the category of suggested improvements are independent of prototype type. Using a chi-squared test yields a value of 10.66. The critical value for a chi-squared at the 0.05 significance level is 7.81 (DF=3), so the calculated value is greater than the critical value.

> 10.66 **>** 7.81 (DF=3; sig=0.05). **I REJECT the null hypothesis that the category of suggested improvements are independent of prototype type**, and **conclude** that **the category of suggested improvements depends on prototype type**.

The numbers in Table 6.19 show that **within an 'active intervention' user-testing protocol, the paper prototype yields more suggestions for improvement than the digital interactive prototype except (perhaps understandably) for interface-related improvements**. In particular, **the paper prototype produces more than twice as many suggestions for improvement that are related to 'new' features (and that includes novel geovisualization elements)**. The fact that the paper prototype is inferior to the digital interactive prototype at eliciting 'interface-related' suggested improvements is an advantage in the context of geovisualization, as such suggestions are not central to geovisualization inquiry.

Table 6.16 and the chi-squared test conducted on that data, shows this is not an order of prototype effect. Table 6.20 gives the distribution of the 'new-related' suggestions by subject, and shows the pattern between paper and digital interactive is consistent across all three CDR subjects. The data are robust in these respects.

	Paper	Digital
Data	70	43
Interface	10	20
Interaction	47	30
New	35	16

Table 6.19: Improvement suggestions by category by CDR subjects in the paper and digital interactive user testing sessions

	C1	C2	C3
Paper	9	10	16
Digital	5	3	8

Table 6.20: "New-related' suggestions by CDR subjects in the paper and digital interactive user testing sessions

It must be emphasised that this important result applies to user testing with an 'active intervention' protocol only, and are not general results applicable to other forms of user testing. However, as argued in section 6.2.2 for geovisualization such active intervention is entirely appropriate.

Table 6.21 shows the data for the category of suggestions made to improve the prototype by CDR subject. Based on a null hypothesis that the category of suggested improvements are independent of individual CDR subjects, a chi-square test yields a value of 13.99, while the critical value of chi-sq (DF=6) is 12.56 at 0.05 significance level.

> 13.99 > 12.56 (DF=6; sig=0.05). **I REJECT the null hypothesis that the suggested improvements categories are independent of subject.**

Examination of the data shows that **all subjects have 'data-related' suggestions for improvement as a predominant category**; the other three categories having more of a range between the subjects.

	C1 5/7	C2	C3
Data	33.6	32	34
Interface	8.6	4	14
Interaction	15.0	33	23
New	10.0	13	24

Table 6.21: Suggested improvements by category by CDR subject for combined paper and digital interactive prototypes in user testing. Subject C1 had 7 user testing sessions, C2 and C3 had 5 in the paper and digital interactive prototyping session. C1's count is multiplied by 5/7

Table 6.22 shows C3's results from both prototypes and both protocols by category of suggested improvement. A null hypothesis is that the categories of suggested improvements are independent of prototype protocol for subject C3. A chi-squared test on C3's digital interactive user-test versus free exploration, results in a chi-squared result of 4.18 which is smaller than the critical value (DF=3) of 7.81 at the 0.05 significance level.

> 4.18 < 7.81 (DF=3; sig=0.05). **I FAIL TO REJECT the null hypothesis that suggested improvements categories are independent of the prototype protocol used (user test v free exploration) for subject C3.**

The comparative similarity of the two digital interactive prototype results with the two very different, protocols is in contrast to C3's results in the paper prototyping, indicating that paper prototyping is providing the opportunity for greater generation of possible improvements.

	user testing		free exploration
	paper prototype	digital interactive prototype	digital interactive prototype
Data	26	8	10
Interface	5	9	3
Interaction	14	9	13
New	16	8	6

Table 6.22: Suggested improvements by category recorded by CDR subject C3 for both prototypes and both protocols

6.3.2 QUALITATIVE ANALYSIS OF USER TESTING WITH PAPER AND DIGITAL INTERACTIVE PROTOTYPES

With 150,000 words of subject transcription on Prototyping, critical selection of quotations is necessary. Those given are intended to illustrate the kinds and qualities of the exploration achieved, to draw out any particular characteristics of prototype and protocol, and to highlight relevant evidence relating to the research questions (see section 6.1).

Insightful quotations are listed by CDR subject, *within* the user-task categories (spatial resolution, spatial zoom, spatial pan, temporal single glyph, temporal multiple glyph, crime attribute – absolute and relative values, and crime sub attributes - the order the subjects encountered them), *within* the categories of exploration (exploratory activity, hypothesising, having ideas or insights, confirming known facts, and having expectations about received facts confounded) and finally *within* prototype (paper or digital interactive). Where quotations are coded to more than one category, they only appear once in this section to avoid repetition. However, some subject think aloud narratives can contain exploratory activity, hypothesis forming and insight in the course of a single sentence, and the choice of category under which to present such text is subjective.

6.3.2.1 EXPLORATORY ACTIVITY

Spatial resolution

Paper	**Digital interactive**
"I'm drawn to the dark green square on here which will be the highest number of assaults. It's in the town centre. I wouldn't say I knew it particularly well but I have a vague sort of idea how the town centre's set out." [C1] *"you pick up this estate here, for example, the name of which escapes me, but there's a lot of shops where this square is*	*"the bit that we are interested in is along this road and where this road forks which is the main kind of town centre area which cuts four squares that we are kind of looking at at the moment… I'll probably…back out to …keep it 200m but then go back to*

here, and at a higher resolution you don't pick that up. [C1 says higher but means "lower"]…and perhaps one or two others, but we probably wouldn't look at those until much further down the line, because in terms of assault it's going to be skewed so much around this town centre area where the crimes take place. [C1] *"I can see that the concentration of crime before...was in a 1km square…so I want to go back to the previous screen…I'm trying to work out whether or not the 1km square that's dark green on the 1km resolution is represented by the squares I think it is on the 500m square - which it is. So I've just defined that that area there is the dark green square…and I've got one square again that's dark green which is a smaller square but obviously contains most of the crime. So I' m going to go 250m…now I'm just going to keep going and get a general gist of the fact that the concentration of crime is in a very very small area. So I' m now at 200m and I'll go to the finest resolution of 100m…to confirm that from one very large square at 1km I've got down to 100m resolution where there is a very large concentration of assault in a very small area." [C3]*	*5km and look at the whole area by 200m and just see if there any other squares across Loughborough that come out as being particularly high." [C1]* *" So the areas of theft within Loughborough as a whole have centred into what I presumed to be the shopping centre…so I would like to zoom in on to that particular area…You can see in relation to the whole of Loughborough that the only colour [high incidence of crime] really is in that area. [C2]* *"Again because the emphasis is drawn to those two squares there…the rest of it is swamped by that emphasis - because I'm drawn to those squares and I would want to drill in and maybe get a better idea of what's going on in that area." [C3]*

These quotes represent exploratory activity by the CDR subjects as their think aloud reveals their tactics for exploring different resolutions. Both prototypes enable systematic investigation of the resolution possibilities and confirmation of the key nature of these data sets (assault for paper; 'all other theft' for digital interactive), which is their concentration in a very small area. The final 'paper' quote shows **the breadth of engagement and exploration possible with paper**.

Spatial zoom

Paper	**Digital interactive**
"you have the town centre area, the night-time economy, centred around what I take to be the town centre…it's the darkest resolution [colour]… geographically, I don't know. But it's obviously the night-time economy town centre. Sitting next to it we have …what I would take to be the daytime town centre in terms of the shopping areas. I guess that these aren't within that…the crimes are very much centred around the night-time economy in terms of the number of assaults that are occurring, so the problem area within the whole of Loughborough is…the darkened area here during the early hours of the morning." [C2] *"I'm contextualising everything at the same time all the time, so…I ve got the same kind of pattern I had at the higher resolution - and what I mean by that is in the darker square with the concentration at 200m resolution, the pattern of crime over time by hour is very similar to the overall pattern of crime for the whole 1x1km square, so I'm almost filtering down the pattern by resolution as well, but from what I can see in front of me, I've not got the next level up, as in: it would be interesting to see…I've got this…200 x 200m square with a time pattern in it; I've got a 1km x 1km square with a time pattern in it…the question I'm asked is…'how does that*	*"I want look at the time of day, so I want to look at Hours and then initially…keep the rest of it….So I'm looking at this 25 glyphs here showing the data by Hour and then I want to compare this to one glyph for Loughborough as a whole…I want to compare this square to a glyph for the whole thing…" [C1]*

compare to the 5x5km square?' - but I can't see that. In order to see that I've got to switch my screen back to 5 x 5kms [paper flipping noise] …so now I've got the other half of the picture. I kind of want to see all of it at the same time." [C3]	

These quotes again show the breadth of engagement with the paper prototype and the surfacing of perceived deficiencies in the prototype and hence possible improvements. C3's think aloud reflects the frustration of having to flip backwards and forwards between pieces of paper – this is unnatural because the obvious thing to do with paper sheets is to position them side by side. **This shows a strength of paper prototyping in its ability to simulate a shortage of screen 'real estate'**. I could have chosen to represent the prototype differently and said 'the screen can show two pieces of paper at once' (in the same way, I could have used two computers/monitors to achieve the same effect on the digital interactive version). The digital interactive quote shows C1 beginning to interact with the temporal information in the form of the glyphs.

Spatial pan

Paper	**Digital interactive**
"this one square seems to dominate … less than the other one did. So overall in this square there's this peak early evening, overall in this kilometre, but within the square, the peak is … slightly different to the other one. But I find it difficult looking between the two. I find it hard work comparing these two … these two things." [C1] *"there are differences between the two, but the differences aren't in one square, it's happening in the early afternoon and in the other one it's happening in the early hours of the morning." [C1]* *"I've now got the crime by 200m x 200m for the square immediately to the E of the town centre. From my recollection of the time distribution in the town centre, there was a concentration of crime after midnight, whereas within this overall 1x1km square, that concentration is not there. So overall I can spot a general difference in the time to the E. The interesting thing is that…this is almost as if I've been scripted [laughs]…the one that square that I talked about…when I looked at the town centre I said there was no information there about the surrounding areas, I've now moved into the surrounding area and found that there is a higher concentration in one of the neighbouring 200m x 200m squares…But I've also got something else of interest that I want to look at which is probably irrelevant to the task. But the fact that I've got another concentration of crime in a completely different kind of geographical 'bucket'… I 'spose…it's being treated in isolation of its surroundings is I 'spose what I' m saying." [C3]*	*"Going back to the centre, and down... the timings…. the patterns here are very different between the two highest green areas, in comparison to the centre... the actual patterns [are] very much centred around late evening… one of the highest, I would say, is the highest one. So, very different to the other high green area, which is more during the daytime.. I would suggest [there] are completely different crime types occurring." [C2]*

The examples show subjects combining absolute levels of crime (from the thematic map) with temporal information from glyphs. In the digital interactive example, C2 describes a spatial cluster of high values, with variation in the time periods when crimes occur. The third paper prototype example, from C3, shows the subject wanting to deviate from the set task to investigate a secondary crime cluster. This had not been noticed earlier due to the thematic map colouring of crime in the central area of Loughborough. **The paper prototype is capable of driving spontaneous desire to explore data.** This also underlines the importance of real subject data that engages subjects and contains rich detail.

Temporal single glyph

Digital interactive
"the resolution on the screen is set how I'd want it to be. I can see the area of interest so I don't want to change that. From the colours I can tell which square you are talking about in terms of the one I want to compare to all the other squares, so I'm clear on that. Um…and from the time point of view…I'm thinking all the information is there and that I don't actually need to change anything on screen to answer your question, is what I'm saying."[C3]

Asked if another view of the data would yield further information, C3's description of the satisfactory set up of the digital interactive prototype shows mastery and integration of its many components.

Temporal multiple glyph

Digital interactive
"If you look at this main one here so you've got a peak between 12 and 3 [pm] and another one between 3 and 6 [pm], and to a lesser extent, you know, sort of 9 to 12. I think it's less useful to kind of say 'well, All Other Theft occurs somewhere between 9 in the morning and 6 at night'. You'd kind of expect All Other Theft not to be related to the Night-time Economy and therefore to take place during the day. So saying it takes place between 9 and 6 doesn't really narrow it down at all, whereas when you put lines for individual hours then you can say more about them. So I think the resolution would be better over 24 hours." [C1]

In this quote from C1, the link between the geovisualization and the nature of the data emerges – the fact that banding of hours – designed to aggregate time to provide larger crime numbers – has the effect of rendering the insights obtained meaningless.

Crime attribute – absolute and relative values

Paper
"the question being the link between volume and whether or not it's above the crimes relative to the 5 years. If I go back to the crimes relative view…it's telling me that there's two squares in the town centre area that are above average…way above average…compared to the 5 years. From that I would make a general judgement that yes, there was a relationship" [C3]

This illustrates a case where the prototype (paper in this case) fails to elicit useful exploration by the subject who bases the response to the task on a limited sub-set of the data (concentrating on two squares out of 25) and draws the wrong conclusion.

6.3.2.2 HYPOTHESISING

Spatial resolution

Paper	**Digital interactive**
"the darker square is the concentration and there is a limited number of squares that have got a high	*"Because the crime type is AOT, within all other theft, then, theft from shops would be the most*

number of crime on here. Now, my answer would have been far more complicated if [the crime] was more dispersed and from the general feeling of the first resolution - the 1km resolution - it was kind of almost obvious from that how the pattern was going to go. Now if it had been…a smoother picture, i.e. a more homogeneous distribution of crime on that first one, then it would have been more revealing what was behind the data as you go down the resolution but ' cos the first screen gave you that - almost gave you a clue of what you were in for…" [C3]	*prominent, I would suggest, so I would suggest that is a shopping area. And I want to zoom in to test that theory. [If there was a more scattered spatial distribution] I would probably zoom into the different areas to try and make some kind of sense of it anyway. Even though I can pin it down to this particular problem area, but my need to know what's underneath it would mean that I would want to zoom in and see if the map can tell me anything that I cannot gather from this [resolution]" [C2]*

The paper prototype quotation provides another example of data affecting task. Concentrated data is different from dispersed data – **what is learned from the paper prototype is data-dependent – that is, it is a combination of prototype *and* data**. The choice of a more spatially dispersed crime category, would have led to different information about the performance of the prototype and hence possible improvements. Nevertheless, the paper prototype has sufficient power to elicit this information from one of the CDR subjects (C3).

The quotation from C2's use of the digital interactive prototype "*I would want to zoom in and see if the map can tell me anything that I cannot gather from this [resolution]*" illustrates the use of the background map layer as a source of additional attribute information. Provided for orientation and navigation, **the background map is an unexpected data source that influences the course of the subjects' exploration and hypothesis forming**. Another aspect is **arguing from the crime pattern to the map**: "*theft from shops would be the most prominent, I would suggest, so I would suggest that is a shopping area*." Here the task has provoked perverse, reverse, exploration and is an indication of the strength of the crime patterns that these subjects are familiar with.

Spatial zoom

Paper	**Digital interactive**
"There are three time periods - or a 2 hour period and a one hour period - so it would be interesting to know…what crime types they were…maybe again at a smaller resolution [higher resolution]… But to look at it in more detail, to look at what crimes are happening in and again look at the days of the week, I think because I suspect there's a school under there and you're looking at lunchtime at schooltime at the end of school are the peaks on that. And you'd probably confirm it by going into your days of the week again. So it's not actually telling you anything new in some respects but at the same time it's put the place, the time, and everything all together. And if you were explaining that to somebody you wouldn't even necessarily have to show them this, though you could take the information from this and explain it to them and knowing damn well that if you reproduced it again you'd get the same result - which is always useful!" [C3]	*"The interesting thing is that there are very different time patterns in there, [they] are very, very interesting to me. But without starting to break down to sub categories of AOT, I would not have a clue what those are, but they do shout out as being of interest." [C2]*

Some quotations from both the paper and digital interactive prototypes highlight the **extent of subject engagement** and - from the paper prototype - **hypothesis formation in action**:

> "*it's put the place, the time, and everything all together*"
> *"The interesting thing is that there are very different time patterns in there, [they] are very, very interesting to me"* and
> "*I suspect there's a school under there and you're looking at lunchtime at schooltime at the end of school are the peaks on that. And you'd probably confirm it by going into your days of the week again.*"

C3 also argues from pattern to map here.

Spatial pan

Paper	**Digital interactive**
"I would expect to see some sort of pattern between the train station and the town centre and that that pattern would relate to what there is between the two. So where the pubs are and where the streets are [where] to walk. I don't know this area that well so… the area that is highest here … is quite a different pattern of crime to the highest area in the town centre in terms of when it takes place." [C1] *" I would be interested in looking at this data in terms of how many of these are [assault and] how many of them are what I would call more low level harassment … and to a degree the spatial pattern by hour, because things like harassment you might be more likely to see... I was going to say it related to the end of school or the working day, but that perhaps that wouldn't be the case…" [C1]* *" this peak does seem to be related to the end of the school day and the end of the working day. And there is a school just off to the side of the peak square, so I would probably be thinking is this more low level kind of assault with young people as victims." [C1]*	*"To the north of the town centre, the area of the highest AOT is around the station as you would imagine. It is at…early afternoon-ish to late afternoon-ish. Around the times predominantly of the car parks being full, but people being away from the car parks if they have used it for work etc, so you would have theft from cars. And probably in the evening with cars being left there, where people go out to the pubs or wherever." [C2]* *"I would want to see literally what is there… this crime type is quite a good one, because there are very separate crimes contained within it. And you would expect different situations that would explain the timings, to be honest. So you have got… what did we say ... nine in the morning 'til nine at night?... you would expect maybe a shopping area, at a guess." [C2]* *"I can see underneath [from the map on the lowest layer] that it is the University and colleges. AOT from students is quite a high category within 'theft from person'. But the timings are relatively distinct between the two - I take that to be the University grounds, and that to be the college grounds? And that might reflect the fact that the college's normal working pattern of 10 etc on through to seven, eight at night, whereas there might be a student Uni bar within the University, which would account for the two early hours. So again, the glyphs work really nicely, I think, in examining the difference…"[C2]*

Hypothesis forming shows a degree of spatial dependency – C1's first paper prototyping quote reasons about crime taking place along **a route joining spatial features**, the railway station and town centre. C1's third 'paper' quote relates afternoon crime to a school marked on the background map. On the digital interactive prototype, C2 hypothesises about the crime and speculat about the underlying spatial attributes. In the digital interactive prototype, C2 describes an **areal pattern** of crime "around the station" and relates the presence of car parks to theft from vehicles. In the third quote, C2 moves from the presence of a university and colleges to quite detailed hypothesised patterns of theft from person. In the second C2 quote, the crime incidence is used to hypothesise the presence of a shopping centre, once again **arguing from crime pattern to map attributes**. This set of quotations reemphasises **the importance of the background map as a carrier for additional attribute data**.

Temporal single glyph

Paper	Digital interactive
"I'm looking at the background map and trying to make a link between the two, so … there's this one in the top left that could be one or two possibly, so that's probably more likely to be domestic [assault]… I dunno. The one next to it that you can pick up by the…playing fields and stuff, and that's quite spread out…" [C1] *"…the dark line there I take to be the midnight line…So my presumption from this is that the majority of crime assault within the darkened square is actually happening in the early hours of the morning. Which would lend itself to an idea that this is a town centre with a night-time economy, assault being strongly linked to alcohol. In comparison to the other areas…well, that's quite interesting…" [C2]* *"Moving back into the centre again, another go round… I'd say there's a similarity with the early hours…[they] do tend to stem round the darkened square in terms of that idea of a night-time economy. But maybe with these areas here [to the west of the area], crime more during the day…to me it looks like the next darkened squares so the second highest square in terms of number of assaults tends to be happening a lot more during the day so my presumption would be, without knowing the area, that this is maybe a market area, shopping area or maybe even a school area." [C2]* *"I'm just looking at this idea that crime…assaults peak around the 3 to 6 o'clock banding [3pm to 6pm]… that's the way we band it as well, so we're not quite sure how accurate it is, but the police have suggested that that happens around areas of school[s] because it might be when schools come out, so I was just looking for that type of pattern." [C2]* *"the general pattern [in this area]…doesn't seem to fit particularly well with any other, but it does highlight that the longest pattern is at 4pm so the 4pm idea would fit with it being a school area and there being a rise in assault" [C2]* *"We've got a town centre area with shops, pubs, clubs. You've got various residential areas that have got schools, pubs. You've got a University that's obviously got a lot of people around during the day. It's got a Student Union so there'll be people around at night. So that's a reflection of when offences [occur] there as well. So I suppose - ultimately - the time distribution that is shown on there is partly a reflection of the behaviour of the people within the square at a given time of day and the geographical features within those squares that will influence whether people are there or not. And if people are there or not the crime will occur." [C3]* *"you can pick out isolated spots in terms of concentrations of crime, so I suppose your natural process is to start looking at natural hotspots of time and trying to break that down. So it's like…in this square here I've got a concentration of crime between 1am and 2am, I can go either way I 'spose, but is it particular days of*	*"Because AOT would include - from my recollection - theft where someone maybe has been in a nightclub etc: they have left their coat on the back [of the seat] and someone takes a wallet out, which would account for the later kind of times as well, and that's quite prolific within that group, so it is quite interesting - it would be quite interesting to match geographically whether this area here, would relate to that kind of activity i.e.,whether it is a night-time economy, or it could be at gyms etc. There might be a gym area, a sports area, around there, where that kind of activity takes place." [C2]*

week for that hotspot? Or do I want to look at it overall and see whether or not it smoothes out over a longer period of time? Or is it during the summer months people are more likely to be outdoors, in the street? Those kinds of questions I think that you'd ask." [C3]	

Hypothesis forming here shows again **the importance of the background map as an implicit carrier of relevant spatial data**. In the paper prototyping, C2's second quote **argues from pattern to geography** to deduce that the location is the town centre of Loughborough, and in C2's third, the location of a "market area, shopping area or maybe even a school area." C3's first quotes draws heavily on the data from the background map to frame hypothesises about what crimes are happening and when. The second of C3's quotes reveal a systematic approach to exploration and hypothesis forming, and recognises the 'multiple route' nature of exploration. The paper prototype is supporting some useful and complex geovisualization. The digital interactive prototype quote from C2 illustrates **hypothesising** and the requirement for spatial attribute data (for example gym and sports area locations) to support or deny it.

Crime attribute – absolute and relative values

Paper	Digital interactive
"The biggest increases aren't in the highest volume areas they're in the ones adjacent to that. I don't know…whether something has been done locally, focussed on this…in this area which might have pushed things into adjacent areas, possibly. Again, there's an area to the south of the town centre where there's been an increase as well, which… I'm not sure what's in that area, it's difficult to draw much conclusion from that." [C1] *"The other thing that would be useful is what's been done in these areas - they are spending money here and done things like…well, in the past they've done things like street wardens. In Leicester City centre, not in Loughborough, they've done these Safer Routes things… things like that would be useful. You know, is this a designated Safer Route? Are they putting more cops in [eastern] area and that's why it's gone down and that's pushed it into other areas? So… the initiatives that have taken place and changes in policing and stuff. Things like they've just been given £25,000 to do something to reduce violent crime, so that's money they didn't have in 2005, 2004, 2003, 2002, 2001, so how have they spent that and is there a link between that and what's happening here?" [C1]* *"…looking at the changes … introduction of the new Licensing Act, for example. That might be interesting to see a kind of before and after. To say "it hasn't really changed" or "it has". If they've put in an extra 10 bobbies and half a dozen taxi wardens or whatever, then that might be why they are recording a lot more crime because there's a lot more people out there to see it." [C1]*	*"I was supposed to be comparing these four different "Theft Of"…four different kinds of theft spatially and then the time for the town centre. So I've looked at All Other Theft previously…if we just change this to Theft of Vehicle…Theft of Vehicle and Theft of Cycle both are much lower in terms of number of offences but I would expect Theft of Vehicle to be not too dissimilar." [C1]*

The paper prototype quotations from C1 again show the need for spatial data: "*I'm not sure what's in that area, it's difficult to draw much conclusion from that*" and for new attribute data – in this case previous initiatives reduce crime and disorder: "*initiatives that have taken place and changes in policing*" or relevant changes to the law " *introduction of the new Licensing*

Act". In the digital interactive prototype quote, C1 **hypothesises** about the similarity in the pattern of two different crime types, showing another way these domain experts are obtaining information from different parts of the prototype.

Crime sub-attributes

Paper	Digital interactive
"Looking at the treemap, Harassment is the crime to come up the most, followed by Other Wounding…My immediate thought when we are looking at change…over time by crime category is what changes have taken place in recording practices, so it might be useful if there were something that indicates that - and that might be just saying 'as far as we know there has been no change in recording practices either through national instruction or through local practices' - how things are recorded. Although I'm not really interested in that to start with. So now looking back at the maps in terms of where these changes have actually taken place… that's quite interesting 'cos the biggest changes have taken place in those areas which have a reasonable volume of crime and aren't in the 'main' square." [C1]	*"Whilst [better car locks] has been a major thing on the volume of vehicles which are now stolen, which cars are stolen…yeah, so that may relate to the fact that, in these areas, are people who have older cars which are easier to nick, and therefore their cars are getting stolen. Or it may be that…there is a theory around that people stealing highly desirable cars and you know like Porche KNs and all these sort of things and being stolen to order… but I can't imagine volumes that accounts for that many. But…maybe it does…And I think the other comment [to make is] the nature of crime and offender behaviour and stuff is relevant as well. So… it may be that an offender's girlfriend lives here and he goes there on a weekend or whatever and nicks cars. So he lives here when he's in Leicester…" [C1]*

C1 uses the treemap during the paper prototype task (the treemap is not available in the digital interactive prototype) to compare crime sub-attributes and then moves back to the map. This indicates **some integration and use of both tools (= pieces of paper),** again **demonstrating the viability of the paper prototype**. Comments by C1 in both prototypes show **how important domain knowledge is as the tasks become more complex**, with some interesting hypothesising about the temporal pattern of theft of vehicles in the digital interactive prototype, and **another instance of wanting additional attribute data** on previous initiatives reduce crime and disorder.

6.3.2.3 IDEATION/INSIGHT

Spatial resolution

Paper	Digital interactive
"The areas of high assault are around Loughborough town centre, although I couldn't be any more specific than that. I'm sort of guessing even then - I don't know Loughborough as well as, say, … if C3 was	*" the first view was using 1km squares so it could mask … 'hot spots' around a group of shops…now that we can see the [5km] data…it is very much focused around this one small area within Loughborough town centre. Where there's a high level of All Other Theft." [C1]* *"I think I was thinking it's probably not going to tell me anything in addition. But let's see if it does. If I move down to here … Hmmm, yeah, that's quite interesting 'cos it changes the pattern slightly and the peak we were looking at here is shifted quite a bit. So, I should have done that before." [C1]*

doing this, C3 knows the town centre very well. C3 could give you a lot more detail about it. And if I didn't know…if it was an area I didn't know at then, then I would have no idea this was the town centre. Other than assuming that because there were a lot of assaults there, because from the background map you don't really pick up what is lying behind it. So without zooming in any further…" [C1] "*Exactly the same area, you have a bigger one therefore you have more crime within that particular area. OK let's go to the next one down…[paper shuffling]…now we can see we still have that one hot spot area but it's dissolved out into more areas…*" [C2]	*"I think the biggest difference here is this piece of this area [this is an area away from the town centre] which has been kind of masked at a higher level…The pattern is pretty much the same that it's still along this kind of fork in the road here and this bit of the road here, but at this level you get a bit more information than using the 200m [resolution]…" [C1]* *"the pattern has slightly changed. It's condensed into one particularly high crime area, surrounded by lighter colours. Areas that don't contain as much theft, and then, more to the east, another area of condensed green." [C2]* At the end of the session, C2 has not gone below the 200m resolution to 100m data. The interviewer requests the 'Computer' to set up the prototype at 100m and then 200m resolution and to flip backwards and forwards between the two resolutions while C2 hovers a finger over the screen to fix attention at one point and thinks aloud: *"Oooooo! [expression of delight or surprise?]… very separated out, there was a space between those were… go back again….followed the line of the road… no, they didn't… okay… the fact that they separated out… it's interesting…that could be a small amount in terms of difference… I don't know… but from the colour range… I would suggest that that is a lot lower than those two, but that is a guess… it is necessary to go to the lower resolution to… otherwise you just combining the whole area together, whereas this is actually pinpointing in much greater detail…"* [C2] *"the only difficulty is working out where those big squares were. But it's what I'd expect anyway. You've got a concentration where your main shopping centre is…which is where that green square is there and then the Marketplace here… It's the centre of Loughborough and as you drill down it's Loughborough Marketplace, and the Rushes Shopping Centre, and…it looks like Market Street as well. So yes, with knowledge of the town, I could tell you where they were. The only difficulty is that I'm relying on my knowledge of the area, but yes, I can tell where they are." [C3]*

C2 relies again on the **background map for additional attribute data** in the first paper prototype quote. C2's second paper prototype quote shows a minor insight into the way the highest crime area changes shape as resolution changes. In the digital interactive prototype, C1 has a similar 'quite interesting' insight into the distribution of 'All Other Theft', and the think aloud quotes illustrate well a gradual process of building an insight.

C2's comment "*I don't know Loughborough as well as, say, … if C3 was doing this, C3 knows the town centre very well. C3 could give you a lot more detail about it"* is supporting evidence for the ecological reality that the CDR subjects exhibit individual characteristics - here that they have different geographical knowledge (see text associated with Table 6.17). **This is more evidence that different subjects have different responses in a geovisualization situation as they hold different (tacit) spatial knowledge. In arguing that prototypes based on real data are important, where these are geovisualization prototypes, they will contain location data, and different subjects will have different knowledge due to their different geographic experiences**.

The digital interactive quotation from C2 is an interesting moment, both methodologically, and for the subject. The session is essentially over and the Interviewer, who has noticed that C2 has failed to select the lowest possible resolution, decides to mention this to C2. In doing so, it is perhaps outside the protocol of the session, but reacting to events in a way that would be natural in a collaborative session between a geovisualisation designer and a prospective application user. It embraces the participatory evaluation approach outlined by (Maguire, 2001). The initial exclamation of surprise or delight by C2, and subsequent think aloud as an unexplored capability is revealed, shows **engagement with the digital interactive prototype**. It also **shows how 'think aloud' breaks down at moments when thoughts are focused intently**. C2's speech is a mixture of explorative descriptions, contradictions, engagement, uncertainty, all in quick succession. Frustratingly, these are moments of high interest.

The final quote from C3 (digital interactive prototype) shows that **the general process of exploration is influenced by prior knowledge**,here C3's familiarity with Loughborough, so prior knowledge of the area partly changes the subject's interaction with the prototype.

Spatial zoom

Paper	Digital interactive
"I think the next two highest volume - the two green areas - have similar patterns… these high volume crimes are non-domestic assaults related to the Night-time Economy and they are taking place in areas around pubs, clubs, taxi ranks, takeaways." [C1] *"[Zooming] into the town centre, it's narrowed the area down to very specific areas…again you have one darkened square that covers a smaller area…Again it's a night-time economy that seems to be highlighted…the night-time being spread out around a number of the adjacent squares - not all of them, but a number of them. The daytime economy [may] not be taken into account the way that the larger picture showed you. So it [zooming] does narrow the area down, but I lose what I take to be part of…the daytime pattern that was on the larger picture…And again, it's the same kind of pattern where it's condensed more within in, around the, darker area. And as it [zooms] out it reduces down." [C2]* *"…if I'm saying the town centre area is the 1km x 1km square then yes, there was a big similarity between [that and] the overall picture of Loughborough. But then when I have drilled down to a smaller resolution I can see that the concentration of crime is still in a very small area, though the distribution of time within that area is completely different. It's very, very concentrated into a 2 hour period." [C3]*	*"I'm noticing the ones around the centre, either side, there's a more pronounced peak for a particular hour which differs in each of those, so the one to the east is an earlier peak; the one to the south has quite a late peak towards the evening, whereas the one actually in the town centre from the late morning through the afternoon…there's kind of an increase but there's not one hour which is particularly more or less than the others, relatively within that area. That's about it." [C1]* *"the glyphs actually help in one way as well because you stated beforehand that only the top 25 would actually show. So, it indicates a little bit more clearly, where the other [significant areas] are. So, that is quite good…I would say that there is very little AOT occurring anywhere apart from around the town centre." [C2]* *"This particular crime type [AOT] is quite interesting.. the glyphs work extremely well with them. I mean, this area [four squares to the north]…these are all very similar… [C2]*

Both prototypes are yielding minor insights into the location of assault and 'All Other Theft' in Loughborough town centre with all three subjects talking about attribute, time and space. C2's first quote on the digital interactive prototype an example of serendipity at work: *"you stated beforehand that only the top 25 would actually show. So, it indicates a little bit more clearly, where the other [significant areas] are. So, that is quite good."* (the 25 limit on the glyphs was designed to speed screen refreshing). The subject think aloud allows such serendipity to be captured and incorporated into the iterated development of the application. The "selective reveal" insight itself has parallels with the animation work in information visualization by Harrower (2007).

C2's second digital interactive prototype quote shows engagement with the crime category: "*This particular crime type [AOT] is quite interesting…the glyphs work extremely well with them".* Prior to this user test, AOT had not been explored in any depth by the CDR team and had generally been regarded as an uninteresting crime category.

Spatial pan

Paper
"I've never looked at crime at this level of detail in Loughborough, you know, by hour, by 200m squares…I've not had the ability to create the glyphs. I've not perhaps thought about looking at [it] this way." [C1] *"…even though you've placed it [the treemap]here…I'm totally drawn to this [the map]…and I might find that [the treemap]useful as an overall picture if I was then to zoom back to the town [centre] but my summary of this would be again that it's early afternoon and pushing into early evening that the…majority of crimes take place, or it's not the majority of crimes but the highest crimes take place within those time periods in this particular area. And if I was then to compare it back to the…town centre…then it's an extremely different pattern …[moves to South of town centre]…I mean this again is quite useful. You're learning from…literarily the exercise I'm doing here, which is quite exciting. We have one darkened area where there's crime happening most periods during the day and to a limited extent midnight and early hours of the morning. Around it I can see no…oh, maybe one similar pattern, bottom right…but mainly around the night-time rather than the rest of the day. Very few areas are actually coloured compared to the centre and I would presume that it's a lot lower in terms of absolute crime anyway." [C2]* *"I've gone E and I've looked at the time distribution and in general terms I can tell you that there's a difference. The difficulty I've obviously got is I haven't got the time items of information in front of me at the same time to make any kind of detailed…or more detailed judgement on those differences. It's just purely in the fact that I know there's a general difference, so I would probably have to flick back…So I kind of confirm those suspicions that there's an inverse or some kind of inverse in the relationship…" [C3]*

C1 first quote is a reflective insight into the way the team has worked and how data has been examined hitherto, rather than an insight into the data itself, and is a refection on how the prototype has expanded the possibilities for exploration and insight when presented as in paper format. C2's quote also captures this: *"this again is quite useful. You're learning* *from…literarily the exercise I'm doing here, which is quite exciting"* as well as giving an example of the insights gained into the data.

Temporal single glyph

Paper	Digital interactive
"the dark green square is exactly what I would expect to see in any town centre if you look at the way the pattern is, in the way that the peaks [on the glyph pattern] appear. Whereas it's less kind of obvious on some of the other squares, so the one immediately to the left of that there's a pronounced peak between 1am and 2am and very little else going on the rest of the time. Just to the north it's much more spread out during the day and I think it's probably between 11am and noon which is quite unusual for a [centre?]. I don't think there's a particular pattern you can pick out from all the other squares. I think they are all quite different…" [C1] *"I think that highest one - the green square - and the one to the left of that are quite similar in the pattern. The one to the NE of the green square seems quite similar to me…generally there is a pattern of higher assault in the evening between 6pm/7pm and the early hours [of the morning] similar to the highest crime [area]. Then there are a few others where it is much more spread out - to the NW of the green square… the peaks are less pronounced in terms of the hourly difference…" [C1]* *" I've been immediately drawn to the summary one [treemap+glyph]…The reason being that I would be…well it's quite apparent - though I would have to do other investigations - that this square here [with the most crime]…is very similar to this square [treemap+glyph], because of the fact that the overall picture will be very biased towards…dominated by the square, purely because you've got a higher volume of crime in there." [C3]*	*"I'm looking at the green square - it's quite different from the Assault stuff that we were looking at before because it's much more focused in a particular area. Also the glyphs tend towards the opposite pattern that the ones I've looked at today. So the peaks are during the day and during the afternoon within the high crime square. That's repeated in some squares but not all. Again there are low volumes… all of the Theft stuff towards the edges of the grid that I'm looking at the moment, the glyphs in those are correspondingly bizarre or don't tell you a great deal 'cos of the low amount of data presumably that they are based on." [C1]* *"[The areas just to the west and to the south of the city centre] are very distinct [in their temporal patterns]. And because of the nature of AOT, then…my idea here would be that they are representing very different AOT [crime sub categories] and it's quite interesting there to tie them all in together… and I would like to investigate more with the separate [crime sub categories]." [C2]* *"I can immediately see that…eight squares roughly…[in the] surrounding area…you've got similar patterns and it's as you get further out - maybe the squares that are further than 1km away - there's a distinct change in the distribution that they are not all the same…when you've aggregated the time up to 3 hours, that pattern is still fairly evident." [C3]* *"[the temporal glyphs are] a clock basically at the moment… It's very difficult to show anything because it's lain on top of some other information. Now the whole point of this is that you're tying the information together and you know that the distribution of time there relates to the geographical area it's sat on top [of]. As soon as you start messing with it and if you changed it to any other kind of traditional graphical representation like a bar chart or anything like that that represented it, then that would ultimately skew your vision of what's underneath it, and suppose undermine what you are trying to achieve in the first place." [C3]*

Some examples in the first two quotes of quite detailed insights obtained in C1's explorations with the paper prototype. The C3 paper prototype quote refers to the treemap with glyphs as a "summary" showing that C3 is using it to indicate the aggregated state of the squares on the map (which is all it can do at this point as it shows no sub-structure). The digital interactive prototype is also providing the opportunity for insight. C2's quote:"*it's quite interesting there* *to tie them all in together… and I would like to investigate more*" shows **engagement with the digital interactive prototype.** C3's second digital interactive prototype quote is an insight into the nature of geovisualization and the compromises necessary to display spatial, temporal and attribute data.

Temporal multiple glyph

Paper
"I'd initially go to the square with the highest volume of assault. You can pick out that the peaks seem to be March and August although there's a fair spread of crimes across all of the months. I don't know whether there are peaks every year or whether just this year... generally I'd expect higher number of offences in the some of the summer months because there's more people about and although you get a peak of offences around things like Bank Holidays, Christmas, New Year, those things might be masked in looking at the data over a longer period. I might have expected December to be higher than it is in this main area [of the town centre]. I'm going to start looking at some of the other squares, [to see] what might be happening…" [C1] *"I don't actually see patterns as easily in the data cut [by month?] so that the different glyphs seem different - this one here has a peak in February and July; the one next to that the biggest peak is in June, followed by September. August is quite low there, and in this one it's quite high. So I find it harder to pick out patterns on the data." [C1]*

C1 has an **engagement with the paper prototype** as it provides C1 with a view into the assault data aggregated by month, with C1's first quote describing a range of insights; the second quote indicates that the temporal patterns by month are not as obvious as by time of day.

Crime attribute – absolute and relative values

Paper	Digital interactive
Interviewer: "why are you focusing on that [map] rather than this [treemap/glyph]?" *C1: "because this [the map] is more interesting."* *Interviewer: "why is it more interesting?"* *C1: "It tells me more."* *Interviewer: "Why?"* *C1: "Because it's much more rich in data - there's so much more on there; you can see things better spatially - you've got 25 glyphs…"* *Interviewer: "why is the spatial thing important to you"* *C1: "…that's kind of the first thing you perhaps look for when you're trying to explain the patterns. So if [you had] this background here, this map, and you just had your data, then it wouldn't be particularly interesting. What could you say about it? 'This square is bigger than this? This square's got a lot more than this square.' Whereas when you can anchor that in some reality… think…human*	*" I'm looking at the two big volume squares here…I wonder whether to turn the background map off?...yeah, let's turn the background map off again…Ok, immediately I'm thinking, there's no obvious relationship between…areas of high volume of All Other Theft and change this year. Because the main two are kind of side by side and show opposite kind of patterns - one of them has increased a lot in the last year, compared to the average, and the other has gone down…although I think this is the exception… this area here where it's a high volume of crime that's gone down. These other fairly high volume ones have gone up, so I'd be interested to know more…what might have happened in that area" [C1]* *"there's something about the fact that this process either highlights where these number of offences cluster together, so we kind of think, 'oh this is our hot spot that we need to concentrate on' but actually this car park [accounts for]…relatively very few number of crimes. And if you look at this area as a whole, you know, there'll be, like, two thirds of all vehicle crime happens in cars parked on a street. And yet this type of analysing data in this way…people focus their crime reduction initiatives on car*

interaction…it makes it…it's then about real life, it's about people going to pubs and town centres and walking from train stations, rather than '25 is lower than 50'." *"…the largest circle would indicate that the final year - the absolute crime was high. And the colour coding would indicate whether that was above average for that square…So you would expect large circle, deep colour….for it to be high and above average. The largest circle seems to be this one with the lighter shade. This - half the size - but a deeper colour…so even though there's less crime in there, it's actually…I would imagine increasing in that final year to be above the average the preceding 5 years …and down here we have a small area so there's a ¼ of the crime in this area but again it seems to have increased in that final year so it's an emerging issue…" [C2]*	*parks 'cos that's where the hot spot is, but more vehicle crime is taking place [elsewhere]" [C1]* *"The two dark red [squares] that indicate they are well above the average are actually quite different in their time pattern. We have a midday through to eight o'clock-ish, which...hmmm… okay, not really sure why. And then we have... I suppose the pattern is quite similar, but it tends to span out into the early hours of the morning as well in the other. So there is a degree of similarity there, but I think there possibly are two things going on in terms of the crime types. And in terms of the relation, the size of the circle, I suppose that is half of that, so… I don't know to be honest, is the answer I would give you." [C2]* *"So I've got probably three squares here that have got a high volume of crime - out of the three of them, two of them have got a much higher than average number in the current year compared to the last five years. Whereas there is one square…is that white?...so there's been no change in that square there." [C3]*

The first quote shows the interviewer probing C1 on the two tools available in the paper prototype. C1 expresses a preference for the thematic map/glyph over the treemap/glyph based on its data-rich graphics and spatiality (the latter regarded as the primary aspect of the crime domain with its ability to relate crimes to '*human interaction'* and *'real life'*).

Other quotes for both prototypes show the subjects dealing with what is the most complex task and gaining insights into the data. The first digital interactive quote shows C1 **exploiting an advantage of that prototype by turning off the background map**. The second digital interactive prototype quote from C1 gives an insight into the data, the fact that theft from vehicles is concentrated in car parks and yet that accounts for the smaller proportion of such crimes that occur on streets.

The digital interactive prototype quote from C2 shows how the think aloud approach is able to record ideation in action as C2 thinks further about the display. C2 first comments that two squares are "*actually quite different in their time pattern*", but then says "*I suppose the pattern is quite similar*", before concluding "*So there is a degree of similarity there, but I think there possibly are two things going on.*"

Crime sub-attributes

Paper	**Digital interactive**
[Context: C1 has been asked to compare a number of sub-crime attribute patterns which can only be viewed	*"[This is] Theft of a vehicle…That has shown me something new and that's quite*

separately, one at a time. C1 has requested and been provided with paper and pencil] "You kind of remember between the two, so…I would probably…do this kind of thing [C1 is sketching]…which is effectively like that and then I'd go to another one…so I'm going for Harassment…[C1 sketching]…and flip to Other Wounding - sorry, Common Assault…[C1 sketching]…[compares different sketches] In terms of the main square the differences aren't that great really, in terms of when things took place. It's pretty similar." [C1] *"I don't know enough about what's in these two squares. What exists there, so again I would need to know more about that - about what is physically there and about … so [for example] an increase in number of uniformed people in these areas or in adjacent areas or reduction in adjacent areas. Or whatever initiatives had been put in place, and the extent of the CCTV scheme; whether they'd detected more crimes … that type of thing." [C1]*	*interesting…I'm interested by how similar these are - all around a similar time of day. All of these the same and then this, this thing here…" [C1]* *"we've got this big heap here but actually that's five Theft of Vehicle over a year, so…what's it really telling me? I'll probably go to Theft From Vehicle now and then I've looked at them all, looked at all four at this level...so Theft From Vehicle is fairly likely to occur at any time … [it] is pretty low to…draw any conclusion from [that]…and it becomes more difficult… I'm trying to remember back…to other crime categories…without having them together." [C1]* *C1: "There's an interesting move…[of the place where the highest crime occurs]…"* *[general hubbub]* *David Lloyd: Suddenly we're engaged.* *Interviewer: We're all thinking "what's there?"*

The first paper prototype quote from C1 shows a rather painful process that is a result of the paper prototype enforcing a 'one view at a time' rule. C1 gamely attempts the task of comparison by recording 'screen shots' with pencil and paper. The second paper prototype quote echoes other requests during the session for **new attribute data**. The first digital interactive prototype quotes shows C1's interest and engagement, the second to difficulties in comparison with earlier screens and how the prototype's depiction of glyphs places the onus of detecting low crime levels (and hence their relevance) onto the subject.

The final quote shows a moment where a change in resolution moves the location of the highest crime unexpectedly that causes interest with subject and researchers alike. There is clear **engagement with the digital interactive prototype** at this point.

6.3.2.4 CONFIRMATION OF EXPECTATIONS

Spatial resolution

Digital interactive
"I'm assuming that's the right one…so it's going to do this and I'm going to end up with 25 squares I'm hoping…if that's the Marketplace in Loughborough [an area of central Loughborough] which it very much looks [like]…yeah, that is the town centre area of Loughborough. So I would expect that 'cos it's a reflection of where all the retail premises and main shopping area of the town centre, so I would expect a concentration there. In terms of…if you are only interested in the spatial resolution, then yes that's what I'm expecting, but in terms of the actual distribution of the crime, then it's not - apart from seeing that square there - as in the one main square - but it doesn't really give me a very clear indication of where the other crimes are taking place." [C3] *"then again that tells me kind of what I already know, so I would want to go kind of…deeper than that." [C3]*

"It's clear where they are. Well, based on the colour scheme, it is apparent where they are and it would…almost match up to where I would have expected it to be. The town centre is actually split though by that grid [the 100m grid lines]…" [C3]

A selection of think aloud quotations demonstrates the ability of the digital interactive prototype to permit explorations that confirm expectations.

Spatial zoom

Paper	Digital interactive
"I knew the geographical area of Loughborough roughly so I knew that there would be a night-time economy around a specific area. This [prototype] has been useful in showing exactly where that might be and that it displaces [assault] around this area, but it pin-points it to this area. I've not [previously worked on the] night-time economy in Loughborough so I suppose this has showed me [these patterns]…but I was aware that that would be probably be the case." [C2]	*"that's a very similar glyph to the one that we've just looked at, so these three lines in particular stand out from 2 o'clock…so the pattern is very similar to Loughborough Town Centre [rather] than for Loughborough as a whole, which you'd expect." [C1]* *"…you've got a steep, sharp change at 9 o'clock - between 8am and 9am. And then…[counts around the glyph…counting ending at] 6pm. Yeah. Shops shut! … I mean you obviously get Other Theft in pubs, restaurants and whatever that are still open…so it's the pattern you would expect." [C3]*

Further examples of both prototypes providing confirmation of expectations. The C3 quote is particularly insightful as C3 counts round the hourly temporal glyph to reach 6pm and announce "*Shops shut!*"

Temporal single glyph

Paper	Digital interactive
"just by looking at this [the glyph in the dark green square] first. Now this is what I would expect to see. This is a typical kind of pattern of assault through the town centre. So it gradually builds up from early evening, peaking between midnight and about 3am and then it kind of tails off - everything is quiet by about 6am. So that's a normal kind of pattern for the town centre." [C1]	*" you can say that from… mid-morning through to the late afternoon, then the predominant amount of theft occurs in there. And knowing a little about AOT, that's unsurprising because the majority of it is theft from a shop. So those times equate with the opening times of the shops. And my assumption geographically is that that area covers the shopping area of Loughborough." [C2]* *"The actual timing of the patterns… do follow in certain areas…similar to the town centre... and specifically thinking of these two areas here and here, one which you can see is the University, which again, all other theft [AOT] accounts for theft from person as well. So you would expect within the university that they would follow a similar time pattern, because that's when they are open etc.… I think the patterns of time here are indicative of the types of AOT that are taking place." [C2]*

C1 gives a clear indication of the pattern of assault expected and finds it present in the paper prototype. C2 with the digital interactive prototype has less experience of 'All Other Theft' but believes the patterns observed are consistent with theft from shops and the hours that shops are open and also theft from person at the times the university is assumed to be open.

Temporal multiple glyph

Paper
" in terms of crime, midnight is a meaningless point at which to break the data. 6am is a better time to do that. Because of patterns in human behaviour - particularly crimes like assault which a lot of it is related around the Night-time Economy… But all crimes have that kind of similar pattern - there's not much happening at 6 in the morning. But it's particularly pronounced for this crime type. So in looking at this there will be lots of peaks on a Sunday which actually are [related to] people out on the beers on a Saturday night. So… that's what it shows on the glyphs in front of me now. Lots of peaks around Sunday and Saturday, and Friday is less than Saturday or Sunday and less than [you'd expect?] 'cos it's only Friday until midnight… of those assaults taking place which are effectively related to the Night-time Economy on a Friday night being counted the next day." *"So when you move outside of the town centre then some of these other areas…you don't get the Night-time things, so the assault in those areas is less likely to be related to the Night-time Economy, less likely to be alcohol-related, more likely to be Domestic [violence]. You can kind of pick that up from some of the yellows [the yellow coloured squares on the map indicating low relative values for assault]. I mean there's a square here to the NNW of the dark green square which is quite a residential are…" [C1]*

The first quote here is included as it is an example of how interaction with a paper prototype can yield information about the domain data – in this case the way that in town centre assault data straddles midnight. The second quote also provides contextual information about the data – that assault is more than just the night-time economy, that a significant element is domestic violence and that the patterns of each are very different.

6.3.2.5 EXPECTATIONS CONFOUNDED

Spatial resolution

Paper
Interviewer: "So there's the 500m resolution." *C2: "So I've actually zoomed out? Right OK. I was expecting to zoom in. So that just shows…how I've got it backwards in my mind. So I assume if I was to go…this is me trying to understand what this is now…if I was to go one out, it would zoom me out again. OK. The colours have changed on this…the expectation would have been for me that the thematic map would have been set over the whole of [Loughborough], so that would remain the same, as I zoomed in or out, i.e. the dark green colour would remain the same."*

Not about expectations in the data confounded, but this quote is included as it shows confusion between zoom and resolution by C2. There is a nomenclature issue with a confused understanding of what happens to resolution when 'zooming in'.

Spatial pan

Paper
"…the highest area is quite dissipated - there's night-time, there's daytime…my presumption had been that it was…my guess would have been that that would have been a darker green showing a lot of daytime activity…but it's not…it's quite dissipated throughout the day, and there's some surrounding ones… where it's a lot more generalised…" [C2]

An example of C2 having confounded expectations with the paper prototype.

Temporal multiple glyph

Paper
"Just before we move on, can I just say that it's interesting that [there are] these crime squares at the bottom where there is this peak on a Sunday which does kind of stand out … initially my eyes were drawn to what was happening there [the town centre] and that's where the big volumes of crime are, but these five areas here, it's quite interesting on Sundays. There's a big, you know… that surprises me a bit. I find that quite interesting. I'd be interested to look at that…" [C1] *"I was initially surprised…interested in the peaks for the high volumes - where the peaks were in March and in August. Which I found quite interesting. If you had asked me beforehand which month would have the peak, I might have gone for August; I wouldn't have gone for March. Although, reflecting on it perhaps I should have done. But I think it…does suggest new things to me as well as confirming things I would expect to see." [C1]*

C1's first quote comes after a particular user test had completed and represents a reflection on what has gone before. C1 narrates the thinking process that culminates in "…*but these five areas here, it's quite interesting on Sundays. There's a big, you know… that surprises me a bit. I find that quite interesting. I'd be interested to look at that…*" The paper prototype again provides sufficient detail and richness to support this degree of engagement and provoke surprise. C2's second quote contains more examples of interest, engagement, expectation confounded and re-evaluation: "*If you had asked me beforehand which month would have the peak, I might have gone for August; I wouldn't have gone for March. Although, reflecting on it perhaps I should have done.*"

6.3.3 SUMMATIVE QUESTIONS – PAPER AND DIGITAL INTERACTIVE PROTOTYPES

When CDR subjects had completed both the paper and digital interactive sessions, they were asked a number of "summative" questions that asked for their retrospective responses on aspects of the session, as outlined in the methodology section, Figure 6.17. The responses are grouped under a number of headings dealing with:

- strengths and weaknesses of the two prototypes
- future direction for the prototypes
- the tasks used
- the data used
- their response to the prototypes in a user testing protocol
- any insights from the process

Strengths/Weaknesses of the two prototypes

Speed

"Speed [was one of the strengths of the paper prototype]…that's probably the main [strength] there.[I would prefer the digital interactive prototype] If you could give me some warranties that it would work a lot quicker….it delays the process where you're thinking 'oh

is this [X]?' and it perhaps discourages you from kind of saying… where you would just flip the map on and off…I can't be [bothered] to sit and wait for it." [C1]

"[asked about prototype speed] I suppose [the digital interactive prototype] seemed quicker, even though it possibly wasn't. In terms of everyday use, it would probably be important that it was relatively quick." [C2]

"neither of the [prototypes] met my expectation speed-wise." "I reckon that the paper-based system was quicker than the computer one" [C3]

Subject perception is that the paper prototype had the edge over the digital interactive prototype in terms of speed. This may be due partly to the nature of the digital interactive prototype interface. While the paper sheet for subject input (Figure 6.11) was completed swiftly by subjects, some of the browser strings that had to be generated were complex and resulted in both slow response and the occasional error that had to be corrected, slowing things further. In retrospect, more practice was needed. The digital interactive prototype was also slow because the data was served from a remote computer on which the calculations were carried out for plotting the glyphs and rest of the prototype. After the first user test, the speed of response was ameliorated somewhat by serving the large background maps from the local computer. Because of the important role of the interface in speed - comparing 'paper prototype and paper prototype interface' with 'digital interactive prototype and digital interactive prototype interface' - a true measure of the impact of the speed of the prototypes themselves is not possible. But **researchers should be mindful of the impact of interfaces to geovisualization prototypes which are not under the control of users**. The 'free exploration' protocol in which the subject has direct control of the interface to the digital interactive prototype provides a way to assess whether speed of response continues to be an issue.

Treemap
"when I had the treemaps side by side with it [on the paper prototype], I found that quite useful….obviously I wasn't able to do that with the [digital interactive prototype]" [C1]

A key advantage of the paper prototype over the digital interactive prototype is highlighted by one of the subjects.

Flexibility/Interactivity
"It got a lot better as we started losing the background, losing the colours of the shading, and doing things like that [with the digital interactive prototype] which we weren't able to do [with the paper prototype]. I found it more useful. I think I would be drawn towards this method that we've used this afternoon [the digital interactive prototype]…Being able to change the backgrounds, turn it on and off…under other circumstances I might have wanted to change the colours of the squares and…certainly being able to turn them on and off [was an advantage of the digital interactive prototype] [C1]

Speed and the presence of the treemap are perceived strengths of the paper prototype;

inflexibility of the paper prototype is a weakness (it cannot remove background and/or glyph and/or thematic mapping to see remaining elements clearer)

"[The digital interactive prototype] is a lot easier to see, it is a lot easier... with the paper you are having to imagine etc. This is more interactive; or it seems more interactive, because we've got the screen in front of [us]. In actual fact, it is not more interactive, is it? " [C2]

"I think this one [the digital interactive prototype] is a lot clearer to see and because it's maybe the last one I have done as well, and it's the nice little toy, isn't it? I would say [the digital interactive prototype], but I actually think underlying that [the] paper [prototype] was exactly the same." [C2]

"[The digital interactive prototype] is more exciting - it's like the free gift that you get with whatever you buy, compared to the paper. But when it comes down to the actual reality of it, they were very similar." [C2]

C2 outlines **advantages of the digital interactive prototype - ease, clarity and excitement/appearance**. But C2 comments on three separate occasions that the different prototypes are at heart, similar.

"[the digital interactive prototype's] strength is it looks more like the real thing…when you first walk in the room and you think "wow, this is a piece of software". And you can easily fool someone into believing that when the reality is …all you were doing was using the screen to show me exactly the same pieces of information on a piece of paper…in a way, I much preferred using the paper, because the paper was serving exactly the same purpose and the paper was more comfortable in its job, in the sense that my expectations with what you get from a piece of paper and from a computer screen are completely different." [C3]

C3 's initial, favourable, impression of the digital interactive prototype gives way to a realisation that behind the superficialities, the different prototypes are serving the same data: "*in a way, I much preferred using the paper, because the paper was serving exactly the same purpose and the paper was more comfortable in its job, in the sense that my expectations with what you get from a piece of paper and from a computer screen are completely different*."

Discussing the input sheet interface for the digital interactive prototype, C3 comments:

" It's a bigger job to do…so every time you decide to change something you've got to send in a different piece of paper, it's got to be interpreted, you've got to pass the piece of paper back." [C3]

This indicates that C3 understands the slowness of the process, but (from earlier comments) is disappointed by the speed of response.

"The only other thing with the paper is that when you put the paper down in front of you at the beginning of a task you are kind of steered…I found myself thinking 'you've got more

than one piece of paper there - I can do something with that' whereas with the screen you've got no idea." [C3]

A useful methodological point by C3 that went unnoticed beforehand and during the session. Because of the practical difficulties of handling 32 pieces of paper, I clearly did not pay enough attention to the cue I was providing by handling more than one piece of paper at a time. The problems of communication are not helped by methodological slips, and this indicates that really careful scoping of tasks associated with these protocols is needed.

"I suppose when you're given a question and given an open toolbox, you never stick to the original question anyway…you always deviate. Whereas you gave me as a specific question and I had limitations in terms of the tools that were available, so that kind of limits the exploration that you can do…if you hadn't limited the tools, then the [digital interactive prototype] would obviously exceeded the paper.." [C3]

An indication here that the user testing protocol interferes with the exploration process.

Future direction of the prototypes

"I think you are on the right track [with these prototypes]. And I would definitely use it…once [I] get over the embarrassment of thinking 'I should have been doing this before!'… I think in terms of the way that we work…I should have perhaps done more starting from the point of view of us exploring the data. We should have done more work starting from there, rather than starting from someone saying 'look" and saying "tell me about crime.'"[for example] I've never looked at All Other Theft in any detail particularly, and no one has requested me to do that to provide them with that information for any work that they are doing. But perhaps I should have taken it upon myself to explore that…" [C1]

"I think you've ended up coming from a position of six months ago to not really being able to visualise where we were going, or whether we might end up, to actually having things to play with…Thinking about all of things we've looked at here in terms of how we cut the data and used the glyphs and colours and all of those sort of things in a practical way with actual data as well." [C1]

In the first quote, C1 provides a positive view on the direction of the prototypes and gives a contextual comment that indicates the process of being exposed to geovisualization prototypes has led to changes in thinking about the approach to the work of this team. The second quote shows how tortuous the journey has been from the subject point of view until they have *'things to play with'*. The final words reiterate the importance of real data.

[asked "How keen would you be to go and use this sometime in the future?"]
C2: "Very keen. Very keen...There is a whole range of crime types which are all totally different, which will all give me different patterns to explore in an extra dimensional way, so this would be a continuous tool. I mean… there is change over time as well, so I would be quite happy playing on this day after day….it's pulling the aspects of the place and the time together that's the important thing for me."

C2 indicates a positive view of the prototypes and their scope.

"it fulfils something we spend a lot of time doing that on a piece of paper looks quite easy to do, yet obviously isn't. The way we work at the moment, you have to choose your area before you've even started - you've not got the ability to zoom in and out, change the resolution - you've almost got to decide or narrow down what your answer's going to be before you've answered your question. Whereas this gives you the opportunity to start with everything and zoom in and out as much as you like, up, down, left, right, side to side, you can do all of that." [C3]

"I end up producing maps like that all the time. But it takes me forever to do it because it's a manual process of coding the data up…drawing a grid...matching it together…there's no consistency in the data that you get. All the usual problems… But in terms of the way the information is presented, then yeah, I would use it [the digital interactive prototype]." [C3]

Hands-on experience of working with prototypes has enabled C3 to establish some of the requirements that C3 would like to perform – in contrast to the failure to establish requirements with the Volere template (Chapter 4). C3 is positive about the prototype, contrasting it to the current way of working. Generally, the three CDR subjects indicate a positive view of the prototypes.

Tasks

"[Asked if the prototype tasks were sensible] Yeah, well…it would be 'yes they're the sort of tasks, but actually no one's ever asked me to look at all of them', so they are the sort of task, but specifically it would be 'no, I've not been asked them', focusing … on the specific crime category. Whereas the actual things we are doing, we have been specifically asked to do them in the past for other types of crime or for other areas." [C1]

"[Asked if the prototype tasks were sensible] Yeessss….[hesitatingly]... but we are very structured within the crime and disorder research team. We do look at time - but we only look at it to date in a kind of timeline or day-and-time. We are only on the brink of what we could do. We haven't really looked at seasonality etc. We look at the visual side of it, of space." [C2]

" these are the types of task that we would pull together within a report if we were doing a report on say, All Other Theft. So we would cover these. But we would not be able to pull them together in the way that [the digital interactive prototype] has done with time and space elements combined." [C2]

"[Asked if the prototype tasks were sensible] But you're only talking [things]so far, and there are so many other questions that you would ask, and that's about the different ways that you cut the data, the different avenues that you'd explore…but you ask a general question, you get a general answer, and that's all you can do" [C3]

"….[in terms of task complexity] it's the kind of thing that you might be asked [to do as part of day-to-day job]." [C3]

"[asked if the complexity of showing time, crime, geography together made sense] Definitely. I think you've got to do that at some point...it's not until you see all the three things together that you've kind of got a full picture. Even if it's not that clear you then you might go off and look one at a time to clarify what each one is telling you and then come

back again to pull it all back together again. I do think it's really helpful – 'time' is the one that's always forgotten…" [C3]

These quotes indicate that the tasks used in the user testing sessions were reasonably realistic of the kinds of tasks that the CDR team might normally undertake, and thus validate the relevant methodological choices made. Also, more indications of a positive view of the prototypes.

Real data

"The difference between the datasets that you [had] and how that affects my enthusiasm for doing the tasks is quite interesting." [C1]

"[AOT] is not a really very interesting crime…Well, I suppose it is, but there's so many different aspects of it and I probably wouldn't be able to answer the questions you gave me…you have no meaning in a way" [C3]

"[Asked about familiarity with the data] Lots more [familiar with Assault] because it's an area of interest - a priority…I've never looked at "All Other Theft" really" [C3]

These quotes give more information about the context of particular crimes. It appears that 'All Other Theft' is not a priority for team members in the same way as Assault. I chose these two similarly spatially distributed crimes for each prototype to avoid a learning effect. But this has unearthed a fundamental fact about their data in context. **Not all crimes are equally important** and some categories seem relatively unexplored. **Some crimes are more interesting than others to these CDR subjects, but this is not tacit** - C1 is struck by the notion of having different enthusiasms for different datasets. **Researchers in this field would be advised to ask future subjects at the 'Context of Use' stage whether they find different parts of their domain data more interesting than others, and if so, why.** But they should also be prepared to design for outside subjects' current 'zone of interest' as their preferences may blind them to what turn out to be interesting explorations and new insights.

"[Asked about how important real data is] Massively, massively…An example for that is the work when David Lloyd came up last and we were looking at some of these things on printed out pieces of paper [wireframes] which had randomised data. I found that really difficult because I'm automatically thinking 'why the hell is vehicle crime higher here?' – 'Yeah I know it's just crap data' [then] 'is this a good way of showing data?' [then]'No, it's wrong!' It's difficult to do…For me using actual data is…incredibly important." [C1]

This is more evidence for **the importance of real data** – and corroboration of the same observation in the wireframe sessions (Chapter 5).

"I think the actual crime type lends itself particularly well to this type of analysis. I think some of the [other] crime types, it would be interesting... I would assume that it would be

less interesting to put them in, but, I would need to put them in to see if anything comes out of it." [C2]

This quote shows that data context permeates the shape of the application - the different distribution patterns of different crimes may call for different tools and the existing prototypes have only been used with data that has a high spatial clustering.

"[Asked about how important real data is] I can see benefits and disadvantages to both. Because it was familiar to me, I half knew what to expect…To be thrown some 'foreign' data would be quite good because you're starting from scratch and you are more reliant on interpreting what's put in front of you rather than throwing in your own kind of prior knowledge. I instinctively relied on my knowledge of the area, of the subject, and it detracts from what the process is trying to tell you. The flip side of that is that if you use data you are not familiar with then you can draw all sorts of crappy conclusions…at one point, I was actually looking at it and thinking 'Right…have you changed this data in any way?'" [C3]

It is important to distinguish 'real data' from 'own data'. C3 is not advocating the use of 'dummy data'. It would be an interesting piece of research to compare subject use of a prototype with 'real, own data' and with 'real, other people's same-domain data'.

Because of the perceived importance of real data and credible patterns, subjects were asked: "What would you say if I told you that in all cases I had flipped the data so that what was north was south and south was north? So that the causal relationships you identified to the background map weren't really there." The responses from the three subjects were:

"I would push the computer off the desk and storm out of the room!" [C1]
"Unless I have totally misinterpreted what was there then I think there were patterns that I probably made fit the crimes, but I think they were a little bit too obvious for you to have made up" [C2]
"I hope that they were really there…I'd be gutted if they weren't! [Because] I would have completely misinterpreted the information….if you' re saying you did that across the whole 5km area, then I would be surprised."

These quotations show the intense confidence that the subjects have in the data portrayed in the prototypes and their attachment to their own, real data and the process with the researchers.

Response to the prototype

Subjects were asked to provide adjectives that described the way they felt about the prototyping sessions. The responses were:

Positive responses:
*"**Interesting**"[C1]*
*"**Interesting**" [C3]*
*"**Insightful**"[C1]*
*"**Useful**" [C1]*

*"**Excited**…about being able to use this in such an interactive way, because before it's been such a labour intensive [process hitherto]." [C2]*
*"**Inquisitive** as to what possibilities are for the data" [C2]*
*"**Enthused**" [C2]*
*"**Enjoyable**" [C2]*
*"**Thought provoking**; I can see where it's going" [C3]*
*"**Inspiring**" [C3]*

CDR subjects indicate a positive view of the prototyping process with these comments.

Negative responses:
*"**Tiring** …**Fatiguing** in describing the differences [repetitive tasks]" [C1]*
*"**Draining**…**tired**" [C2]*
*"It's **tiring**. It* is ***draining** because you are trying to be honest and think out loud…" [C3]*
*"I was definitely **confused** earlier on" [C2]*
*"There might have been a bit of **apprehension** in there" [C3]*
*"Quite **daunting** in some respects…**frustrating** as well, in that you are…simulating a computer and obviously you've got the time element in there…you're deliberately blocking off certain functionality…you're limiting [it]." [C3]*

These comments reflect a common thread from all three subjects of the exhausting nature of the user-testing process. There are also indications of some anxiety about the session:

*"I was definitely **confused** earlier on" [C2]*
*"There might have been a bit of **apprehension** in there" [C3]*
"*Quite **daunting** in some respects*" [C3]

There may be a dilemma here is using domain experts in a user-testing situation – these are not volunteers from 'off the street' paid for their time. Clearly there is a limit to how much can be expected of even the most interested domain experts.

Insights

The subjects were asked if the prototyping sessions had provided any insights to see what elements were highlighted and whether any contradictions arose from the think aloud captured during testing.

"I knew very little about All Other Theft and some of that was quite interesting, particularly in the…you know, how skewed the data was…I was interested by the fact it was just this square…" [C1]

"[the variation between days] was quite interesting and not something I've looked at before. So there was new stuff in terms of understanding the data , and I've not used glyphs before, so..using them to understand the data, the combination of those and the circles and the colour and in terms of looking at comparative change - last year to last five. I think that was a really interesting process." [C1]

"in terms of being able to being able to pick out something immediately, then no. In terms of promising angles of investigation, then definitely. I can see two on the screen [now] that I would be interested in…!" [C2]

"To be able to manipulate the spatial resolution of the data is really, really useful - because a lot of it is target-driven and volume-drive and people saying 'we've got a problem - how spatially dispersed is it?'" [C3]

"I'd say no, really. And that is purely because of the time available." [C3]

C3's summative response is interesting, claiming no real insights, whereas C1 and C2 do. C3 believes that insight that will be gained if more time was available. This may be a 'throw away' summative response at the end of a long session– set this against copious examples from C3's think aloud of successful exploratory activity recorded as it occurred. It is also possible that C3's view of an 'insight' is exacting and C3 has simply not had any 'eureka moments'. Another possibility is that C3's specialism within the team as 'GIS expert' gives C3 familiarity with spatial crime data, and so novel insights are harder to come by. Or again, it may be that C3's greater familiarity with Loughborough means novel insights are harder to come by. Certainly C1 and C2 know Loughborough in less detail than C3: "*I don't know this area that well*" (C1); "*I don't know Loughborough as well as, say, … if C3 was doing this, C3 knows the town centre very well. C3 could give you a lot more detail about it" (C2).*

During the user testing session there are seven instances of 'reverse' arguing from observed crime patterns to inferences about the geographical area. Of these five are from C2, with just one each from C1 and C3. C2 appears to be less "expert" because of the lack of specific geographical knowledge. From C3's comment that the prototypes were: *"thought provoking; I can see where it's going*", there is a suggestion that C3 is seeing them as useful for identifying new ideas for functionality. This indicates that **results from the user testing are dependent on the geographical and general knowledge of the subject.**

"[I] particularly [like] the crime relative to five year average [view] I found that particularly useful because I could study…different aspects of one thing at the same time. So the fact that there was an indication of volume where it took place and how it's changed this year compared…there's several things combined there which I can kind of look at together and which then raise lots of hypotheses which I can in some way explore and try and answer. So why are these areas in these parts of the town centre which account for a high volume of All Other Theft...and then in these other ones there hasn't been an increase? They go in opposite directions. That's a great question that…for someone in my role to come up with a kind of answer for, and…it was only by showing the data in that way that that question could be raised." [C1]

This is an insightful quotation because in exposing these CDR subjects to their data in a geovisualization prototype it has created a new question that C1 had not been able to pose beforehand. Geovisualization design and applications are difficult because they demand the support of new processes for subjects like C1. As well as introducing new tools (glyphs, treemaps), new ways of presenting data has also been a feature of the prototypes, and the signed chi-statistic view is valued by C1 for exploration and hypothesis creation.

6.3.4 USER TESTING PROTOTYPES SUMMARY AND COMPARISON

The results this summary section correspond to case numbers 8, 9 and 10 on Table 2.2 (an extract of which is at the start of this chapter). In this summary, we can draw a number of results from these cases.

6.3.4.1 SUMMARY OF STATISTICAL ANALYSIS OF USER TESTING RESULTS

6.3.4.1.1 SUMMARY OF EXPLORATION

- **paper and digital interactive prototypes yield similar numbers and types of exploratory information within an 'active intervention' user-testing protocol** (evidence from section 6.3.1.1, Table 6.10)
- first-encountered prototypes yield similar numbers and types of exploratory information to second-encountered prototypes within an 'active intervention' user-testing protocol (evidence from section 6.3.1.1, Table 6.11)
- the level of exploration obtained by the three CDR subjects from paper and digital interactive prototypes within an 'active intervention' user-testing protocol is similar (evidence from section 6.3.1.1, Table 6.12).

6.3.4.1.2 SUMMARY OF SUGGESTED IMPROVEMENTS TO PROTOTYPES

- **within an 'active intervention' user-testing protocol, the paper prototype yields more suggestions for improvement than the digital interactive prototype except for interface-related improvements** (statistically significant at 0.05 significance level) (evidence from section 6.3.1.2, Table 6.15 and section 6.3.1.3, Tables 6.19 and 6.20). **In particular, the paper prototype produces more than twice as many suggestions for improvement that are related to 'new' features (a category that includes novel geovisualization elements)** (evidence from section 6.3.1.3, Table 6.19).

- first-encountered prototypes yield similar numbers and types of suggestions for improvement to second-encountered prototypes within an 'active intervention' user-testing protocol (evidence from section 6.3.1.2, Table 6.16)
- there is a difference in generation of improvements between CDR subjects for the paper, and separately, for the digital interactive prototype within an 'active intervention' user-testing protocol. This is a function both of the absolute number of suggestions and the balance between explicit and implicit suggestions (statistically significant at 0.05 significance level). User testing with active intervention is particularly poor at producing implicit suggestions for improvement (evidence from section 6.3.1.2, Table 6.17)
- CDR subjects' suggested improvements in different categories are independent of subject (statistically significant at 0.05 significance level; evidence from section 6.3.1.3, Table 6.21). **All subjects have 'data-related' suggestions for improvement as a predominant category.** The other three categories (interface-, interaction- and new-related) have more of a range.

6.3.4.2 SUMMARY OF USER TESTING WITH PAPER AND DIGITAL INTERACTIVE PROTOTYPES

6.3.4.2.1 PAPER PROTOTYPE

There is **some evidence** from individual subjects that:

- the paper prototype is **capable of driving spontaneous desire to explore data (**section 6.3.2.1),
- the paper prototype **promotes reflection on current work practices (**section 6.3.2.3),
- paper prototyping can **replicate the shortage of screen 'real estate'** that would occur with a computer-based application (section 6.3.2.1),
- subjects use and integrate both the piece of paper bearing the thematic map/glyphs and the piece of paper bearing the treemap/glyphs, demonstrating **the flexibility of the paper prototype to handle multiple tool representations** (sections 6.3.2.1 and 6.3.2.1),
- subjects sometimes need knowledge about areas on the map and additional attribute data (such as initiatives to reduce crime and disorder) to create hypotheses of what are the causes of a pattern of crime (sections 6.3.2.1 and 6.3.2.1),

- what is learned from the prototype is data-dependent – that is, it is a combination of prototype *and* data (section 6.3.2.2).
- that **different subjects have different responses in a geovisualization situation as they hold different (tacit) spatial knowledge**. I argue that geovisualization prototypes based on real data are important, and these will contain location data. Different subjects will have different knowledge due to their different geographic experiences, for example when C2 says:"*I don't know Loughborough as well as, say, … if C3 was doing this, C3 knows the town centre very well. C3 could give you a lot more detail about it*"

6.3.4.2.2 DIGITAL INTERACTIVE PROTOTYPE

There is **good evidence** from individual subjects that:

- **subjects argue from the crime pattern to the map** (five instances from C2, one each from C1 and C3; three from paper prototype and four from digital interactive prototype) (section 6.3.2.2)
- the process of exploration is influenced by prior knowledge (section 6.3.2.3) One example is C3's familiarity with Loughborough.

There is **some evidence** from an individual subject that:

- the ability to turn off the background map to unclutter the display is an advantage with the digital interactive prototype (section 6.3.2.3).

6.3.4.2.3 PAPER AND DIGITAL INTERACTIVE PROTOTYPE COMMONALITIES

There is **strong evidence** from individual subjects that:

- both paper and digital interactive prototypes generate **considerable breadth of engagement, hypothesis formation, exploration, ideation/insights and expectations confirmed or confounded** (sections 6.3.2.1 to 6.3.2.5),

There is **some evidence** from an individual subject that:

- the **background map is an unexpected data source** that influences the course of the subjects' exploration and hypothesis forming in both prototypes (five instances; one from C1, two each from C2 and C3; four from paper prototype, one from digital interactive prototype)(section 6.3.2.2).
- both prototypes show that **as tasks become more complex, domain knowledge is increasingly important** (section 6.3.2.2).

6.3.4.3 SUMMARY OF USER TESTING – SUMMATIVE QUESTIONNING

The summary of the main points contributed by the subjects in the summative interviews is:

- the tasks used in the user testing sessions were reasonably realistic of the kinds of tasks that the CDR team might normally undertake, and thus validate the relevant methodological choices made (**some evidence** from section 6.3.3),
- **not all crimes are equally important to subjects** and some categories are relatively unexplored. Some crimes are more interesting than others, but this is not tacit knowledge (**good evidence** from section 6.3.3),
- subject perception is that speed of response is important in the user testing sessions, and that the **paper prototype had the edge over the digital interactive prototype in terms of speed** (**good evidence** from section 6.3.3),
- the user testing protocol limits subjects to tools and tasks and interferes with the exploration process (**some evidence** from section 6.3.3),
- there is a **good evidence** to support **the importance of real data** to subjects. Quotations show **the intense confidence that the subjects have in the data portrayed in the prototypes and their attachment to their own, real data** (section 6.3.3),
- **speed ,** and the presence of **the treemap** are the **perceived strengths of the paper prototype; Inflexibility** of the paper prototype is **a weakness** (**some evidence** from section 6.3.3),
- **ease, clarity and excitement/appearance** are the **perceived strengths of the digital interactive prototype** (**some evidence** from section 6.3.3),
- the process of being exposed to geovisualization prototypes has led to changes in thinking about the approach to the work of this team (**some evidence** from section 6.3.3),
- Hands-on experience of working with prototypes enables **requirements to be established** (**some evidence** from section 6.3.3),
- **subjects indicate an overall positive view of the prototypes** using words such as **interesting, insightful, useful, exciting, enjoyable, thought provoking** and **inspiring** (**good evidence** from section 6.3.3),
- subjects' main negative response to the prototyping sessions were related to **tiredness** and **fatigue**, partially due to the **length and intensity of sessions**, and partly to the **repetitive nature of the tasks** (**good evidence** from section 6.3.3).

Distilling the key points from these three strands of evidence:

- paper and digital interactive prototypes yield similar numbers and types of exploratory information within this 'active intervention' user-testing protocol. Both generate considerable breadth of engagement, hypothesis formation, exploration, ideation/insights and for expectations to be confirmed or confounded.

- the paper prototype yields more suggestions for improvement than the digital interactive prototype except for interface-related improvements. In particular, the paper prototype produces more than twice as many suggestions for improvement that are related to 'new' features (a category that includes novel geovisualization elements). The relative success of paper prototyping in user testing is in line with the findings of Virzi, Sokolov and Karis (1996), Catani and Biers (1998), Walker, Takayama and Landay (2002) and Lim et al (2006). It does not support of work of Liu and Khooshabeh (2003) who found that "interactive prototype captured the same usability issues that the paper prototype studies did and more" (see section 6.2.1.1).
- all subjects have 'data-related' improvement suggestions as a predominant category.
- the paper prototype is powerful enough to encourage geovisualization, promote thinking about current work practices, and handle multiple tools representations.
- important information about data-in-context, including the fact that crime categories holds very different interests for the subjects, emerges during prototyping showing that contextual issues arise in the later stages of ISO13407.
- the process of working with geovisualization prototypes in a user testing protocol contributes to shaping a subject's requirements. This is in contrast to the failures encountered in attempting to communicate using the Volere template and with a geovisualization lecture (Chapter 4) and suggests that the process of establishing requirements is fertilized by encounters with real data prototypes.
- the importance of real data to the subjects is re-emphasised.
- speed, and the presence of the treemap are the perceived strengths of the paper prototype; inflexibility its weakness. Ease, clarity and excitement/appearance are the perceived strengths of the digital interactive prototype.

The free exploration results are considered further in section 6.3.5 and look at the detail in the text blocks comprising the basic counts of 'think aloud'. The detailed 'suggested improvement' think-aloud quotations are analysed further in Chapter 7, which focuses the human-centred approaches to prioritising improvements to iterate a prototype.

6.3.5 FREE EXPLORATION WITH THE DIGITAL INTERACTIVE PROTOTYPE

The results in sections 6.3.5 and 6.3.6 correspond to case number 11 on Table 2.2 (an extract of which is at the start of this chapter).

The free exploration protocol differs from user testing in that the subject is in complete control of the digital interactive prototype and chooses the exploratory task. As outlined in section 6.2.3.2, only one CDR subject (C3) was able to take part in this part of the investigation whcih limits the evidence base. In addition, as section 6.3.3 indicates, C3 has greater geographical knowledge of the Loughborough area than colleagues, and this fact may mean that C3's responses may not be indicative of the CDR team as a whole.

C3 was asked about the choice of topic:

> *"In terms of testing this, I thought what be interesting is looking at something like Criminal Damage (CDM). The reason I've picked that is because I feel that there's going to be multi-dimensions to the kind of behaviours behind it. i.e. I'm expecting at least two different parts of the day when there is going to be different things happening, 'cos when you look at it traditionally over the day you normally get a peak at after school, and a peak late at night. And the fact that you've got a nice, large town centre area with the pubs, nightclubs and night-time economy in it, but also - it's Loughborough - it's got some big schools and the schools all tend to be together as well, so it's kind of to test out a theory I suppose that you've got a set of data that can explain spatially and temporally…" [C3]*

The free exploration was conducted away from C3's place of work, and in two sessions separated by the loss of the link to the server. While unfortunate, this interruption is not felt to have affected the session in any material way.

The results from the think aloud are organised under the exploration headings used for the user testing analysis – exploratory activity, hypothesising, having ideas or insights, confirming known facts, or having their expectations about received facts confounded.

6.3.5.1 EXPLORATORY ACTIVITY

> *"I'm looking at Loughborough, 1km square, Criminal Damage, I've got a hot spot over the town centre, I'm looking at all years data together. So I'm just going to have a look at the last couple of years to see whether or not there is any difference in the current year compared to the last 5 years. I suppose there's several ways I could do this, 'cos I could do this by the chi-squared as well. But then again, the chi-squared is not something I'm used to using, so I'm just sticking to what I know to start with and then I'll go and use a different way to see if I come up with the same conclusion." [C3]*

> *"I'm looking at 2005 compared to 2006…so I'm looking at what I know is the hot spots 1km square which is the town centre. So it' s the centre with the highest volume of crime…I'm just quickly toggling between this year and last year…the fact that it's very above average in*

2005 and not so [in 2006]..I've found that difference kind of thing and it's whether you go back another year…[clicking and doing so]…to 2004…it gives quite a different picture." [C3]

"Now that's interesting, because the time [of the peak] has shifted [now three to six in the afternoon, and nine to 3am]… I'm trying to work out… these *are flats here. So I'm not quite sure…* these *are houses. But…ah!... I think the pub's further down here. There's a basketball court, and it's got fencing… quite big fencing around it… looks quite snazzy now… I don't know how long it has been there." [C3]*

"I am going to look at this area here…[long pause]… one thing I have been doing is… I suppose the difficulty you have got… is I have got two relative hotspots outside of the main, kind of, town centre. And it is trying to clarify it... because obviously you have got the town centre, and it always remains the focus for the agencies that deal with Loughborough, or Charnwood, or Leicestershire, because of the fact that it is a concentration where a lot of people go, there is a lot of criminal activity, but it is trying to make sure that you keep these hotspots in the context of what's happening in your main overall crime hotspots. So I am trying to work out how I would decide whether or not… I've got a hotspot of crime at 100 m squared, but the fact that when you start changing your resolution, your whole picture changes, you are kind of detracted away from the town centre…" [C3]

"that is interesting again. Because that area there… the smaller hotspots were in there and then sort of round here, and you are drawn to a completely different [area]. [clicking]…. is 2 (100m) the last [resolution setting]? [is told it is and tries resolution of 4 (200m)… so that's shifted!" [C3]

*"…which is why I go back to where I have done the bigger squares, and it is like if I ultimately go back and remind myself what this looks like at a bigger resolution…**I have been drawn into these by being able to manipulate the resolution of the data**… so I have found two areas of interest, which… I don't know what the volume is, now, so I don't know how it much it can contribute to the overall crime reduction in the area. **But if I change the resolution and these disappear, then I have taken away the ability of the agencies to do anything about it, because the information I have provided them with initially is at a higher level**" [C3].*

The six quotations above show a significant depth of interaction, engagement, exploration and fluidity and rapidity with the digital interactive prototype with a free exploration protocol:

- *"there's several ways I could do this"*
- *I'm just sticking to what I know to start with and then I'll go and use a different way to see if I come up with the same conclusion"*
- *"I'm just quickly toggling between this year and last year"*
- *"Now that's interesting…"*
- *"I'm not quite sure…* these *are houses. But…ah!... I think the pub's further down here"*
- *"…trying to make sure that you keep these hotspots in the context of what's happening in your main overall crime hotspots"*
- *"that is interesting again"*
- *"I have been drawn into these by being able to manipulate the resolution of the data…"*
- *"But if I change the resolution and these disappear, then I have taken away the ability of the agencies to do anything about it, because the information I have provided them with initially is at a higher level"*

The last two quotes are particularly insightful. In the penultimate quotation, we see that the **geovisualization possibilities generate data exploration possibilities and desires in this prototype/protocol** from C3. The last quote reflects the **choices made in geovisualizing may have a real impact on decisions that affect policy**.

6.3.5.2 HYPOTHESISING

> *"I'm trying to get a clearer story out of what the data is telling me, because it's all well and good…'cos we provide like one static map in a report which would show a year over a resolution, now ultimately what can you actually extract out of that one piece of information? Or is it kind of misleading in the way that you're showing so many things that you kind of don't show anything in the end apart from where the volumes of crime are. But…I suppose by drilling down in various different ways you get a better idea of what's going on." [C3]*

C3 is wrestling with an exploration v presentation dilemma that is at the heart of what the CDR team do (see section 3.3.3.1).

> *"So I'm drawn to that area being greater than average in 2004…then I go to 2006 and it disappears. So it's like 'Oooo…something might have happened there two years ago that's no longer there' - and I start asking questions about how does that affect the overall picture, I suppose - I just wonder if I'm going down a route that I want to go down." [C3]*

This reflects the other side of the possibilities offered by this prototype with free exploration - the siren call of almost endless exploration – and hence the need for discipline in conducting explorations in a systematic way.

> *"It is quite a busy road, that is…there is a pub along there, and I drove along there not so long ago, and the pub is derelict now, so I was just wondering at what point did it close down… now I look at it at the most recent year… but isn't that what this is supposed to do… in my view, you ask more questions, and then it prompts you to ask more sensible questions…" [C3]*

> *"it is a high crime area traditionally, around there. And this area here, is a kind of problematic area, which is on the Ashby Road, out of Loughborough to the west. The dark red square, or around that area there, it is a set of shops, where there has been problems. Now… it has gone red, there has been an increase, but at the same time, this is fairly recent information. Now, they installed closed circuit television in that area.That might actually increase the reporting of crime. So again, you have to be careful how you interpret that information." [C3]*

> *"The interesting thing is that the area that I thought would come up … there's a high school and two - how would I put this - not rival secondary schools, but…. they are kind of here. Now, you have got this patch here, and I know the shops are there, I think there are more shops here, so I don't know what the flows of people are and whether a lot go this way or a lot come this way, or … it is just interesting that the school… there's a big blank area - you can actually see where the school buildings are.[so they are] off the premises…to commit their offences…apart from this dot here. Bike sheds or something…" [C3]*

The last three quotes show highly detailed local and domain knowledge deployed to make hypotheses about the patterns observed in the data.

6.3.5.3 IDEATION/INSIGHT

> *"All the time you are trying to work out the whys and the wherefores of what is going on, you picture worst areas, and then it is trying to look at it from other people's perspectives. But, I mean, it's got all this information in front of me, and it's nice to play with it, but at the end of the day I've got to make some sense out of it. So, it is like, yes, I know there's a problem in the town centre, but we always focus on that, I want to go and look at somewhere else, what is it about* this *place that is different?; what is it about this? And so on. What geographical attributes has that that makes it different?; and why is the crime different, or is it similar, to the kind of common crime within Loughborough, all within the residential areas? Or are all the little geographical hotspots dispersed around the town similar in nature in terms of days of week, times of day…?" [C3]*

> *"I think the more work I do, the more it is to do with comparing it with other areas, and looking to differences and similarities, because you cannot always provide a [reason?]… if I say there are 25 crimes in there, then big deal, what does that tell you? Whereas if I put it into the context of the surrounding area, or say there are similar areas to this that portray similar characteristics that have relatively high crime compared to neighbouring areas, or using the change to say it has gone up a lot in these areas, compared to the last five years, you then pull those areas out, and present them to the people who have the powers to do something about it." [C3]*

These two quotes show C3 prompted by the detail of the data, the interaction with that data or a combination of the two, to consider how such a flexible prototype is best deployed to achieve the ends of the CDR stakeholders.

> *"…what I don't get is…there's a building there - an isolated building. But there's…is it definitely Sunday at the top? [told it's Sunday starting at 6am]. Well if that's the case then if I change the crime type [to Assault]…I'm questioning the data! It's the fact that there's a peak there [that worries me]…it appeared on Saturday and Sunday…I would maybe have said Friday and Saturday with the Night-time Economy…which is why I'm looking at violent crime and saying…you see that's the kind of what I'd expect…[counting round the temporal glyph] Sunday, Monday, Tuesday, Wednesday, Thursday…That's Friday and Saturday…Yeah that's interesting…" [C3]*

This quotation describes a complex interaction. C3 is looking at criminal damage and sees that there is a peak on Saturdays and Sundays. This confounds C3's expectation that criminal damage is related to the night-time economy which has its peaks on Friday and Saturday. C3's reaction is to see if the prototype is presenting the data correctly. C3 changes the crime attribute from criminal damage to Assault to check that the peaks appear on Friday and Saturday for that crime category, which they do.

> *"the bottom [resolution] is 2 [100m]?…[clicking]… I have just confirmed it… I am completely…. just a minute, it is not there at all… So….[pause]… so you have got to be*

careful with resolution in a sense. Resolution…"dilutes" the town centre, to enable you to see these other areas. But if you only show the one, you lose this…"

" I think it is great to be able to drill in and out, because I can do these maps [in a GIS]… but to be able to switch between the two, well from my point of view, it raises so many questions about how you do share the data to other people and how it completely affects how you interpret that information. Ultimately, if you looked at that straightaway, that 100m square map as it is, you could be almost drawn into saying 'right, well, we want to do all crime fighting on these two little streets here'. Whereas, holistically, you've got a much bigger problem in the town centre, which needs dealing with in a completely different way." [C3]

"it shows how localised problems can be overshadowed by.. the overwhelming town centre]…and the fact that if you used super output areas to do this kind of thing, again, you would still end up with a big blob in the town centre - a big red blob - for the small super output area that covers the town centre. These hotspots [the two smaller hospots] are probably much larger geographical areas, and the crime within those areas will just get completely diluted and you would be none the wiser." [C3]

These three quotes illustrate the prototype showing the consequences of using different resolutions - C3 perceives that the 'message' changes at each resolution – and is wondering where the focus should be. Each are valid, and beg the question as to which message is selected for onward transmission to the CDR stakeholders. The third quote shows **the multi-scale nature of space and spatially recorded phenomena.**

"I have mapped criminal damage at 100 m square in that town centre area before, and I thought it was more concentrated than that. Now whether it is to do with the scale, I don't know, but when I have done it before it has kind of picked out lines of squares that almost follow the main roads or the pedestrianised areas within the town centre, and that wasn't as apparent as I've seen it before. So, whether that is down to the classification of the bands, or whether it's down to actual changes in the data over time, I don't know." [C3]

6.3.5.4 CONFIRMATION OF EXPECTATIONS

[discussing a spike of criminal damage between 6 'til 9 in the evening] "That is the stereotypical peak of young people out after tea before they go to bed."

This is again a case of the context of the data - domain knowledge is needed to extract meaning.

6.3.5.5 EXPECTATIONS CONFOUNDED

"… it happens to be…oh no… I was thinking 'there's the hospitals' and it's not there…[zooms in]…I think that is a primary school. It is a Primary School…[identifies some secondary schools]…Which is where I was kind of expecting to see…things that I'm not. [pause] I would be interested to know how many it was." [C3]

" …there's a bar on that corner there… these are the taxi ranks round there. But why there would be a difference on a Friday or a Saturday night in that area I don't know. [pause] So that clarifies then that the days of the week are as you say, so I'm surprised then…or not

surprised…But then you would be asking who were committers of these offences…it's interesting how the whole thing shifts to a Sunday…'cos all the assumptions are kind of made that everything happens on a Friday or a Saturday night, whereas if you could look at this maybe by…break it down by the different hours of the day, you might find it's not…the case might not be that it's all within that small window and I'm just wondering whether or not it's during the day on a Sunday, and Saturday when kids are about." [C3]

In these two examples, the think aloud struggles at points where expectation is confounded. A particularly fertile moment for new knowledge discovery, C3's thinking processes appear to be concentrated on the confounded expectation. In the first quote, the background map is being employed here to give meaning to the pattern of crime observed.

C3: "First day is..?"
David Lloyd: "Sunday is at the top" [of the temporal glyph]
C3: "…is that definitely Sunday?" [is told it Is] "…Monday, Tuesday, Wednesday, Thursday, Friday, Saturday [counting round the glyph]…well I can't explain…doesn't help me at all! I don't what…[adjusts the time of day when the day ends to 6am from midnight]… Is that Monday? [is told it is]…but that's interesting…if you pan across where's…pan is?...here it is…[sound of mouse panning]…I can find it without having to zoom out…is that the Town centre?..."

"That's odd.. I suppose the 9 to midday will probably be when businesses ring in…so this is where the whole time thing because difficult…You've got those where you've probably got police presence on the streets at that time to actually take the crime down, and you've got those where it's been reported by the victim themselves by the phone or whatever." [C3]

In this pair of quotations, free exploration with the digital interactive prototype leads to a strong expectation being confounded, and to hypothesising that the observed pattern is an artefact of when the crime is reported (criminal damage is typically damage to premises during the hours of the night-time economy and might be reported either at the time or when the shopkeeper opens for business on the next working day).

6.3.6 SUMMATIVE QUESTIONS - FREE EXPLORATION WITH DIGITAL INTERACTIVE PROTOTYPE

The results in sections 6.3.5 and 6.3.6 correspond to case number 11 on Table 2.2 (an extract of which is at the start of this chapter).

C3 was asked a set of questions at the end of the free exploration session with the digital interactive prototype in order to provide an additional source of evidence to triangulate with the think aloud, and related to:

- strengths and weaknesses of the two protocols (user testing v free exploration)
- positive and negative aspects of the prototype in a free exploration protocol

- insights gained from the free exploration process
- usefulness (or otherwise) of the prototype in the free exploration process
- use of real data in the prototype

Positive and negative aspects of the prototype

Positive

*"**flexibility** - if that is an adjective?... I **enjoyed** it. And the more you go on with it, the more you get sucked into particular areas" [C3]*

Negative

*"the overall thing is about the **potential to be misled**. Because you've got a set of raw data behind there, and this is a filtering mechanism that is deciding ultimately how that information is shown. Which determines how you interpret it." [C3]*

The prototype's flexibility in a free exploration protocol is seemingly both a positive attribute and provides potential for misleading the unwary user. The comment "*the more you go on with it, the more you get sucked into particular areas*" is important as it is **evidence that when C3, a domain expert, engages with a spatial pattern in free exploration the effect is to focus the attention.**

Strengths/weaknesses of user testing v free exploration

"compared to using a paper prototype and all those things, it is far quicker… I was in control of it. Whenever button I pressed, I decided… I didn't have to fill out a piece of paper [in user testing mode] or tell you what I needed to do. When [in user testing mode], you are more "do I need to know this?" kind of thing. Because there's more effort involved in actually getting information you want…here you could do what you like." [C3]

This quotation shows the difficulty inherent in trying to separate the interface from the geovisualization prototype in the user testing protocol. In the paper prototype, the 'Computer' responded to the subject pressing printed buttons on a paper interface to select a new piece of paper for the subject to view. This interface was possible because the choices inherent in a paper prototype are very limited. In the digital interactive prototype in user testing, the interface had to cope with the possibility of multiple changes in each user input where changing one attribute at a time would have been tedious and unnatural. Hence subjects made their inputs via (multiple) choices on a piece of paper. The method also provided a useful session history. But far from disconnecting the role of the interface from the prototype, these paper input methods interpose a brake on the desires of the subject. The alternative course of action - educating the subject in the apparently arcane byways of compound PHP string creation - in fact liberates C3 to control interaction with the prototype and explore the data faster. In seeking to 'shield' the subject from the rather clumsy interface, I unwittingly created a barrier. Geovisualization is so immersive that such a hindrance acts against exploration.

Speed of response is of importance in geovisualization and **paper form-based interfaces to prototypes are not suitable**, and data on process and interactions can be recorded in other ways.

> *"you get as well a better feel for the geographical resolution and is zooming in and out, and the whole panning thing because you are actually dragging the map across and you can see things moving. It's partly to do with the speed of the way things work, and what you're used to with live applications doing for you, and I suppose that's the biggest strength - that it is more like a real application that you're playing with. So you relate to it like you would if you were doing your own work on something like MapInfo or another similar package… it's a more realistic experience." [C3]*

> *"The weakness of giving you a more realistic experience [is that it] can detract from what you are trying to look at. I thought with the paper one, it showed me that it didn't matter how wonderful or technical the application that is put in front of me is, because ultimately, the paper part of it proved to me it is how it is presented and actually looking at what it's telling you that is the important thing. So I'm not saying it's a specific weakness, but I'm saying it's not an out and out strength to be an all singing, all dancing, technical solution. The fact that the paper based exercise can almost fulfill the same objectives." [C3]*

> *"[asked about the speed of the digital interactive prototype operated directly by the subject] no [problem]. The only thing that changed was when it zooms back to the original [screen]…[the fact that when you change something with the PHP string] it takes you back. Because I can imagine that could be really annoying in a place that you don't know very well. Particularly if you have changed from completely different aspects like your relative change in the last five years…" [C3]*

C3 believes the main differences are speed, control/flexibility, realism and less constraint on what the user wants to do. The enabling of browser zoom and pan plays a part in this.

Insights gained from free exploration process

> *"I was drawn to a very small geographical area that I've never looked at before. Which shows [that] adding that flexibility means that you explore what might seem less important or less significant avenues. Which I would say is really important. Because otherwise we are forever looking at the same problems in the same areas. Which is a path that you tend to go down, because you have got limited time to analyse and look at information." [C3]*

The first quotation "*I was drawn to a very small geographical area that I've never looked at before",* is further evidence that **when C3, a domain expert, engages with a spatial pattern in free exploration the effect is to focus the attention**.

> *"But when you start messing about with a resolution in the way that the information is presented, it can pull out different areas. And it is not even saying that all those areas are more or less significant, the fact is that there will be local people in those areas, or local projects in those areas that need to know what impact they are having, or how things can be changed." [C3]*

"[Asked what drove the discoveries made] : I am initially driven by the spatial resolution. The time part of it…it is flawed in terms of the data [a reference to the problem of the time of recording crime may be very different from the offence time], but I put that aside. Though the 'days of the week' thing was interesting, [once] you start comparing different places and realise that the volume of crime is not necessarily the only aspect of it. The fact that it may be a seven day a week problem, it might be a one-day a week problem, and the fact that you identify that somewhere is not necessarily a massive hotspot. But if everything happens on one day of the week, then you would tackle that problem differently." [C3]

"the ability [of the digital interactive prototype] to move around and change things straightaway… so you're kind of working intuitively. As soon as you see something you adapt the information that you got in front of you to kind of work with your thought process. Which is really good. Because normally, you work the other way around. You kind of think about what you might find, and present information that way, rather than looking at what might be interesting, and pulling those things out there" [C3]

"[Asked if found anything that confirmed something already known] I suppose like that area where I said there was a CCTV camera" [C3]

"it was interesting, the fact that there was no criminal damage immediately outside [that] school, which [you would] maybe expect. But it was interesting how it was displaced within walking distance." [C3]

A number of quotes here bring together the ability of the digital interactive prototype in free exploration to permit exploration of smaller spatial areas not normally considered, explore areas with different resolutions, filter information by days of the week, explore intuitively without preconceptions, confirm or confound expectations.

Usefulness (or otherwise) of the free exploration prototype

David Lloyd " How acceptable would it be to you, if we disappeared and left you with this prototype. If you actually had to operate it through the interface – with this PHP string - how acceptable would that be to you, if that is all you had?"
C3: I can't say it would be acceptable, because you'll give it me then! [laughs]…if I had a choice, because we…have limited time and resources to do things, I would rather use the row at the top to type in the commands as I have done today, but to be given access to more data, rather than be given a cleaner, working model that only gave me that one geographical area."

"[Asked if C3 could see the team using an application that does these kind of things] Without a doubt…. if we don't get something out of it that you can build at the end of it all, or tidy this [prototype] up in some way, then I will go away and do something in MapInfo…. to the best of my ability…which obviously won't be as good as that. I will end up setting up my data at various resolutions, cutting it by the various crime types. I don't think I would get to the time of day, day of week…it would be a really limited model in the fact that I would have to summarise the data… and then you start saying, at what time intervals?" [C3]

The first quotation expresses C3's preference for an application that covered LCC and had a rudimentary interface as opposed to an improved version of the existing prototype limited just to Loughborough. This sets up a conflict between a researcher wanting to test research questions and the end user who has pragmatic goals. This tension in prioritising the suggestions for improvement in the prototype is explored in greater deal in Chapter 7. The second quote reveals C3 is so taken by some aspects of the design and prototyping sessions that C3 will "*do something in MapInfo…. to the best of my ability…which obviously won't be as good.*" This shows the extent to which **geovisualization techniques have been successfully communicated to at least one CDR subject through a working digital interactive prototype under subject control, with real user data**.

Use of real data in the prototype

> *"If you have real data you have the advantage that it is familiar, and you can find things that you know about. But - and I don't know whether everybody does this - when I see something that is unfamiliar in this kind of crime context then I normally look to flaws in the data, rather than the actual [application]…" [C3]*
>
> *"[Asked about how important real data is]… I can see advantages and disadvantages. It is useful, but because it is familiar, then does that create an element of almost laziness in your interpretation." [C3]*

The second quote presents a counter to the notion that real subject data is essential for HC geovisualization work with subjects that has been a strong result from this research. Data, subject and prototype are clearly woven together in a more complex way than is at apparent at first sight. Perhaps a two-stage progress is needed, with real subject data followed in subsequent experiments by real, non-subject, same-domain, data. Or real subject data that has been simply and subtly amended to introduce false but convincing patterns to fascinate the 'lazy' subject.

Other

> *David Lloyd: "how well did the tutorial I gave you start help you operate the prototype?"*
> *C3: "yeah, perfect."*
> *David Lloyd:" how well did a crib sheet [of controls and options] help you operate the prototype?"*
> *C3: " Everything is on there, as you explained it. And there is no extra information on there that I didn't need either."*

This final exchange checks the adequacy of the tutorial and controls crib sheet given to C3 in advance of the free exploration session.

6.3.7 FREE EXPLORATION PROTOCOL SUMMARY AND COMPARISON WITH USER TESTING

6.3.7.1 FREE EXPLORATION PROTOCOL SUMMARY

The results in this section corresponds to case number 11 on Table 2.2 (an extract of which is at the start of this chapter).

6.3.7.1.1 METHODOLOGY

Some evidence from the summative questions (section 6.3.6) indicates **the tutorial and controls crib sheet were adequate to operate the digital interactive prototype**.

In the free exploration think aloud, there is **some evidence** that **the background map is used as a source of attributes to give meaning to the pattern of crime observed, as is the case in the user-testing protocol** (section 6.3.5.5).

As with the user-testing protocol, in the free exploration there is **some evidence** that **the think aloud struggles when the subject is focused intently**, in this case where expectation is confounded (section 6.3.3.5).

Subject C3 comments during free exploration that **the almost endless exploration possibilities needs discipline to conduct explorations in a systematic way, a contrast to the user testing protocol** (section 6.3.5.2).

6.3.7.1.2 DOMAIN KNOWLEDGE

The free exploration think aloud provides **good evidence** of where **detailed domain knowledge is needed to make hypotheses about, and extract meaning from, the patterns observed in the data**:

> *"There is a pub along there, and I drove along there not so long ago, and the pub is derelict now, so I was just wondering at what point did it close down… now I look at it at the most recent year…"* (section 6.3.5.2)
> *"That is the stereotypical peak of young people out after tea before they go to bed."*
> *"That's odd…I suppose the 9 to midday will probably be when businesses ring in…(to report criminal damage)"* (section 6.3.5.4)

6.3.7.1.3 CONTEXT

Quotes from the free exploration think aloud show the pattern changing at different resolutions, and C3's concern about which message is selected for onward transmission to the CDR stakeholders (section 6.3.5.2). This and another quote from the free exploration reflects the **choices made in geovisualization exploration may have a real impact on decisions that affect policy**.

> *"if I change the resolution and these [hotspots] disappear, then I have taken away the ability of the agencies to do anything about it, because the information I have provided them with initially is at a higher level"* (section 6.3.5.1)

6.3.7.1.4 EXPLORATION

Good evidence from a large number of quotations from the free exploration (section 6.3.5.1) show **a significant depth of interaction, engagement, exploration and fluidity and rapidity with the digital interactive prototype with a free exploration protocol**.

In **some evidence** from the free exploration (section 6.3.5.1), it is clear that **geovisualization possibilities generate data exploration possibilities**:*"I have been drawn into these [areas] by being able to manipulate the resolution of the data…"*

In **some evidence** (section 6.3.6), the **importance of real data** is reiterated in this quote from the summative questions:

> *"If you have real data you have the advantage that it is familiar, and you can find things that you know about…"*

However a counter to this is provided by the same subject (C3):

> *"It [real data] is useful, but because it is familiar, then does that create an element of almost laziness in your interpretation."*

Some evidence from the summative questions (section 6.3.6) to using the digital interactive prototype in a free exploration way is that it is **flexible**, **enjoyable** and **engaging**, and that when C3, a domain expert**, engages with a spatial pattern in free exploration the effect is to focus the attention** (section 6.3.6) ("*the more you go on with it, the more you get sucked into particular areas*"). The implication for this is that responses and reactions to a geovisualization prototype may be non-uniform across space, time or attributes within the same area. A 'smooth' spatially representation in a geovisualization application might engender a 'response landscape' that was startlingly different and varied from subject to subject, dependent on general and geographical knowledge.

There is **some evidence** of **the multi-scale nature of space and spatially recorded phenomena** (section 6.3.6).

> *"it shows how localised problems can be overshadowed by.. the overwhelming town centre]…and the fact that if you used super output areas to do this kind of thing, again, you would still end up with a big blob in the town centre - a big red blob - for the small super*

output area that covers the town centre. These hotspots [the two smaller hospots] are probably much larger geographical areas, and the crime within those areas will just get completely diluted and you would be none the wiser."

There is **some evidence** that **paper form-based interfaces to prototypes are unsuitable** for use with geovisualization prototypes, as they hinder exploration and slow down interaction (section 6.3.6)

There is **good evidence** that **speed of response is important in geovisualization** and that **paper form-based interfaces to prototypes are not suitable** for this reason.

6.3.7.1.5 UNDERSTANDING/LEARNING

The summative questions give an indication of C3's preference for an application that covered Leicestershire and had a rudimentary interface, as opposed to an improved version of the existing prototype limited just to Loughborough (section 6.3.6). This sets up a conflict between a researcher wanting to test research questions and the end user who has pragmatic goals. This **tension in prioritising the suggestions for improvement in the prototype** is explored in greater deal in Chapter 7.

The summative questions (section 6.3.6) also reveal that C3 is so taken by some aspects of the design and prototyping sessions that *"[I will] do something in MapInfo…. to the best of my ability…which obviously won't be as good."* This provides **some evidence** of the extent to which **geovisualization techniques have been successfully communicated** to at least one CDR subject **through a working digital interactive prototype under subject control, with real user data**.

6.3.7.2 COMPARISON OF PROTOCOLS - FREE EXPLORATION WITH USER TESTING

The results in this section corresponds to case number 12 on Table 2.2 (an extract of which is at the start of this chapter).

In comparing the two digital interactive protocols – user-testing with a active intervention, and free exploration – it should be borne in mind that only one of the CDR subjects, C3, was able to participate in the free exploration testing, and that the validity of the results are thereby constrained. Recall that C3 is the CDR team GIS expert and is the most familiar with Loughborough, the area covered by the CDR prototypes.

- The overall **level of exploration in free exploration is over twice the level observed in user testing** in a session that lasted about the same time as the user testing with active intervention session (**good evidence** from section 6.3.1.1, Table 6.13)
- There is a difference in C3's geovisualization exploration of the digital interactive prototype with the two different protocols, with **more possible improvements emerging in the free exploration, and markedly more implicit suggestions** (statistically significant at 0.05 significance level; **good evidence** from section 6.3.1.2, Table 6.18)
- In **some evidence** from the summative questions (section 6.3.6), C3 believes **the main differences between the user-testing and free exploration protocols are speed, control/flexibility, realism and less constraint on what the user wants to do**. The enabling of browser zoom and pan in the free exploration clearly plays a part in this.

In both protocols, there is **good evidence** from sections 6.3.2 to 6.3.7 that:

- **the background map is used as a source of attributes to give meaning to the pattern of crime observed.**
- **the think aloud struggles when the subject is focused intently.**
- **detailed domain knowledge is needed to explore the patterns observed in the data**.
- each **supports thinking by the subjects about the way they do they work currently.**
- there is **interaction, engagement, and exploration. The free exploration protocol is perceived to have advantages of fluidity, rapidity and less constraint** over the user-testing with active intervention protocol.
- **the importance of real data** is emphasised

A fact that emerged in the user-testing with active intervention that subjects considered 'All Other Theft" (AOT) category 'boring' would mean that AOT would be an unlikely selection by the CDR subjects for free exploration - and yet when the subjects were confronted with AOT in a user testing with active intervention prototype, they did explore the data, hypothesise and achieve insights (and were pleasantly surprised by that). So regardless of the protocol used, choice of the data to examine will affect the outcome - **there is a subject - data axis to consider as well as a subject- prototype axis and prototype- data axis**.

This concludes the prototyping work with the CDR subjects. The next section presents the results of the Library subjects using the SomVis application as if it were in a prototype, with a free exploration protocol. This will provide a comparison for the CDR free exploration session from another part of LCC.

6.3.8 FREE EXPLORATION WITH SOMVIS FOR LIBRARIES

The results in this section correspond to case number 13 on Table 2.2 (an extract of which is at the start of this chapter), and results from Libraries will be compared with those from free exploration in CDR, as part of case number 14.

The reader will recall that the three library subjects (L1, L2 and L3) are using SomVis (Guo, 2005) as a geovisualization 'prototype' to visualise data on library borrowers in order to produce clusters that may be of use in tailored marketing. L1 has suggested (section 3.3.1.3) that clusters are likely to have a spatial component. The three subjects conduct a 'free exploration' visualization collaboratively using think aloud. I use an 'active intervention' protocol (Dumas and Redish, 1999) in a facilitating role. The reader may also recall that the count of exploration recorded by the three library subjects ('L123') was not statistically different from the 'free exploration' conducted by C3 with the CDR digital interactive prototype (see Table 6.14, reproduced here)

	C3 Free exploration	L123 Free exploration
exploratory activity	12	8
hypothesising	10	21
insight/ideation	22	45
confirmation	1	8

Table 6.14 (reproduced) Exploration recorded by C3 with the CDR digital interactive prototype compared with that of the LCC Libraries subjects with SomVis, both with free exploration protocol

The libraries subjects chose to explore four sub-sets of their library data with SomVis: 'aged 45 to 54'; 'aged 55 to 64'; 'males'; and 'borrowers responsible for the top 80% of borrowings of issues of all kinds'. SomVis is displayed on a large screen that all users refer to, and contains a parallel coordinate plot, a spatial treemap and a self-organising map, as well as a control panel (see SomVis description in section 6.2.2.3 and see Figure 6.20 in section 6.2.3).

The think aloud protocol in a collaborative situation delivers a different kind of narrative to solus think aloud. The subjects hardly ever needed prompting to articulate their thoughts. On the contrary, their communication with each other is almost continuous and less structured than think aloud from one individual. It can also mix together many aspects of exploration (exploratory activity, hypothesis forming, ideation/insight, and so forth) sometimes simultaneously. They can be referring to different tools in different parts of the screen, or different parts of the same tool. The effect can be disjointed, and subjects sometimes cut across each other or finish each other's sentences. Insights, for example, can arrive from more than one person, as a summation of subjects' individual contributions. This has been noted by Jared Spool, quoted in Snyder (2003), an expert in low-fidelity prototyping techniques, who refers to it as 'married people's syndrome'.

The results from the think aloud are organised under the exploration headings used for the user testing analysis – exploratory activity, hypothesising, having ideas or insights, confirming known facts, or having their expectations about received facts confounded.

6.3.8.1 QUOTATIONS FROM THINK ALOUD

The quotations from the library subjects think-aloud of their exploration of their data in this section are quite extensive, particularly the ideation/insight category. Nevertheless they contain the raw material for understanding to what extent these subjects conduct exploratory activities, hypothesise, ideate/gain insight, and have their expectations confirmed or confounded. They form the basis for case number 14, the comparison with the free exploration of the CDR prototype.

6.3.8.1.1 EXPLORATORY ACTIVITY

L1: So the blue line… probably, to start with. Mind you, it's not one of the smallest., is it, that darker blue?
L2: they are quite high in crime and adventure…
L1: they are very fiction based aren't they?

This is a quote from early in the process with the subjects getting to grips with the application and looking currently at the parallel coordinate plot (PCP).

L1: because very quickly, we have been able to identify some clusters the further exploration.
L2: but coming back to this one, were getting there, aren't we?
L1: that's yellow one there, which is very close to the…well..close-ish because it's dark grey [referring to the background shading of the SOM] … but it has got a very similar pattern to the green one. But these two are miles away from each other.
L1: the green and the red are very far away from each other, but the yellow and green are a very similar shape [on the PCP].
L1: so you could argue… well, could you argue that they are similar clusters, but just at a different degree of borrowing? So they do the same thing…
L2: the pattern is the same
L1: … they behave the same, but they don't necessarily do it quite so heavily.

The subjects are thinking about the extent to which clusters are different in degree, and are **using both the self-organising map (SOM) and the PCP**.

L1: the next one is pink maybe?
L3: yellow.
L2: yellow, yes.
L1: where are you getting that from? Because I have lost that.
L2: here you are [passes over a sheet that allocates a number to each SOM colour]
L1: oh right

This is included to show the semi-structured approach adopted for exploration, and also because it shows the subjects using one of the pre-prepared aids to conducting the session (a sheet that related colours to numbers for easier communication).

L1//L2: Ah! [looking at a red cluster].
L1: do we have a geography thing going on for once?…for the very first time!
L2: So this is high…
L1: and they are also pretty high borrowers of other things…. or they might be high borrowers of ethnicity…

The library subjects had a prior assumption that there were going to be spatial clusters in their borrowing data. During their exploration, such instances were comparatively rare and this piece of transcript outlines one occasion when **subjects detect a spatial pattern** for the first time.

6.3.8.1.2 HYPOTHESISING

L3: what would be useful is to do as a different one; would be to do it on different age bands, to see if that applies to all of them.
L1: Yes. That would be useful, actually.
L3: because what we are looking at here is … middle-aged?
L2: Yeah

Having observed a pattern, the subjects express an interest in seeing whether it is replicated in different age ranges.

L3: the other thing of course is that we may have picked the wrong variables, if we are looking in terms of volume….they might borrow high numbers of different kinds of books.

L3 shows an understanding that the data under examination does not represent the totality of what is available and that other data may need exploring.

L3: they are males.
L2: what makes you say that?
L3: well, on their ages, they are males. Because they are borrowing crime and adventure stories in the main
L1: there will be females… and that is based on other information.

These shows a **strength of collaborative approach** where an assertion by L3 is challenged by L2 and L1.

L3: I was interested in that [selected yellow and green clusters], but I don't know.
L1: but they are very, very similar. Are there any other…ones that follow a similar… because you could actually potentially, in terms of marketing, group those two together…the green and the yellow. Because we would try to limit the possibilities, or segment at the base, so that it made sense. And because you could name them in the same way, and you could call one low medium or high. But in terms of a name that you could call them [the same]…
L3: [selects white, aquamarine, and light blue clusters] I was just trying to peer through all the lines in that bottom right pane…but… it does have a certain categories, I suppose…. books, sagas, crime, adventure.
L1: the blue and white one - apart from geography… now, without assuming too much from the data because we did not split out male and female - there may be a difference, if you did a different filter with male and female on there [separately], you might find the blue and white one are the same. But that is assuming without really knowing.

Newly acquired familiarity with the SomVis application, and newly revealed data, leads the subjects to hypothesise about whether to aggregate clusters for practical purposes [two clusters that have different characteristics appear to be more important than two clusters that are similar except in intensity]. L1's final quote indicates a hypothesis that gender needs considering separately. This whole quote is a good example of **the disjointed nature of the collaborative think aloud**.

L1: now, quite interesting, going back to some other than those other ones [dark green cluster]… they had this high junior fiction/junior non-fiction/ethnicity, which lead you to assume, possibly, that the parents borrow for the children, rather than the children borrowing for themselves…so if you are targeting that particular market, you would be targeting the parents as opposed to the children. Your marketing activity would be related to… you would be talking to the parents. Because they're going to be doing the ones that are doing the borrowing.
L2: But we can't say that, because we don't know what the children are borrowing either. We are filtered on that age band, so that is just what those people are doing. But it could be that the children are also borrowing high as well.
L1: Yeah - but this is about the adult borrowing for the children….there is a segment that when we target… because currently in terms of our marketing activity, a lot of the junior stuff is actually targeted towards the child, when actually, there is a potential target some junior activity to parents - particularly cross-fiction and non-fiction to people who are maybe of an ethnic minority. Okay. That's useful.

This section shows how exploration provokes thinking about targeting to a new segment for junior book borrowing (adults borrowing junior books, not juniors borrowing junior books). It also shows L2 being systematic and stating the limits of what is being viewed, showing the **strength of the collaborative approach**.

L1: now what we would possibly do at a later stage is look at that again, but split out the filter of the male and female to see… I mean, we would definitely do that, wouldn't we?
L2: are you talking about this one now, or the green one?
L1: I am sorry. I am jumping. The bluey one and the white one.

L2: because I have not actually written much down about it, because we went on to the [green one]… So it's…
L2: so, I have got 4, 5 and 8 [these numbers refer to a "key" to the 3 x 3 SOM colours] - they are the ones that we are looking at the moment…5 and 8 … L1: the green one- the greeny one - is different, isn't it?
L2: so that is number…4. So what have you said about that? I haven't written anything down for this particular view yet.
L1: the blue and white one, we have said that there is a similar pattern emerging on the blue and white one, apart from on geography. And we could maybe assume that that could be a gender thing. But without exploring it in the data, we wouldn't know for definite.

This exchange is happening quickly and contains more hypothesising about the need to filter the dataset (on gender), plus an illustration of the problem of L2 recording their discoveries and conclusions in such a rapidly developing exploration. **Recording is a bottleneck to exploration** here.

L1: [speaking about an apparent correlation between 'geography 'and 'biography']: [I'm] not overly [surprised by this].Because there are quite a lot of male - potentially male - I am making assumptions here that they are male, but there are quite a lot of male biographies on sport, and all those sort of things, so I do not think that biography is as gender specific as geography. But you might make a conclusion that they could be a male thing going on there.

Domain knowledge is important here as L1 hypothesises that it is males who are making up a geography/biography cluster.

L3: there's a purple peak with geography. If it is, as we think, people preparing to go on holiday, and places to go, we split that by gender, it only tells us, who has actually gone to the library to get the book out. Not… do you know what I mean? Is it like 'let's go on family holiday; let's go to Spain; let's get a book on Hungary; and we'll have a read and decide where to go'. It just so happens, we have talked about it at home, and both agree, and then it is just chance, almost, who goes in to get it on their ticket. I still think it would be interesting, but I'm just…
L1: it is worth looking at. And that is one of these things you are never going to be able to [determine]…
L3: … then you might find, of course, that it ties in with, say, mums taking their kids into the library to get the junior books out. I think that is going to take us some [time]…a lot more steps, isn't it?

Domain knowledge is important again as L3 hypothesises that a pattern of borrowing may not be the same as patterns of reading. The subjects discuss the limits of their data and how they might link it to other borrower behaviour.

L1: I think the thing that makes it more difficult is the fact that the colours have changed. Because visually, we have homed in, and in our minds we have labelled things as "green", "blue" rather than the name for them…
David Lloyd: but would it be misleading if they stayed the same colours - because these are completely different clusters.

L1: they should change… it is just about is trying to get our heads round the fact that we can't know a cluster by its colour, almost. We had to call it something…. It does look different, but if you look at each one individually, we can still give them... If we were going to have named them something, we would still be calling them the same names… if we were calling them 'the parents who borrow fiction and non-fiction and ethnic books for their children', those clusters still exist, even though the weighting has changed.
L3: I think this proves that, doesn't it. You have got three distinct peaks on those. And did it not follow this… what's this? … Domestic… didn't that follow the profile of the junior fiction, junior non-fiction, ethnicity… and now, you can't really see it, but it drops... the connection, if you like, now is the ethnic books, and the Domestic books in. When they are not in the junior fiction and non-fiction area to the same extent.

L1 perceives a problem with the SomVis application that is actually an issue with stability of identified clusters when different weights are applied, compared to the assumption of stability in the subjects' minds. L3 hypothesises about to what extent the clusters before them reflect characteristics of previously seen clusters.

L2: so this orange [colour perceived by some as red] here is a big cluster, which is the low borrowers… but I have just seen some big rectangles on there [the map]…so that would mean they are borrowing a lot of something else - not those [book categories].

L2 recognises they do not have the full data loaded into the application and that this limits their ability to reach conclusions. Another point is that the 'orange' cluster was perceived by others as having a 'red' colour. This issue was anticipated in advance by providing subjects with a numbering scheme for each colour, but the subjects are not rigorous in using numbers, making recording of results more complex.

L1: Which one jumps out at you as having the biggies in it?
L2: Red
L3: that may be the colour that just strikes your eye though.

L3 showing some appreciation of the effects of colour here, recognising the danger of the colour red on maps, a point made by one of the geovis experts (Chapter 4).

L2: so there is nothing to say on the red?
L1: it is an interesting group, because out of 55-64s, the majority of people borrow books more than anything else. But there is a significant number - because they are fairly big-ish - that are borrowing books less than they borrow other things. They love their library, but they don't like reading….[…]… they borrow across other media.
L1: Or do they <u>love</u> the library? They <u>like</u> their library… but they don't like reading… [pause for thinking]… could we go back to the original bit, and change the weighting, so that we have books at something like 4… I mean, when you book the issues are there compared to the other…maybe 5. What is the second biggest category of borrowing? That is film. So if we have 5 for books, 2 for film and the others here on 1... maybe [talking books] is a 2…. OK 6 for books; 3 for film and 2 for Talking Books…just as a…very rough…yeah.
[new weightings entered]
L3: doesn't make any odds does it? I mean, it has made a difference, but…

L1: very slightly.
L3: clarified it, I guess. That is what we were saying before, isn't it?
L1: maybe that's the bit of the weighting…. making sure you have got your weighting right, just to help you to reaffirm a theory that you might have.
L2: doesn't really change at all, does it?

Domain knowledge is important here as L1 outlines the profile of the 55-64 year olds and hypothesises about the attachment of this group to their library and requests a **reweighting of the different types of borrowing** to highlight book borrowing and test whether the pattern changes significantly. It doesn't.

L1: …some other particular clusters in this 45 to 54… they are the 'Travellers', but whether they were the armchair travellers, or whether they actually do go out travelling…but they very much just borrow Geography. Maybe a bit of biography… but they are not particularly heavy users.

L1 hypothesising about the actual behaviour of a cluster called 'Travellers'. This tagging of clusters with 'catchy' names is instigated by the library subjects and encapsulates the key aspects of the cluster. None are spatially related. It is reminiscent of the names given to demographic clusters in products such as Mosaic (Experian, 2009).

L1: Yeah. OK. …. shall we go on to the 80%? … because I think all that one [the males] is doing is reinforcing what we sort of knew.
L3: but I think that is useful.
L1: It is, yeah.
L3: and if you did a similar one for females, I guess you would expect sagas to be… one of the biggest categories.

Expectation about male borrowing is apparently confirmed here, and a hypothesis formed about female borrowing.

L1: but then you do have this group - that apart from ethnicity - are borrowing across a broad range…
L2: but we have got no ethnicity here. Could we assume that the ethnicity comes from the junior [fiction and] non-fiction issues, then?

Here L1 and L2 explore and hypothesise about the source of ethnicity (book) borrowing.

6.3.8.1.3 IDEATION/INSIGHT

L2: And this is where they [live]? [indicating map]
L3: All over.

An initial insight into the (lack of) spatiality on borrowing cluster patterns

L1: So junior and ethnicity [genres] seem to be going together [in this cluster]

L1: there is also this Domestic one - it is as equal to junior fiction and junior non-fiction. Does that mean that they are borrowing across all four categories? [told 'yes']…so there is a group of people who are borrowing some kind of Domestic - whether it's build your own barbecue type book - as well as junior fiction and non-fiction in equal measures, and ethnicity.

Two quotes from L1 with different levels of insight.

L1: [the purple cluster]…they are geography fanatics. And not that interested in anything else.
L2: Travellers. Not as in 'travellers'…[laughter] … I mean, they like to travel.
L1: They like their geography., don't they? They like their books…
L3: 'geography and travel is the [library] classification.
L2: … but they are fairly close to the non-borrowers [on the SOM]…
L1: Or low borrowers.
L1: they're not borrowing anything else are they?
L3: they're only using the library…
L1: …when they've got a reason, when they're going…
L3: .. going on holiday, and they want to learn the language. Well, no. They wouldn't learn the language, would they? But it is where to go on holiday, or what to see and do, isn't it? I suppose.

This is an instance of the subjects applying a 'tag' to a cluster, with an exploration of their possible motivation – language learning, deciding where to go on holiday, looking up sights. This quote also includes an example of 'married couple syndrome'

L3: they're only using the library…
L1: …when they've got a reason, when they're going…
L3: .. going on holiday,

L2: we have done 3, 7... we haven't done anything with 6. Pink. This one here. What is that one?
L1: that is almost the same pattern as your geography people.
L3: As geography. It's …biography, isn't it.
L1: biographies... so they like a little bit of geography as well? So they flirt a bit?
L3: the volume is smaller, though, isn't it?

Subjects are referring to the colours in SomVis using numbers predominantly, and are **seeing a connection between borrowing genres** (geography and biography).

L3: you have got five peaks now. Innit? Of the same sort of level.
L1: but the thing that we weighted the highest was the junior fiction… so the biggest peak of there is… junior fiction.
L2: Yeah. I can't get in my head how the weighting has affected the results, and what we should take from it.
L3: well, there is more peaks… it is more jagged, if you like. Certainly those five. Whereas there was a distinct trough in the middle of the other one.
L2: Yeah
L1: don't you see, the actual behaviour in the other one? And in this one you see more the importance of individual clusters?

L2: if you put no [=equal] weighting on them, that’s it.
L3: I mean, you have got your…your junior fiction and non-fiction are still up with the relatively high ethnic borrowing. But your geography has gone, hasn't it? There is no peak on geography.
L2: but there was only a peak on geography on purple [9] last time…
L3: but the colours don't bear [comparison]…
L2: I know, I know.
L3: because the weighting has gone on to junior fiction, hasn't it?
L2: yes.
L1: there is still that pattern. I mean, I think that is something that you can draw from it. You have still got… you have changed the weighting, but you have still got a cluster that is following a similar trend. Which means, possibly, that it's actually a real cluster

✧

L3, I think these three here, just to show us what we saw at that end of the screen, that is: the junior fiction and the junior non-fiction and the Domestic, coupled with an ethnicity tie-in…
L1: yeah…
L3: … shows us what we were seeing in the last model.
L1: this one here as well, the biography and geography one, that still exists. But it has included a little bit more Domestic…
L3: yeah, but we put the weights on here, didn't we?
L2: we didn't change the weights for the others…
L3: and I think it shows that there

✧

L1: and these are the peaks here?
L3: no no no. There were no peaks like that in that other model. Having weighted, what we see now is 'yes, that was the case' - we were right in seeing that - but when you pick… you have got three distinct peaks… they are discreet borrowings, I think. Because there is your high Domestic, and it only ties in with…at that end…a high Ethnic. Yeah? Similarly, I think, junior fiction has got the peak… not anywhere else apart from ethnic, really. Do you see what I am driving at?
L2: so we have got…
L3: they are discrete. Whereas in the other one, before we weighted it, it followed the same profile, and you didn't have that… isolation.

In these three sets of quotations, the subjects are experimenting with different weightings to see the effects, and draw conclusions about stability of the patterns they observe, showing **deeper engagement with the SomVis 'prototype'** and the results it presents.

L2: you have got a couple of big borrowers in the yellow that I can see. There are two. So they must be taking out a lot junior non-fiction and domestic.
L1: shall we go on the ones that have the same patterns? So the yellow and green ones to see if there is… to see if they live somewhere together…. [map is displayed]… no. [laughter] … but it's worth exploring that, isn't it? Even if you just discount it.

The subjects are being systematic, testing for a spatial effect and find none.

L3: So…people aged 55-64 borrow books…and films! [laughter] that is about it. Is that what it tells us?
L1: there is a group of people that go across all media, and is higher on Talking Books. That green one.

L2: so what are we saying generally about this?
L3: people who borrow books… a lot, do just that. Don't they?

A basic but important insight.

L1: I looked at it differently. Because I picked up this line, this line, this line and this line which was very much "just books" - nothing else.
L3: but can you pick them up like that? [these are four discontinuous SOM blobs which, it transpires, it is not possible to select together]…what I could do, is that though…[selects 5, 8 and 9]….we have missed one of them, haven't we by not being able to do it that way?...which colour have we missed?
L1: [pink]: but potentially, in terms of marketing, you would possibly group all of those together, because they are all the same. Their volume of borrowing is slightly different, but for all intents and purposes, they are fairly high borrowers of just books. They are the "Solus Books", you'd maybe call them.

Another cluster is identified and 'tagged' with a memorable name ('Solus Books'). This quote also shows a limitation of the application (the inability to select groups of clusters at will).

L1: the one where there was a fair amount … the green one … where it went up on the Talking Books. They are a fairly big group, aren't they?
L3: they are broad users aren't they?
L1: Yeah.
L3: "broad users of library services".
L1: they love their library. They are 'Library Lovers'.

Another cluster identified and tagged – the 'Library Lovers'.

L1: I am writing down my names for these people [clusters].
L2: is that for the green one? No 1? ['Library Lovers']...what are you calling these?
L1: I am just, like, in my mind, thinking of what potentials are…
L2: Hang on a sec, let's just go back here…
L3: I think you've got 'Library Lovers 1' and 'Library Lovers 2' [laughter]
L2: So [inaudible] book borrowers… that is 5, 8 and 9.
L3: I think you have got two different levels - but you've got two lots of Library Lovers there, haven't you?
L1: yeah, they cross over on the Sound and the Talking Books. So it is almost like a group that will veer towards Talking Books, and a group… they love the library, but they prefer a talking book….or they prefer [to seek] their music from the library. They are still Library Lovers across a broad range.
L3: it would be interesting, possibly, to see how you can manipulate their behaviour with a promotion. If you're doing…[say].. 'borrow six books, you get a free film or a free Sound recording or free Talking Book'… these people might well boost their book issues to get a film for free.

The subjects have further thoughts about a cluster and whether it is one cluster or two. There follows contextual material about how L3 would want to use this cluster information.

L1: [considering 'Library Lovers' cluster] They seem to be a little bit community library based…around this sort of area…which is… it is different from what you would expect on the basis of …
L2: it's Great Glen [Library]!
L3: This is geographical, isn't it?
L1: it is a bit disproportionate, on the basis that they [the community libraries of Great Glen and South Wigston] don't have as high a stock, they don't have a varied stock.…so it is significant. There's a lot of older people, heavily using those libraries - they love the library in their community. If the library was going to be shut down, they would be the first ones to complain.

There is exploration of where the 'Library Lovers' cluster may be located spatially. This is **an instance of spatiality in the data** that L1 considers 'significant'. **More domain-specific context is given** about the libraries users.

L1: you have got that big group that are very much [into] fiction and not a lot else, haven't you?
L2: do you want to specify groups so I can write it down?
L1: so you have got a big fiction, and not much else going on…[not many] heavy users.
L3: not many users at all are there?

L1 identifies a 'big' cluster focused on only fiction, but L3 comments there are not many users. An example of the 'correction' possible because of the collaborative approach to the exploration.

L1: [describing a cluster]: they like their crime! Are they the South Wigston lot?
L2: no, they are not.…so it is 'Crime Lovers'.

The context here is that the library subjects have domain knowledge that the small library at South Wigston issues a disproportionately large number of crime fiction genre books. L1 is asking whether a newly identified cluster focused on crime fiction is spatial. It is not.

L1: on that green one, that is in the bottom there, that looked very much non-borrowing, but borrowing when you actually look at this map here. It showed that they were heavy users of the library. So they are using the library, but are borrowing other things, obviously.
L3: It's this big fat green line When you look at it, there are a lot of them, but they are not doing very much is what you would think. But when you finally let go [click]…
L2: you've got big rectangles there
L3: … they are just not doing a lot of book borrowing.
L3: there are borrowing something, because…[the rectangles on the map are big]
L1: dead clever.

Rich ideation here as the subjects identify a large cluster from the map of total borrowing (the rectangular cartogram), although they are **using the cartogram as an indicator of absolute numbers** rather than to locate the cluster spatially within Leicestershire. This parallels the use of the crime attribute treemap and glyph as a 'summary' in the CDR subjects' exploration of their data.

L1: Ooooh.
L2: Ooooh.
L1: there are distinct ones there, aren't there?
L2: peaks there…
L1: big peaks at the junior fiction and junior non-fiction. So, obviously, really high borrowing at those particular stock types, for "male"…. but also, a cluster on adventure and crime… biography, domestic, geography - so quite a broad range. Obviously, they don't like sagas…

This describes the reaction of the library subjects to a seeing a new subset of the data that clearly has an interesting pattern. L1's subsequent reasoning explores and shows insight into the new clusters.

L1: [map is showing a great deal of the colour blue] It is still blue…A lot of heavy users. Adventure, crime... that is one of the heaviest maps that we have seen, spatially, of all of them.
David Lloyd: ah, be careful… because what you are observing here… you only had to 2200-odd [last time]. You now have three times as many actual cases, so the map has more on it.
L1: right. So I am not comparing like with like…a big biography. A big geography. So in terms of supporting some of those other theories that we had before… there is a potential there to explore that dataset on the geography in terms of gender… but again… on that one geography and ethnicity go together…
L2: so what are we saying that this? So 1 and 3…
L1: ethnicity is sitting in with geography and also with biography.

This shows the cartogram **map of total borrowing used as an indicator of absolute number** rather than any spatial aspect. A cluster is identified formed of ethnicity + geography + biography.

L1: …. what is that light green? That's a very small number though, isn't it?
L3: which is light green?
L2: yellow you mean?
L3: there's only one light green.
L2: that one there. Aqua.
L1: there are some quite heavy users there. Even though it is a very small cluster. So they must be borrowing other things.

Some insight here, but included to show the problem of referring to the colours. This would not happen with a solo subject, so is an 'overhead' of the collaborative process.

L1: [considering a dataset of the top 80% of borrowers] so, whereas before we were seeing adventure and crime together very distinctly, and saga dropping sort of like on a male front, you've got the three of them…
L1: they are either fiction, or non-fiction on that particular cluster.
L2: what are we looking at? 1 4 and 7?

L3: there is a broad borrowing, isn't there, across certainly those.
L1: … So you've got your biggest group that just aren't interested in non-fiction at all. Maybe a bit of biography, again coming into it, like we had before.

L2: So [colour] 3 shows high ethnicity borrowers also borrowing geography?
L1: slightly… but it is the fact that they are… having a lot of issues. But there is not that many of them.
L3: Oh, I don't know…
L1: in terms of the circle; the size of the circle [on the SOM], there's not that many instances across the whole…

L2: [No.] 1 is high borrowers. Isn't it?
L2: [greens are] high borrowers.
L1: there are lots of them. And apart from ethnicity, they are borrowing higher on, sort of, non-fiction, but they are borrowing fiction as well….[pause]…
L2: See, these are good library users. They are still 'Library Lovers', I suppose, aren't they?
L3: yeah, it is *the top 80%!*
L1: Oh yeah!

L3: quite bunched.
L1: there is a lot of black on there [the SOM]. There is a lot of mountains or whatever…that blue, particularly, if you just look at that…we have got 'Solus Book Borrower' as one of our main groups really, haven't we?...film, sound, talking books - they don't like sagas… can you just highlight that bit, so we just have that line?
L3: what else do they like?
L1: they don't like sagas
L1: [renting] the music…?
L3: who is your highest saga? Green.
L1: Ooooh. They like film, but they don't like the CDs [Music] and the Talking Books…. ethnicity as well… fairly static, isn't it?...there was that red one that sort of went like that…
L3: Yeah. I thought that was interesting. The difference between your pink and your green.
L1: ...there's a drop on…Sound and Talking Books sort of swap.
L3: Yeah
L1: that there is a preference for one or the other…
L2: So that… that is [No.] 6, isn't it; that is the pink. Film and sound are high, but not like in sagas….
L1: what about that…purple…they dabble a bit with film…

L1: Mmmm [interested in something seen on the screen] - they don't like books. But ethnicity...that is quite an interesting one. They are the… maybe they can't read?
L2: Ah yeah!
L1: Non-reading Ethnics.
L3: Watch and Listen.
L1: they are not even listening to books [Talking Books]…
L3:… there is not a lot of…. ethnic Talking Books.
L3: …or they don't want to read the books in English that we stock. And I don't know enough about the stock, as to whether…
L1: they may not be appealing…
L3: … the ethnic language books are the same sort of category.

The subjects have arrived at possibly their most significant data filter – looking at the 5000-odd borrowers responsible for 80% of all borrowing, and these last five quotations cover the process of their insight into this data. The penultimate quote is particularly fractured – by now **the subjects have been working together for some hours and are getting slick at evaluating the data and calling up views that interest them. They are exploring, hypothesising, and ideating at speed** through free exploration using SomVis as a geovisualization digital interactive prototype.

6.3.8.1.4 CONFIRMATION OF EXPECTATIONS

L3 so they don't borrow very much - but there is a lot of them.
David Lloyd: this is something you already knew?
L1-3 [in unison]: yes!
L1: yes, it is something we already knew. We knew there are lots of people that didn't borrow very much. In fact, the Pareto rule applies to the library data. And so, in terms of getting anything further from this, it is just really reinforcing our thoughts here.

L1: there is that….the blue one (no 7)… which is fairly big… if you have got adventure and crime together… but you still have some small growth in biography and geography, so obviously that's a male stock…okay
L3: I think that confirms what you would generally think about male borrowing, doesn't it?

Two examples of finding things in the data that confirm expectations.

6.3.8.1.5 EXPECTATIONS CONFOUNDED

L1…. one of the things we found when we were [looking at SomVis last time], was there did not appear to be any real geographic differences between some of the clusters that were coming out. ***We initially started looking at the clusters in terms of… "can we find clusters in terms of certain geography?"*** *But what was actually coming out more, was about people's behaviour. As opposed to where people actually lived.*

L1 has started to discover that the 'borrowers clustering problem' is far less spatial than expected and more related to individual behaviour. A profound insight from L1's point of view.

L3: It's the Asian population in Oadby and Wigston, isn't it, borrowing…?
L2: no [looking at the map] Because there are no geographic differences
David Lloyd: is this something you might have suspected…?
L1: No. Not something that we would have… now, some of the librarians at the site level might have come up with that, but in the meetings that we have had with them, no one was really saying that kind of behaviour.

Another significant instance of confounding of expectations occurs when a pattern associated with the borrowing of ethnicity books is found to be unrelated to the known major spatial areas of high ethnicity.

6.3.8.2 INDIVIDUAL SUMMATIVE QUESTIONNAIRE

Because the session was conducted in a collaborative way with the three libraries subjects, an individual questionnaire was used to gather individual assessments of aspects of the session and the prototype, before a group summative session (section 6.3.8.3). The results are in Table 6.23 and the majority are markedly positive (Likert scale result of ‘1’ or ‘2’).

The subjects find the SomVis 'prototype' fast, easy to learn and use, easy to select variables, weightings and SOM size, and easy to interpret the component tools. All subjects feel they could operate the prototype very well, and that the use of real data is very important. From the overwhelmingly positive responses to questions 1-22, it is clear that the session has been a success from the subjects' point of view. As such, there is a possibility of a 'halo effect' (Thorndike, 1920). These responses to the individual questions should be treated cautiously until compared with the evidence from the statistical analysis of count instances and the summative question session with all three Library subjects together, which is reported in the section 6.3.8.3.

The exceptions to the markedly positive individual summative questions are:

- L3 (Q11) found it hard to interpret the map of borrowers (‘map’) when it showed “equal area” rectangles in SomVis, but found interpretation of the ‘total issues’ rectangles ‘easy’. L1 and L2 both found rectangular cartograms ‘very easy’ and ‘easy’, respectively. L3 (Q13) also found it 'hard' to interpret the SOM (L1 and L2 found it ‘very easy’ and ‘easy’, respectively).
- L1 replied ‘neither easy nor hard’ to three questions (Q15-17) relating to **selecting different areas** on different parts of the prototype.

Q25 was a 'catch all' question, in which:

- L1 described two limitations of the prototype – relating the rectangular cartogram to the real geography, and not being able to filter once visualization had started Foe example, not being able to switch to 'male' once within '45-54 age').
- L2 was concerned about recording exploration and the importance of thorough note-taking, and not being able to select clusters not in close proximity to each other.
- L2 commented "*Because the software is easy to use it is possible to lose yourself and get carried away analysing the data and going off in different directions and not record of what you find*"

The last quotation echoes that of a CDR subject engaged in free exploration: "And the more you go on with it, the more you get sucked into particular areas" [C3], **suggesting that it is the**

free exploration protocol that engenders engagement of this kind. While in the CDR case it is spatial/geographic engagement, in this example it is not.

The questionnaire asked the subjects for positive and negative adjectives to describe their work with SomVis, in order to compare the result with those of the CDR subjects with the crime prototype. The libraries positive adjectives offered were: excited (x2), relieved, interested, insightful, pleased, addictive (x3)). There were no negative ones.

	Library subjects			Likert scale	
Question	**L1**	**L2**	**L3**	"1" means:	"5" means:
1 How good an understanding do you have of how to do clustering of library variables using	1	2	1	*very good*	*very poor*
2 How good was the instruction you received in how to use SomVis?	1	2	1	*very good*	*very poor*
3 How good was the supporting materials for the day (record sheets, map pictures, prompt sheets on "thinking aloud" etc)?	2	1	2	*very good*	*very poor*
4 Overall, how easy did you find SomVis to learn?	1	2	1	*very easy*	*very hard*
5 Overall, how easy did you find SomVis to use?	2	2	1	*very easy*	*very hard*
6 Did you prefer the map of borrowers based on 'total issues' or the 'equal size' one?	2	1	1	*strong preference for 'total issues' map*	*strong preference for 'equal area' map*
7 How easy was it to select variables in SomVis?	1	1	1	*very easy*	*very hard*
8 How easy was it to select weightings in SomVis?	1	1	1	*very easy*	*very hard*
9 How easy was it to select SOM size in SomVis?	1	1	1	*very easy*	*very hard*
10 How easy was it to interpret the parallel coordinates plot ('PCP') in SomVis?	3	2	2	*very easy*	*very hard*
11 How easy was it to interpret the map of borrowers ('map') when it showed "equal area" rectangles in SomVis?	1	2	4	*very easy*	*very hard*
12 How easy was it to interpret the map of borrowers ('map') when it showed "total issues" rectangles in SomVis?	1	2	2	*very easy*	*very hard*
13 How easy was it to interpret the SOM ('SOM') in SomVis?	1	2	4	*very easy*	*very hard*
14 How easy was it to select different areas on the parallel coordinates plot ('PCP') in SomVis?	2	1	2	*very easy*	*very hard*
15 How easy was it to select different areas on the map of borrowers ('map') when it showed "equal area" rectangles in SomVis?	3	2	2	*very easy*	*very hard*
16 How easy was it to select different areas on the map of borrowers ('map') when it showed "total issues" rectangles in SomVis?	3	2	2	*very easy*	*very hard*
17 How easy was it to select different parts on the SOM ('SOM') in SomVis?	3	1	2	*very easy*	*very hard*
18 How easy was it to work with different representations of the data (parallel coordinates plot, map of borrowers and SOM) simultaneously in SomVis?	1	2	2	*very easy*	*very hard*
19 How important was it for you that you used real LCC Library data in SomVis?	1	1	1	*very important*	*very unimportant*
20 How good was the speed at which SomVis produced the SOM and other graphics?	1	1	2	*very good*	*very poor*
21 How useful would it be for LCC Libraries to acquire SomVis?	1	1	2	*very useful*	*useless*
training)?	1	1	1	*very well*	*very poorly*
23 Please write down three positive adjectives that describe your work with SomVis	excited relieved addictive	interested excited addictive	insightful pleased addictive		
24 Please write down three negative adjectives that describe your work with SomVis	none	none	none		

Table 6.23: Summative questionnaire results from library subject free exploration session with SomVis

6.3.8.3 SUMMATIVE GROUP QUESTIONS

The results of the summative question session are categorised under the following headings:

- SomVis strengths
- SomVis weaknesses
- changes subject would make to SomVis as a result of the session
- new discoveries as a result of the SomVis session
- confirmation as a result of the SomVis session
- other items (includes ‘confidence in ability to run SomVis’; 'feedback on the session’; and ‘future direction’)

6.3.8.3.1 APPLICATION STRENGTHS

Recall that I am treating SomVis as a digital interactive prototype, and therefore it is consistent to ask the subjects for their feedback on SomVis's strengths and weaknesses, and the changes they would make to it.

Detail

L1: you could go into quite a fine detail in some instances, if you wanted to identify an individual [borrower], you could do.
L2: it knows who each individual is.

Ease of use

L3: ease of use.
L1: just easy to use; easy to see.

Flexibility

L3: you can have so many variables in it
L2: easy to tweak
L1: you can go backwards
L2: if you have a cluster that you are interested in, you can then get that individual’s data, save it, and then trace back to the individual. So you have got that flexibility as well.

Intuitive

L1: you could be very intuitive
L1: you can play a lot

Multiple views

L1: The fact that you could look at different things in one go, so you had a more rounded picture before you dismissed something or put something further forward.
L2: The more rounded view. You have got your SOM; you have got your PCP, and to see them together as well as the map, I thought that was useful. It is the whole thing; it is the interaction and the view that you have.

Saving/exporting

L1: you can save it as you go along; you can print the screen so you can compare and go back to something.
L1: you can export the data into other systems.
L2: And it saves it as a csv…you can actually do something with other systems.

Speed

L1: you could move on quickly. Speed.
L3: the views are very quick. If there is something to be seen, you see it like that [snaps fingers].
L1: easy to make decisions, quick decisions.
L2: it's instant updating
L1: you can get a lot done in a very short space of time with it.

These quotations commenting favourably on the speed and rapid response of the 'SomVis prototype' echo the comments by C3 undertaking free exploration with the crime digital interactive prototype (section 6.3.6), and are in contrast to the CDR subject comments about the slowness of the paper and digital interactive user testing protocol where the subjects' interactions with the prototypes were communicated by paper-based interfaces.

Other comments

L3: If you have got your data set right in the beginning, it is a lot more useful. I don't know whether that is a strength or weakness.
L1: it doesn't do the work for you, so you don't just go: "right, I'll press a button and it will go 'chunk chunk chunk chunk', and it will work out and churn out [an answer]".

6.3.8.3.2 APPLICATION WEAKNESSES

Comparison

L2: you needed to [have a strong structure – file naming convention]. You wouldn't have been able to have gone back if we had not had that.
L3: it would be handy if you could have more than one [window]...available, at the same time. So you could [compare].

Help

L1: I think the fact that…this sort of "sense checking", "are you doing it right?"; "have you got the right weightings?"; "have you interpreted it correctly?". I mean, there is no sort of warning to say "Remember! If you are looking at this, don't do this!" and "Don't read this as being this" sort of thing…Because there were lots of times today, when you said "Ah but, be careful, because you are not comparing blah with blah"…But actually, when you are left to it, then you could go horribly wrong…there will [need to] be some "sense checks", I'm sure, within it, when we are making decisions about things…

Map (spatial treemap)

L1: that thing about the map. [Not] being able to overlay with a real map on it was a definite weakness.

Output/Export

L3: it can't print.
L2: yeah. You say you would end up with a stack [of printouts after an exploratory session] but it would still be quite useful.

L3: I think from our point of view it would be a weakness that you can't "export" without going through several stages. Something like that, which would be useful for presentations.
L2: presentations to the senior management team and stuff. I think it is important - this isn't necessarily a negative of the actual software as such but is important that you write everything down…
L2: it doesn't record it. It would be good to remember that can have a "notes field" where you can start writing the notes within the actual cluster that [you are looking at].
L3: or if it was like SPSS, where in the output it tells you what it has actually done. Yeah - that would be fantastic. I don't think it's a killer, though.

Comments here on recording and on provenance reflect an acknowledgement by the subjects of the need to change processes: "[*It*] *is important that you write everything down"*, and some of the aspects that led to the rise of geovisual analytics with its emphasis (see section 1.1.3 and references to Keim et al (2008) and Armstrong and Densham (2008)).

Selection

L3: you can't separately select the SOM components.
L2: unless they are together and you can draw a line through them, you can't always do to together on the SOM.
L1: you can't do it with the PCP either, if you want to pick one and another.

Presentation support

L1: I think… it is not necessarily for… public display … or for library staff. It is very much a management information team doing the work, coming to the conclusions and then presenting something [in PowerPoint or something].
L1: the story needs interpreting, and told in a different way. But I think maybe it does need something built into it, because from my perspective - as you have probably seen along the way - half of the job is just keeping the management buy-in to use spending the time doing what you are doing, even if they are not necessarily seeing anything coming out of the other end. And you have got to keep selling [to] people that it is worth progressing, and that we are making progress. And even though they are not directly seeing anything, [you need them to see] it is a valuable piece of work that will result in something, if you let us [get on with it]…

6.3.8.3.3 CHANGES SUBJECTS WOULD MAKE TO SOMVIS AS A RESULT OF SESSION

Flexibilty

L1: just those… being able to select….isolate things… I suppose… one thing that would be nice to be able to do, is if you selected on a particular segment that you could then drill off into that automatically to say "within this segment, these people look like this, with these other variables". So, you then overlay other variables on top of that.
David Lloyd: so, can I play that back to you? So, for example, if you are looking at the 45 to 54-year-olds, and you are thinking "ah, that is the men, isn't it?" to be able quickly to be able to…

L1: proof that, yes.
L3: once you got it loaded.

Setting defaults

L3: maybe a template on the settings, that you can choose. Instead of you loading one up and put it to "original", then you load your next one in and it's gone to "optimal"…

In these strengths/weaknesses/change sections, as well as comments on SomVis, there are **indications of the extent to which the library subjects are engaging with a geovisualization 'prototype'.** The two quotes under 'Multiple views' indicate that **the library subjects value the the ability to combine multiple tools and display results simultaneously** – an essential interactive feature of a geovisualization application. **The speed of being able to visualize data** is referred to by L3: "*If there is something to be seen, you see it like that [snaps fingers].*"

L1's comment about "[Not] being able to overlay with a real map on - it was a definite weakness", shows the limitations of SomVis in being able to signal hierarchical data (in this case, where data was located by library), and that the provision of a paper map with this information on did not fully meet L1's needs. Nevertheless, the process of working with SomVis with real user data as if it were a prototype does elicit this information.

In the first L1 quote in 'Presentational support', L1 demonstrates **the library subjects' understand the exploratory nature of the SomVis 'prototype'** – that it is not a tool for presenting results and that a different process is needed to communicate discoveries.
The second L1 quote sets exploratory software in a situated context – **the situated reality of the need for buy-in by the subjects' management.** Reflecting on my engagement with domain subjects, throughout I have emphasised the 'exploratory' nature of geovisualization and that it is not primarily a tool for presentation. However, the experience of working with both sets domain experts makes it clear that in the world these subjects find themselves, communication to stakeholders is extremely important, as they can switch resources away from exploration unless they are convinced of the benefits. **Geovisualization researchers should consider the ways they can effectively persuade prospective subjects' stakeholders of the benefits of exploration and 'exploration through visualization'**. The modified 'Dibiase' graphic in Figure 1.3 (Armstrong and Densham, 2008) is relevant here, as is the proposal of Shneiderman and Plaisant (2006) that "HCI and information visualization researchers accept responsibility for a second outcome: the achievement of users' goals within their domain of work. This is a substantial increase in expectations for researchers, which raises the responsibility of researchers for the successful work of their subjects/collaborators."

6.3.8.3.4 NEW DISCOVERIES AS A RESULT OF SOMVIS SESSION

Clusters

L1/L2 (together): Ethnic Parent Borrowers!
L1: Fantasists
L1/L2 (together): Non Reading Ethnics
L1: People that like a library, but don't like reading. "Library Lovers"

The library subjects are focused on the desired outcome from their viewpoint – to identify clusters they can market to. Plus another example of 'married couple' syndrome.

Relative unimportance of space

L1: one of the new things that came up, not necessarily from today, but from the previous one [the exploratory data session held on month earlier] was about the spatial thing. The fact that I was sure there was going to be something spatial coming out in some way, shape or form. And it hasn't. And I think that, in itself, was a learning, because, potentially, we can carry on the work we are doing on the dataset that we have got, rather than going back to the database and extracting a random sample from everything. Now that potentially could be flawed, because it could be unique to that area, who knows? But I think we can take less of a risk by saying, well, we are not doing anything really dangerous by continuing to work on this dataset. We have expanded out from two libraries to four… so I think that was a learning, not necessarily from today, but from the other day. But it has been reaffirmed today, with some of the extra work that we have done.

This quote shows **the importance of triangulating evidence from multiple sources**. L1 believes there was no spatiality at the end of the session, although on at least two occasions during the free exploration with SomVis, spatiality was identified and commented on. Nevertheless, **the clusters that have emerged are not spatial in character**, and this confounds these subjects' prior expectations.

6.3.8.3.5 CONFIRMATION AS A RESULT OF SOMVIS SESSION

Male borrowing

L3: … suspicions. Prejudices, even, maybe… males - what they tend to borrow.
L1: with the males, I have got down "reinforces what we already know" with the male borrowers.

Borrowing clusters

L1: quite a lot, wasn't there, in terms of… sort of fiction and non-fiction people.. there was some of that coming out quite strongly…we had a group of Fantasists…
L3: I think you got three types of borrowers. There were those who tend to borrow fiction; those who tend to borrow non-fiction; and those who tend to borrow both.

L1: the junior fiction and non-fiction thing… it was, like, "it is nice to see some peaks and stuff in things, because you think that's telling you something, but then when you get to it, you go 'ah well, that's obvious isn't it?'"

L1: It is when you come across something you have never really seen before, or not understood before, that it becomes more interesting.

L1's final quote here another example of the way that geovisualization exploration engages the subject.

6.3.8.3.6 OTHER ITEMS

Confidence in ability to run SomVis

David Lloyd: are you confident, you could run this by yourself, given enough training?
L2: yes
L3: yes
L1: Yeah....I suppose the thing that concerned me slightly after last time [the session a month ago] was "cor that looks so easy to use… blah, blah, blah". Then we came to actually do the exercise, and our heads were like, "whow! We can't really remember"
L2: I think the system is easy to use; the software is easy to use, but it is still quite difficult to interpret it. It gives you the information, you have still got to think about it. It doesn't give you the answers. But the actual tool, for what we actually want to try and get out of it, is good.

L1: what has to be done is making sure that there is enough time to be able to spend on it.
L3: whether you can actually do it in your working day, is another question.
L2: For LCC Research to do [the exploration], they have not got the depth of knowledge that [we have]…the benefit of us doing it is our knowledge of the data that we have been analysing. LCC Research would be able to do it, but I think we have got the insight to make it more meaningful to us.

The subjects feel confident in being able to run SomVis themselves in the future. This is quite an end result given the complexity of the tools (PCP, SOM and cartogram), the abstract nature of the presentation of the data, the limited understanding these subjects had of their data beforehand, and the comparatively short time the subjects had to master the software. **The components of success include working with their own, real data, on a highly focused task, with simple outcomes** (discovering clusters). To get to this point, **it was not necessary to provide a tutorial on geovisualization, or work with subjects over an extended time period** (as with the CDR subjects).

Feedback on session

L1: I feel much better after the session, which obviously one would expect that to be the case, but in the last one [a month ago] I remember thinking "how am I going to apply this to anything?" I could see that it was going somewhere, but I couldn't see the application with marketing. Whereas, today, I have been able to see that. It sounds stupid, but just making up these names is part of the process. It is trying to make sense, tell a story, create a normal world of something that is fairly [complex].

L1: I think it's been really good. I think it been really great.
L2: I think it's been brilliant.
L3: And I think it's been wonderful! [laughter]

L1: it's been a pleasure to work with you.

The first L1 quote is an indication of the trust a subject places in a geovisualization researcher to **produce a result that contributes something to subjects as well as advance the research objectives**. It is an argument for a 'win-win' situation, and echoes again the proposal of Shneiderman and Plaisant (2006) that "HCI and information visualization researchers accept responsibility for a second outcome: the achievement of users' goals within their domain of work." In the second set of quotes the subjects feel the experience has been worthwhile and the contact with the researcher pleasurable. But the downside is the possibility of a 'halo effect' (Thorndike, 1920) in their responses to specific questions.

Future direction

L1: when we first picked out all of the filters, after that first session, what we wanted to do - we wanted to know everything! And we wanted to look at the age breakdown of every single one, and we wanted all the variables in there, and all the rest of it. And I think, just focusing it down onto four [filtered datasets] has meant that you can spend a bit more time on it, and you can see why you want to break it down in more detail. Rather than just chuck everything in and out the other end.
L3: I can quite see why we came up with four [filtered datasets], and I quite agree with that for the purposes of today. However, it reinforces to me, the need to break it down by…
L1: …every age
L3: … every age band, every gender… But I appreciate that wasn't the purpose of today. But it's certainly needs doing, that way.
L1: the main thing, from my point of view, is that it just reconfirmed that we spend far too much time producing stats for other people that don't necessarily take your business forward. And if you could reallocate your time differently, you would spend much more time on things like this than you would do on a visitor's survey or… whatever.
L3: [there are] several reasons [for this]. One is historical. They have always had information like that, in that format. They don't know any better, if you know what I mean.
L1: they can't do anything about it because they have got to do it.
L2: a lot of it is statutory, isn't it?
L3: There is that, the situation where we have to do this. We have to do visitor surveys, or whatever. There has never easily been the mechanism to show this sort of clustering. Peaks and troughs in types of issues, for example. We have not had that mechanism before. So it is new.
L2: it has also been very difficult to get data out, which has been an issue. Because I think if we had been able to get data a lot more easily then you would have been in a better position to have done something with it.
L3: yes. I think what you have to do… as fantastic as it is... what we need, and yes, at last we can start looking at this stuff, and seeing what is what, and the clusters and the patterns, and all the rest of it. We have to put it across in such a way that they are going to use it to make a difference.
L1: and the biggest challenge to me is that because we generally tend to work on a year by year's planning cycle - very tactical, short term, sort of thing. To actually invest the resources on something like this that won't necessarily give you a return within a year, it is very much more part of your strategic infrastructure… I mean, that is a real challenge….

A number of strands emerge or re-emerge here: the size of the on-going exploration task when the data needs to be filtered, and SomVis run, in a large number of ways; the difficulties of introducing radically new methods in a team resourced on the basis of current, periodic tasks; and the difficulties of accessing raw data, gathered for other purposes, in legacy systems.

> *L1: how we would like to just scrap doing loads of other things! And just get on with this. Because that is my concern. You could get somewhere much faster, if you allowed just to get on with it…. I think the one good thing is…from our library management point of view, is that whilst they might not necessarily see anything specific in terms of a practical application at this stage - because it is still very much work in progress - one of the things that is very important to them is reputation in the whole library world. And getting across the message that we are trying to be more innovative, more cutting edge, and all the rest of it, actually brings Leicestershire up there in terms of reputation. So it serves two different jobs. If we can then apply it to the customers, and actually do something with it, then great. But if we just managed to boost our reputation in the process, then it keeps them on board really.*

In the first part of this quotation, L1 crystallises the motivation of these libraries subjects - they are dissatisfied with current processes, want to do things differently and are motivated to change to achieve their ends. The libraries context is very constrained by lack of data, tools and expertise, but the libraries subjects are enthusiastic about change*: "how we would like to just scrap doing loads of other things! And just get on with this [clustering with SomVis]" [L1].* Clearly, **another contextual factor that determines how subjects respond to prototypes is their perception of how these might contribute to a positive change to their work situation**.

In the second part, L1 reemphasises the need to win resources and take management with the team in taking the work forward, and provides context by indicating that 'reputation' is a commodity that can be used to gain support with local management, as well producing locally based results. Future researchers might gain improved commitment and subject time by learning from contextual dialogues exactly what subjects and their managers' value, and providing it. Investing time in joint articles (researcher plus domain experts) and/or joint conference papers come to mind for those who value 'reputation'.

> *L2: when do we get somVis? Where can we get hold of it?*
> *L3: Now. Just download it. You can download it - but it will take three months for ICT [local IT people] to install it!...I will get it off [Guo's] website. I have been there.*
> *David Lloyd: [Doing it] all at home on your home computer?*
> *L3: Yes. Which is what I'm going to do.*

This exchange is included because it shows how the availability of an application on the web means that a subject – once made aware of the possibilities it offers and its existence – could access it and experiment with it in advance of a scheduled session. It is also a sign of how the power of a geovisualization application yoked to real user data can motivate a subject to seek it out for downloading at home in L3's own time.

6.3.9 LIBRARIES FREE EXPLORATION SUMMARY AND COMPARISON WITH CDR

This summary brings together the key strands from the statistical analysis of the coded instances of exploration in the free exploration with SomVis, the think aloud transcripts from the free exploration, the individual questionnaire filled in at the end of the session, and the transcription of the summative group questions.

6.3.9.1 LIBRARIES FREE EXPLORATION SUMMARY

The results in this summary section correspond to case number 13 on Table 2.2 (an extract of which is at the start of this chapter).

6.3.9.1.1 METHODOLOGY

In the CDR subject prototyping sessions, subjects do not (and were not encouraged to) record the exploration undertaken and any results. From the work with the library subjects, they were motivated from the outset to record their findings, however there is **some evidence** from their free exploration think aloud and from the questionnaire that such **recording of findings by subjects is a bottleneck to exploration** (section 6.3.8.1.2).

A key methodological difference is that free exploration in CDR was with a solus subject, C3. Whereas free exploration within libraries was a collaborative effort with three libraries subjects L1, L2 and L3. The advantages and disadvantages of collaborative working are discussed in section 6.2.3.3, where Snyder (2003) highlights the advantages as "more comfortable for the users, easier for the facilitator and generates more data." Dumas and Redish (1999) concur with the last point. **Good evidence** from the SomVi s prototype sessions indicate that the library subjects were comfortable with the experience based on their individual question responses (section 6.3.8.2), and they generated voluminous data (as section 6.8.1 testifies). As a facilitator, the session was easy to be part of, given that roles had been established for the collaborating subjects in advance.

The free exploration session with three **collaborating** subjects has strengths and weaknesses. The **strengths** include evidence from the collaborative free exploration think aloud of:

- **untested assertions made by one subject that can be challenged or corrected by others** (**good evidence** from sections 6.3.8.1.2 and 6.3.8.1.3)
- **systematic approaches** to the session are articulated and made explicit by one subject for the benefit of the team (**some evidence** from section 6.3.8.1.2)

The **weaknesses** include **some evidence** from the collaborative free exploration think aloud of:

- **the disjointed nature of subjects' narratives** for the purposes of attribution and analysis (section 6.3.8.1.2)
- **the need to articulate and agree aspects that would not occur with a solo subject** (for example, whether a line or circle is referenced by everyone as 'red', as occurred in section 6.3.8.1.2)

6.3.9.1.2 DOMAIN KNOWLEDGE

The importance of domain knowledge is shown on a number of occasions in **good evidence** from free exploration think aloud. Specific examples are:

- a hypothesis that it is males who are making up a geography/biography cluster (section 6.3.8.1.2);
- patterns of borrowing may not be the same as patterns of reading (section 6.3.8.1.2);
- knowledge of the profile of the 55-64 year old library users and a hypothesis about their attachment to their library necessitates a reweighting in SomVis (section 6.3.8.1.2);
- knowledge that the small library at South Wigston issues a disproportionately large number of crime fiction genre books (section 6.3.8.1.3).

6.3.9.1.3 CONTEXT

Echoing similar findings about context with the CDR subjects 'late' in the process (when it was discovered that the CDR domain experts have 'favourite' crimes), a number of responses to the summative group questions illustrates **aspects of the library subjects' context in use that were not apparent earlier in the process**. **This illustrates that such context information is not just disclosed at an early stage of the ISO 13407 process**. These include **some evidence** of:

- **the need for buy-in by subjects' management**, as they can switch resources away from exploration unless they are convinced of the benefits (section 6.3.8.3.3),
- **practical difficulties in introducing radically new methods in a team resourced on the basis of current, periodic tasks** (section 6.3.8.3.3 and 6.3.8.3.6) *"how we would like to just scrap doing loads of other things! And just get on with this…You could get somewhere much faster if you [were] allowed just to get on with it…." [L1]*

These constraints on Libraries subjects bring to mind the effective observation in section 3.3.2 of a member of the CDR team. Here, the observation of the direct financial link between CDRP partners and the CDR team established, as a consequence, a limit to the time CDR subjects were able to spend on the exploration of crime data, given their commitment to support their 'paying customers'.

Some evidence from section 6.3.8.3.6 indicates that a **contextual factor that determines how subjects respond to prototypes is their perception of how these might contribute to a positive change to their work situation**.

6.3.9.1.4 EXPLORATION (WITH SOMVIS 'PROTOTYPE')

Central to this research is the extent to which subjects engage in a range of exploratory activities with SomVis and their ability to extract useful knowledge from their data with the SomVis 'prototype'.

There is **good evidence** from individual questionnaires (section 6.3.8.2) that **the subjects find SomVis fast, easy to learn and use, easy to select variables, weightings and SOM size with, and easy to interpret the component tools. All subjects believe the use of real data is very** important.

There is **some evidence** from the free exploration think aloud supports this in instances where subjects:

- think about the extent to which clusters are different in degree, and **use both the self-organising map (SOM) and the PCP** (section 6.3.8.1.1)
- **explore and hypothesise** about the source of ethnicity (book) borrowing (section 6.3.8.1.2)
- confirm an expectation about male borrowing (section 6.3.8.1.2), and form a hypothesis about female borrowing (section 6.3.8.1.2)
- **establish a connection between borrowing genres** (geography and biography) (section 6.3.8.1.3)
- experiment with different weightings to see the effects, and draw conclusions about stability of the patterns they observe, and hence show **deeper engagement with the SomVis 'prototype'** (section 6.3.8.1.3)
- show **rich ideation** as they identify a large cluster from the map of total borrowing (the rectangular cartogram) (section 6.3.8.1.3)

- **use the rectangular cartogram creatively** as an indicator of absolute numbers rather than as a location tool, paralleling the use of the crime attribute treemap and glyph as a 'summary' in the CDR subjects' exploration of their data (**good evidence** from section 6.3.8.1.3)
- **explore** and shows **insight** into new clusters (section 6.3.8.1.3)
- **identify** a new cluster formed of three different genres: ethnicity + geography + biography (section 6.3.8.1.3)
- gain **fluency** and **confidence** with SomVis, **exploring**, **hypothesising**, and **ideating** at **speed** and calling up different views that they find interesting (section 6.3.8.1.3)
- find items in the data that **confirm expectations** (good evidence from section 6.3.8.1.4)
- **confound expectations** with a discovery that a pattern associated with the borrowing of ethnicity books is unrelated to the known major spatial areas of high ethnicity (section 6.3.8.1.5)
- **identify**, **hypothesise** about, and **name** clusters that they feel represent discrete categories of library borrowers who can be the recipients of targeted marketing. **These categories are all non-spatial** and are named: 'travellers', 'solus books', 'library lovers', 'ethnic parent borrowers', 'non-reading ethnics' and 'fantastists' (**good evidence** from sections 6.3.8.1.2, 6.3.8.1.3, and 6.3.8.3.4)

In the summative group question session, there is **good evidence** of further **indications of the extent to which the library subjects are engaging with a geovisualization 'prototype' -** two quotes (sections 6.3.8.3.1 and 6.3.8.3.3) indicate that **the library subjects value the ability to combine multiple tools and display results simultaneously** - an essential interactive feature of a geovisualization application.

The breadth of evidence for exploration from multiple sources gives confidence that the results from the individual questionnaires can be relied upon and are unlikely to be the result of a 'halo effect'.

6.3.9.1.5 SPATIAL PATTERNS

This research is centered on geovisualization and the exploration and discovery of spatial patterns is a particular focus. L1 had the expectation before the data session that preceded the SomVis session that any clusters found would be spatial in nature. However, during the SomVis exploration, such instances occurred only twice, as evidenced by the free exploration think aloud (**some** evidence from 6.3.8.1.1 and 6.3.8.3.3). During the summative group questions (section 6.3.8.3.4) L1 believes no spatiality was discovered at all.

This shows **the importance of triangulating evidence from multiple sources,** and in particular**, not relying on summative evidence alone.**

6.3.9.1.6 UNDERSTANDING/LEARNING

As well as evidence from subjects use of SomVis from the free exploration, the summative group questions give an insight into the understanding of, and learning from, SomVis. There is **some evidence** that L1 demonstrates **an understanding the exploratory nature of the SomVis 'prototype'** (section 6.3.8.3.3) – that it is not a tool for presenting results and that a different process is needed to communicate discoveries.

For the library subjects, the **components of success include working with their own, real data, on a highly focused task, with simple outcomes** (discovering clusters). There is **good evidence** for this from summative group questions (section 6.3.8.3.6). To get to this point, **it was not necessary to provide a lecture on geovisualization, or work with subjects over an extended time period** (as with the CDR subjects). From this, **I hypothesise that working with subjects over a long period of time may not, in itself, be necessary**. The results from Libraries show that understanding context and explaining tailored geovisualization tool approaches in the context of subjects' data is sufficient for these subjects to use even sophisticated visualization tools in a free exploration environment, given adequate support.

6.3.9.2 COMPARISON WITH CDR FREE EXPLORATION

The results in this section corresponds to case number 14 on Table 2.2 (an extract of which is at the start of this chapter).

In spite of large differences of subjects, number of participants, prototypes and tasks, there are a good number of similarities between the free exploration of the crime digital interactive prototype and the SomVis 'prototype' used by the libraries subjects.

Methodological there were problems with think aloud in both C3 and L123 sessions. In the CDR session, there is **some evidence** that **the think aloud struggles when the subject is focused intently** (section 6.3.3.5). In the libraries session, there is **some evidence** that think aloud suffers from **the disjointed nature of subjects' narratives** (section 6.3.8.1.2).

The count of exploration recorded by the three library subjects ('L123') is statistically indistinguishable from the 'free exploration' conducted by C3 with the CDR digital interactive prototype (see Table 6.14)

The need for structure is noted in **some evidence** from subject C3's comments during free exploration that **the almost endless exploration possibilities need discipline to conduct explorations in a systematic way** (section 6.3.5.2). This need for structure is also noted in **some evidence** from the libraries free exploration think aloud and from the questionnaire, that **recording of findings by subjects is a bottleneck to exploration** (section 6.3.8.1.2).

There is **good evidence** from both the CDR (sections 6.3.5.2 and 6.3.5.4) and libraries (sections 6.3.8.1.2 and 6.3.8.1.3) free explorations that **detailed domain knowledge is needed to make hypotheses about, and extract meaning from, the patterns observed in the data**.

There is **good evidence** from both CDR and libraries of examples of the situated context of these subjects that may affect their response to geovisualization prototypes. In the case of CDR it is how the **choices made in geovisualization exploration may have a real impact on decisions that affect policy** (section 6.3.5.1 and 6.3.5.2). In the libraries case, **the need for buy-in by subjects' management** (section 6.3.8.3.3), the **practical difficulties of introducing radically new methods in a team resourced on the basis of current, periodic tasks** (section 6.3.8.3.3 and 6.3.8.3.6) and **their perception of how these might contribute to a positive change to their work situation** (section 6.3.8.3.6).

There is **good evidence** from a large number of quotations from the CDR free exploration (section 6.3.5.1) that show **a significant depth of interaction, engagement and exploration** with the CDR digital interactive prototype with the free exploration protocol. Similarly, there is **good evidence** from a large number of quotations from the libraries free exploration (sections 6.3.8.1.1, 6.3.8.1.2 and 6.3.8.1.3) of **exploration, hypothesis forming, confirming expectations, rich ideation** and **insight** with the SomVis 'prototype' with the free exploration protocol. The libraries team finds and names clusters of library borrowers.

There is **good evidence** that both the libraries subjects (section 6.3.8.1.3) and CDR subject C3 (section 6.3.51) **gain fluency and speed** with their respective free exploration prototypes.

In **some evidence** from the CDR free exploration, **geovisualization possibilities generate data exploration possibilities** (section 6.3.5.1):*"I have been drawn into these [areas] by being able to manipulate the resolution of the data…"* Similarly (section 6.3.6) C3 **when engaging with a spatial pattern in free exploration the effect is to focus the attention** ("*the more you go on with it, the more you get sucked into particular areas*"). In the libraries case, there is **some evidence** showing **deep engagement with the patterns of clusters** (section 6.3.8.1.3), although these are not spatially based, as in the CDR case.

There is **good evidence** that both C3 (section 6.3.6) and the libraries subjects (section 6.3.8.2) believe it is important to use real data in the prototypes.

The positive and (where given) negative feelings about the two free exploration prototyping sessions are shown in Table 6.17. Feelings recorded in the CDR user testing sessions are also included. Both free exploration sessions contain far fewer negative adjectives than occur in **the user testing sessions,** which **were clearly more taxing and intimidating**.

	User testing	Free exploration	
	C1,C2, C3 (section 6.3.3)	C3 (section 6.7.6)	L123 (section 6.3.8.2)
Positive	Interesting (2) Insightful Useful Exciting Enthused Enjoyable Inquisitive Thought-provoking Inspiring	Enjoyable 'in control'	Addictive (3) Exciting (2) Interesting Insightful Relieved Pleased
Negative	Tiring (3) Draining (2) Fatiguing Confusing Daunting Frustrating Apprehensive	"Possibly misleading"	none

Table 6.24: Positive and negative feeling about the prototypes

This concludes the section on the results from the Libraries free exploration (case number 13) and the comparison with CDR free exploration (case number 14).

6.4 CONCLUSIONS

Research question 5 asks: **How well do human-centered approaches concerned with prototyping work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of prototyping of geovisualization applications with prospective users?**

The results from the user testing with active intervention in CDR, free exploration with the digital interactive prototype in CDR, and free exploration with SomVis 'as a digital interactive prototype' in LCC Libraries are given in sections 6.3.4, 6.3.7 and 6.3.9, respectively, along with the references to the evidence. These voluminous results will not be repeated in as much detail in this concluding section, which highlights the main findings and recommendations.

RQ5.1 How well do human-centered approaches concerned with prototyping work in an applied geovisualization context?

1 Paper prototype with user testing, active intervention and chauffeured interface (CDR subjects) – case number 8

Speed , and the presence of **the treemap** are the **perceived strengths of the paper prototype; Inflexibility** of the paper prototype is **a weakness** (**some evidence** from section 6.3.3),

The paper prototype in this case produces more than twice as many suggestions for improvement that are related to 'new' features (a category that includes novel geovisualization elements) (**good evidence** from section 6.3.1.3, Table 6.19 and from the details of the user testing think aloud transcripts (section 6.3.2)).

There is **some evidence** from individual subjects that:

- the paper prototype is **capable of driving spontaneous desire to explore data (**section 6.3.2.1),
- the paper prototype **promotes reflection on current work practices (**section 6.3.2.3),
- paper prototyping can **replicate the shortage of screen 'real estate'** that would occur with a computer-based application (section 6.3.2.1),
- subjects use and integrate both the piece of paper bearing the thematic map/glyphs and the piece of paper bearing the treemap/glyphs, demonstrating **the flexibility of**

the paper prototype to handle multiple tool representations (sections 6.3.2.1 and 6.3.2.1)

- **subjects' sometimes need knowledge about areas on the map and additional attribute data** (such as initiatives to reduce crime and disorder) to create hypotheses of what are the causes of a pattern of crime (sections 6.3.2.1 and 6.3.2.1),
- what is learned from the prototype is **data-dependent** – that is, it is a combination of prototype *and* data (section 6.3.2.2).
- **different subjects have different responses in a geovisualization situation as they hold different (tacit) spatial knowledge** (section 6.3.2.3)

The relative success of paper prototyping in user testing is in line with the findings of Virzi, Sokolov and Karis (1996), Catani and Biers (1998), Walker, Takayama and Landay (2002) and Lim et al (2006). It does not support of work of Liu and Khooshabeh (2003) who found that "interactive prototype captured the same usability issues that the paper prototype studies did and more" (see section 6.2.1.1). Snyder (2003) cautions "complex or subtle interaction usually can't be simulated perfectly" with paper prototyping. But by using real subject data, high quality graphics and by confining subjects to a limited number of screens with realistic tasks, paper has not been at a disadvantage.

2 Digital interactive prototype with user testing, active intervention and chauffeured interface (CDR subjects) – case number 9

Digital interactive prototyping is successful at engaging subjects, eliciting exploration activity, hypothesis forming and establishing possible improvements with a user-testing with active intervention protocol, and with a free exploration protocol (**good evidence** from sections 6.3.2.1 – 6.3.2.3)

The digital interactive prototype's strong points over the paper prototype are its **ease**, **clarity** and **excitement/appearance** (**some evidence** from section 6.3.3).

Some evidence, in this case, C3's familiarity with Loughborough shows, that **the general process of exploration is influenced by prior knowledge**, so this plays a part in changing the subject's interaction with the digital interactive prototype (section 6.3.2.1)

3 Paper and digital interactive prototypes with user testing, active intervention and chauffeured interface (CDR subjects) – case number 10

There is **strong evidence** from individual subjects that in this case both paper and digital interactive prototypes generate **considerable breadth of engagement, hypothesis formation, exploration, ideation/insights and for expectations to be confirmed or confounded** (evidence from counts of coded think aloud and from the details of the user testing think aloud transcripts, sections 6.3.2.1 to 6.3.2.5),

Subjects indicate an overall **positive view of the prototypes** using words such as **interesting, insightful, useful, exciting, enjoyable, thought provoking** and **inspiring** (**good evidence** from section 6.3.3)

Subjects' main negative response to the prototyping sessions are related to tiredness and fatigue, partially due to the length and intensity of sessions, and partly to the repetitive nature of the tasks (**good evidence** from section 6.3.3).

Paper and digital interactive prototypes yield similar numbers and types of exploratory information within an 'active intervention' user-testing protocol (evidence from section 6.3.1.1, Table 6.10)

Within an 'active intervention' user-testing protocol, the **paper prototype yields more suggestions for improvement than the digital interactive prototype except for interface-related improvements** (statistically significant at 0.05 significance level) (evidence from section 6.3.1.2, Table 6.15 and section 6.3.1.3, Tables 6.19 and 6.20).

User testing with active intervention is particularly poor at producing implicit suggestions for improvement (evidence from section 6.3.1.2, Table 6.17, for both paper and digital interactive prototypes)

All CDR subjects have 'data-related' suggestions for improvement as a predominant category. The other three categories (interface-, interaction- and new-related) have more of a range (evidence from Table 6.21, section 6.3.1.3).

Subjects' perception is that the **paper prototype had the edge over the digital interactive prototype in terms of speed** (**good evidence** from section 6.3.3),

The process of being exposed to geovisualization prototypes has led to changes in thinking about the approach to the work of this team (**some evidence** from section 6.3.3).

Hands-on experience of working with prototypes enables **requirements to be established** (**some evidence** from section 6.3.3),

The user testing protocol limits subjects to tools and tasks and interferes with the exploration process (**some evidence** from section 6.3.3)

4 Digital interactive prototype with free exploration (CDR subject C3) – case number 11

There is good evidence from a large number of quotations from the free exploration (section 6.3.5.1) show **a significant depth of interaction, engagement, exploration and fluidity and rapidity with the digital interactive prototype with a free exploration protocol**.

There is some evidence from the summative questions (section 6.3.6) to using the digital interactive prototype in a free exploration way is that it is **flexible**, **enjoyable** and **engaging,** and that **the tutorial and controls crib sheet were adequate to operate the digital interactive prototype**.

5 Digital interactive prototype with user testing, active intervention, chauffeured interface v free exploration (CDR subjects) – case number 12

The overall **level of exploration in free exploration is over twice the level observed in user testing** in a session that lasted about the same time as the user testing with active intervention session (**good evidence** from section 6.3.1.1, Table 6.13)

There is a difference in C3's geovisualization exploration of the digital interactive prototype with the two different protocols, with **more possible improvements emerging in the free exploration, and markedly more implicit suggestions** (statistically significant at 0.05 significance level; **good evidence** from section 6.3.1.2, Table 6.18). While statistically significant, this finding must be bear a caveat given C3's role in the CDR team as the GIS expert, and possessing a good knowledge of the geography of the area featured in the prototypes.

In **some evidence** from the summative questions (section 6.3.6), C3 believes **the main differences between the user-testing and free exploration protocols are speed, control/flexibility, realism and less constraint on what the user wants to do**. The enabling of browser zoom and pan in the free exploration clearly plays a part in this.

6 Digital interactive prototype with free exploration in collaborative session (Library subjects) – case number 13

There is **some evidence** from their free exploration think aloud and from the questionnaire, that such r**ecording of findings by subjects is a bottleneck to exploration** (section 6.3.8.1.2).

The free exploration session with three **collaborating** subjects has strengths and weaknesses. The **strengths** include evidence from the free exploration think aloud of:

- **untested assertions made by one subject that can be challenged or corrected by others** (**good evidence** from sections 6.3.8.1.2 and 6.3.8.1.3)
- **systematic approaches** to the session are articulated and made explicit by one subject for the benefit of the team (**some evidence** from section 6.3.8.1.2)

The **weaknesses** include **some evidence** from the free exploration think aloud of:

- **the disjointed nature of subjects' narratives** for the purposes of attribution and analysis (section 6.3.8.1.2)
- **the need to articulate and agree aspects that would not occur with a solo subject** (for example, whether a line or circle is referenced by everyone as 'red', as occurred in section 6.3.8.1.2)

A number of responses to the summative group questions illustrate **aspects of the library subjects context in use that were not apparent earlier in the process**. **This demonstrates that such context information is not just disclosed at an early stage of the ISO 13407 process**. These include **some evidence** of:

- **the need for buy-in by subjects' management**, as they can switch resources away from exploration unless they are convinced of the benefits (section 6.3.8.3.3),
- **the practical difficulties of introducing radically new methods in a team resourced on the basis of current, periodic tasks** (section 6.3.8.3.3).

- a **contextual factor that determines how subjects respond to prototypes is their perception of how these might contribute to a positive change to their work situation**. (section 6.3.8.3.6)

There is **good evidence** from individual questionnaires (section 6.3.8.2) that **the subjects find SomVis fast, easy to learn and use, easy to select variables, weightings and SOM size with, and easy to interpret the component tools. All subjects believe the use of real data is very important.**

In the summative group question session, there is **good evidence** of further **indications of the extent to which the library subjects are engaging with a geovisualization 'prototype' -** two quotes (sections 6.3.8.3.1 and 6.3.8.3.3) indicate that **the library subjects value the ability to combine multiple tools and display results simultaneously** – an essential interactive feature of a geovisualization application.

L1 had the expectation before the data session that preceded the SomVis session that any clusters found would be spatial in nature. However, during the SomVis exploration, such instances occurred only twice, as evidenced by the free exploration think aloud (some evidence from 6.3.8.1.1 and 6.3.8.3.3). During the summative group questions (section 6.3.8.3.4) L1 believes no spatiality was discovered at all.
This shows **the importance of triangulating evidence from multiple sources,** and in particular**, not relying on summative evidence alone.**

As well as evidence from subjects' use of SomVis from the free exploration, the summative group questions give an insight into the understanding of, and learning from, SomVis. There is **some evidence** that L1 demonstrates **an understanding the exploratory nature of the SomVis 'prototype'** (section 6.3.8.3.3) - that it is not a tool for presenting results and that a different process is needed to communicate discoveries. There is also **good evidence** from the same source and the individual questionnaires that **the subjects feel confident in being able to run SomVis themselves in the future**, and are clear about the scale of the on-going exploration task (section 6.3.8.3.6)

For the library subjects, the **components of success include working with their own, real data, on a highly focused task, with simple outcomes** (discovering clusters). There is **good evidence** for this comes from summative group questions (section 6.3.8.3.6). To get to this point, **it was not necessary to provide a lecture on geovisualization, or work with subjects over an extended time period** (as with the CDR subjects).

7 Digital interactive prototypes with free exploration (CDR subject C3 and Library subjects) – case number 14

In spite of large differences of subjects, number of participants, prototypes and tasks, there are a good number of similarities between the free exploration of the crime digital interactive prototype and the SomVis 'prototype' used by the libraries subjects:

Methodologically there were problems with think aloud in both C3 and L123 sessions. In the CDR session, there is **some evidence** that **the think aloud struggles when the subject is focused intently** (section 6.3.3.5). In the libraries session, there is **some evidence** that think aloud suffers from **the disjointed nature of subjects' narratives** (section 6.3.8.1.2).

The count of exploration recorded by the three library subjects ('L123') is statistically indistinguishable from the 'free exploration' conducted by C3 with the CDR digital interactive prototype (see Table 6.14)

The need for structure is noted in **some evidence** from subject C3's comments during free exploration that **the almost endless exploration possibilities need discipline to conduct explorations in a systematic way** (section 6.3.5.2). This need for structure is also noted in **some evidence** from the libraries free exploration think aloud and from the questionnaire, that **recording of findings by subjects is a bottleneck to exploration** (section 6.3.8.1.2).

There is **good evidence** from both the CDR (sections 6.3.5.2 and 6.3.5.4) and libraries (sections 6.3.8.1.2 and 6.3.8.1.3) free explorations that **detailed domain knowledge is needed to make hypotheses about, and extract meaning from, the patterns observed in the data**.

There is **good evidence** from both the CDR and libraries of examples of the situated context of these subjects that may affect their response to geovisualization prototypes. In the case of CDR it is how the **choices made in geovisualization exploration may have a real impact on decisions that affect policy** (section 6.3.5.1 and 6.3.5.2). In the libraries case, **the need for buy-in by subjects' management** (section 6.3.8.3.3), the **practical difficulties of introducing**

radically new methods in a team resourced on the basis of current, periodic tasks (section 6.3.8.3.3 and 6.3.8.3.6) and **their perception of how these might contribute to a positive change to their work situation** (section 6.3.8.3.6).

There is **good evidence** from a large number of quotations from the CDR free exploration (section 6.3.5.1) that show **a significant depth of interaction, engagement and exploration** with the CDR digital interactive prototype with the free exploration protocol. Similarly, there is **good evidence** from a large number of quotations from the libraries free exploration (sections 6.3.8.1.1, 6.3.8.1.2 and 6.3.8.1.3) of **exploration, hypothesis forming, confirming expectations, rich ideation** and **insight** with the SomVis 'prototype' with the free exploration protocol. The libraries team finds and names clusters of library borrowers.

There is **good evidence** that both the libraries subjects (section 6.3.8.1.3) and CDR subject C3 (section 6.3.51) **gain fluency and speed** with their respective free exploration prototypes.

In **some evidence** from the CDR free exploration, **geovisualization possibilities generate data exploration possibilities** (section 6.3.5.1):*"I have been drawn into these [areas] by being able to manipulate the resolution of the data…"* Similarly (section 6.3.6) C3 **when engages with a spatial pattern in free exploration the effect is to focus the attention** ("*the more you go on with it, the more you get sucked into particular areas*"). In the libraries case, there is **some evidence** showing **deep engagement with the patterns of clusters** (section 6.3.8.1.3), although these are not spatially based, as in the CDR case.

There is **good evidence** that both C3 (section 6.3.6) and the libraries subjects (section 6.3.8.2) believe it is important to use real data in the prototypes.

The positive and (where given) negative feelings about the two free exploration prototyping sessions are shown in Table 6.18. Feelings recorded in the CDR user testing sessions are also included. Both free exploration sessions contain far fewer negative adjectives than occur in **the user testing sessions,** which **were clearly more taxing and intimidating**.

RQ5.2 How might human-centered approaches concerned with prototyping work in an applied geovisualization context be changed?

The paper and digital interactive prototypes work well in producing both suggestions for improvements and a rich subject involvement with copious examples of exploration, hypothesis forming, ideation/insight, and confirming and confounding expectations.

However, while the success of the paper prototype in eliciting both exploratory activity and suggested improvements from the CDR subjects is encouraging, it is important to recall that it relies on a system to produce multiple paper representation containing real subject data. In practice, this has meant that the paper prototype relies on the prior existence of the digital interactive prototype. While this is acceptable in a test situation, it is impractical for wider use as a technique, unless it brings some special advantages over presenting essential the same material as a digital interactive prototype. These might include its less intimidating nature with subjects. However, this advantages makes a poor case for 'real data paper prototyping' as a viable 'real world' approach.

The user testing protocol with active intervention requires task construction by the researcher. Understanding of subject context of use has been shown in Chapters 4 and 5 and in this chapter to be a communications process that is not finalised in the first ISO 13407 phase. There is a possibility that tasks may not be fully understood and lead to problems in prototype user testing. User testing also requires more resources to administer especially where a 'Computer' undertakes interface control, and this also affects speed of operating the prototype for the subject and places a barrier between the subject and the prototype.

Free exploration yields the same quantity of result (section 6.3, Table 6.9) but without interposing the experimenter between the subject and the prototype, and needs fewer resources to administer. The task can be selected by the subject within parameters selected by the researcher). While it is necessary to tutor the subject in operating the interface to the prototype this was not a problem in practice in either the CDR or the Libraries cases.

The free exploration protocol is perceived to have advantages of fluidity, rapidity and less constraint over the user-testing with active intervention protocol for CDR. There is a difference in C3's geovisualization exploration of the digital interactive prototype with the two different protocols, with **more 'possible improvements' emerging in the free exploration, and markedly more implicit suggestions** (statistically significant at 0.05 significance level; evidence from Table 6.18)

The results from the library users show that they generate considerable exploratory activity in a free exploration protocol with the SomVis 'prototype', and succeed in identifying (non-spatial) clusters of borrowers they consider meaningful. Understanding context and explaining tailored geovisualization tool approaches in the context of subjects' data is sufficient for these subjects to use even sophisticated visualization tools in a free exploration environment. This is dependent on providing adequate support and may indicate that it is the **quality** of the communication between researcher and subject that is important, and not necessarily communication over a **long period**.

RQ5.3 How does the nature of geovisualization affect the process of prototyping of geovisualization applications with prospective users?

Work with prototypes in a user-testing environment with active intervention, and free exploration in two domains, produces further evidence for conclusions drawn in earlier chapters on:

- **the importance of real data**.
- **the importance of domain knowledge** (especially as tasks become more complex)
- **the emerging context of subjects and their data**

There is now **very strong evidence** to support **the importance of real data** to subjects from different subjects, in different domains, with different prototypes and different protocols (see RQ5.1 for evidence sources).

There is now **strong evidence** from frequent instances that **detailed domain knowledge is needed to make hypotheses about, and extract meaning from, the patterns observed in the data** (see RQ5.1 for evidence sources).

There is **good evidence** from section 6.3.3 that **not all crimes are equally important to subjects** and some categories are relatively unexplored. Some crimes are more interesting than others, but this is not tacit knowledge (see RQ5.1 for evidence sources).

Methodologically, the work with both CDR prototypes and both protocols reveals:

- **the importance of the attribute information conveyed by the background map**
- subject behaviour in arguing from pattern to map

And the work in both domains reveals:

- **think aloud limitations when thoughts are sharply focused**
- **the influence of prior knowledge on exploration**

(see RQ5.1 for evidence sources).

Examining Table 6.18 (section 6.3.9.2) highlights two negative aspects experienced by the CDR subjects around the user testing. These are that the tests were tiring/fatiguing, and that they were daunting/induced apprehension.

The first of these implies the user tests were too long. I consider that this is a problem that stems from using domain experts in a protocol that typically uses recruited subjects (see my analysis of visualization literature with human-centered approaches in section 1.3.2). Such subjects are expensive to recruit but are essentially interchangeable - the clock is reset with each new subject. But the domain experts are not interchangeable. A long sequence of interviews, questions, observations, geovisualization wireframe and prototyping sessions, even over a long period span of time, places a large burden on these domain expert subjects. Most of the interactions with these domain expert subjects are 'one shot' – the act of showing a wireframe or a prototype changes subjects' perceptions. They cannot be taken back and become 'unseen'. Consequently, there is going to be a balance between trying to extract as much as possible from these unique subjects, and exhausting them, perhaps to the point of them withdrawing their cooperation.

The second of these points refers to apprehension of, and being daunted by, the user testing. My view on this is that in choosing user testing as an approach, even with active intervention as a 'helpful' protocol, I had not given enough thought to the nature of user testing. As I have said above, it is a protocol that typically uses recruited subjects. To motivate such recruits often payment or (for students) credits are offered as inducements. I was expecting the domain expert subjects to undertake user testing encouraged by nothing more than my assumption of their motivation to contribute to my research questions. To compound matters, they were not permitted to control the interface to the prototypes. Contrast this experience to the free exploration with both C3 and the libraries subjects. Here both were allowed to choosing the data/task, and control the interface to their prototypes themselves.

I believe that user testing as an approach may be fundamentally at odds with the notion of 'partnering' with domain experts and attempting to understand their context of use over a long period of time. This touches on a wider theme of the power balance between the subject and the researcher that I discuss in Chapter 9.

RECOMMENDATIONS

I strongly recommend visualization researchers use **real subject data.** However, **I caution** that the use of real subject data in a paper prototype entails an effort that may negate its usefulness as a 'real world' technique.

I recommend that geovisualization researchers should consider the use of both paper and digital interactive prototypes in both user testing with active intervention, and free exploration protocols, subject to considering (a) the impact of the need for real user data on paper prototypes, and (b) the appropriateness of user testing with domain expert subjects.

I recommend both paper and digital interactive prototyping in user testing with an active intervention protocol as a way to communicate geovisualization ideas to subjects and elicit exploratory responses from them in a user-testing environment with an active intervention approach. Both prototypes have advantages, and both can contribute to the process of iterating towards a final geovisualization application. However, this is subject to the caveats concerning (a) the impact of the need for real user data on paper prototypes, and (b) the appropriateness of user testing with domain expert subjects.

I particularly recommend paper prototype in user testing with an active intervention protocol for improvement suggestions. However, this is subject to the caveats concerning (a) the impact of the need for real user data on paper prototypes, and (b) the appropriateness of user testing with domain expert subjects.

I particularly recommend the paper prototype in user testing with an active intervention protocol for improvement suggestions related to novel tools/interactions for use in geovisualization. However, this is subject to the caveats concerning (a) the impact of the need for real user data on paper prototypes, and (b) the appropriateness of user testing with domain expert subjects.

I recommend that researchers should be mindful of the impact of interfaces to geovisualization prototypes that are not under the control of users, as the perception of a prototype will be a composite of the prototype itself plus its interface.

I recommend that researchers would be advised to ask future subjects at the 'Context of Use' stage whether they find different parts of their domain data more interesting than others, and if so, why. **I further recommend** that researchers expect, look out for, record and consider new contextual information from their subjects during prototyping sessions, as such information arises not just in the initial Context of Use phase.

I recommend future geovisualization researchers should note that transcription of audio is arduous and that having a well trained 'note taking observer' to record pertinent subject commentary in real time will be faster and far less effort.

I recommend that geovisualization researchers consider the ways they can effectively persuade prospective subjects' stakeholders of the benefits of exploration and 'exploration through visualization' to gain commitment by learning what subjects and their managers value from contextual dialogues with them.

I recommend future researchers working with domain experts take care to ensure that the origin of freely available software employed is concealed to ensure subjects do not access it directly outside any experimental sessions.

I caution that user testing results are valid **only within an active intervention protocol** as part of prototyping an application, and **not as a summative evaluation** of a final application.

I propose that it would be an instructive piece of research to compare subject use of a geovisualization prototype with 'real, own data' and with 'real, other people's same-domain data' to understand better the relative importance of these factors.

6.5 DISCUSSION

Using two different prototyping methods appropriate to a design at this stage of development - paper and digital interactive prototyping - three subjects from LCC's crime and disorder reduction team undertake a series of simple spatial, temporal and crime attribute tasks within a protocol of 'active intervention' (Dumas and Redish, 1999). Interfacing with the prototypes is by means of paper which is interpreted by a research acting as a chauffeur (Nunamaker et al., 1991) to the prototypes. The prototypes are based on the designs from the wireframe sessions described in Chapter 5.

Think aloud is used to record subjects' reactions to the tasks with the prototypes, and is recorded, transcribed and coded according to an emergent scheme to highlight (a) instances of exploratory behaviour – exploratory activity, hypothesis forming, ideation and forming insights, expectations confirmed or confounded, and (b) implicit and explicit suggestions for improvement that might drive the development forward. This material is supplemented by individual summative questioning. The digital interactive prototype is also used within a different protocol – free exploration – where the interface is under subject control.

A further set of subjects from LCC's library unit are introduced to aspects of the multivariate and spatial aspects of their data and existing tools and techniques available. They undertake a free exploration with the application SomVis (Guo et al., 2005), treating it as a prototype, and using its tools (self organising map, parallel coordinate plot and a spatial cartogram of borrowers) to explore library data spatially and by attribute to establish clusters of library borrowing, thought to be spatial in nature. The library subjects interact collaboratively with the 'prototype' and engage in extensive amounts of exploratory activity.

Earlier work with the LCC subjects outlined in chapters 3 to 5 has charted the course of communicating the subjects' context, and my attempts, using HC approaches, to communicate geovisualization to these subjects in a range of ways. Research results have been rich, but in terms of moving the subjects forward towards a working application, less productive (see Figure 2.1). In this chapter, with the arrival of tangible prototypes, there is a palpable difference.

I have strong evidence that the subjects - typical of their position in UK local government – can interact successfully with quite complex geovisualization prototypes to explore their data and get useful results. Rich geovisualization exploratory activities are elicited from different individuals, in two different domains, with different tasks and data, different skills and expertise, different prototype fidelities (paper and digital interactive), different protocols (user testing with active intervention and free exploration), and different prototypes. For CDR, where the prototype was not as well developed as the libraries 'prototype', subjects provided many hundreds of possible suggestions for improvement. There are, of course, differences in degree - evidence that A is preferable to B in this or that aspect, and so on, and these are outlined in detail in section 6.4. **These prototypes work for geovisualization applications**.

This is quite a result given the various combinations of individuals, domains, tasks, skills, expertise, geographies, prototype fidelities and protocols. However, the results from this chapter indicate that there are even more variables in play:

- To visualization researchers, application-data interactions are fundamental to tool selection for different tasks (see sections 1.1.2 and 1.1.3). One of the more surprising findings in this chapter is of a subject-data effect. There is good evidence that CDR subjects believe that not all crimes are equally important, some categories are relatively unexplored, and some crimes are more interesting than others. Domain experts can have favourite datasets.
- The impact of individual geographical knowledge plays a part in how subjects interact with prototypes. C3's explorations of crime in Loughborough are noticeably richer than those of C1 and C2, who are less familiar with the town.
- Subject attention working with a prototype varies over time. At the end of a long session they are tired and fatigued and therefore different results (or a different quality of results) might be expected.
- Whether subjects work together in collaboration or solus to explore a prototype will have an effect.
- How subjects interface with prototypes will have an effect, as shown when direct control is removed from subjects when using the digital interactive CDR prototype in user testing. Evidence of rich geovisualization exploration activity from free exploration in CDR and libraries contradicts the notion that taking away control of the interface from subjects in some way frees them up to concentrate on the geovisualization.

This complex mix of factors makes a quantitative approach very challenging. But the qualitative approaches used here are able to make an evidence-based contribution.

So why does it "all work"? I conjecture that what is different about the prototyping stage is subjects seeing real domain data, transformed and presented 'geovisually', which invites engagement and exploration:
"I have been drawn into these [areas] by being able to manipulate the resolution of the data…"
"*the more you go on with it, the more you get sucked into particular areas*" [both C3]

For the reason above, inconsistent results between subjects are to be expected. Individuals are the subjects of geovisualization and their own preferences will influence results and need accommodating. This implies that the way forward for geovisualization researchers working with domain experts should be to develop ways to achieve flexibility in application design, with continual iteration and quick prototyping. This needs building based on creating bonds, understanding and confidence with subjects.

It is notable that a group of geovisualization-naïve library subjects, in a relatively short time (a few days face time for interviews/observation to get context, plus two one day sessions), were competently (and enjoyably) using an advanced geovisualization application containing a spatial treemap, parallel coordinate plot and self-organising map. Up to that point, these subjects had no multivariate knowledge of their own data, little by way of tools, and no expertise in GIS. With help, these subjects progress to a situation where they produce useful insights into the clusters of their customers' borrowing. Preparation and organisation is vital to make this work, as is motivation to change and learn critical on the part of the subjects. The results from LCC Libraries show that understanding context and explaining tailored geovisualization tool approaches in the context of subjects' data is sufficient for these subjects to use even sophisticated visualization tools in a free exploration environment, given adequate support. As a consequence, I conjecture that working with subjects over a long period of time may not, in itself, be necessary, but that the intensity of the engagement is what matters.

There are a number of other reflections on the prototyping work in this chapter:

- The transcriptions of subject interactions with prototypes for this chapter totalled 150,000 words. However, while this degree of detail is necessary to understand the detail of the way subjects interact with geovisualization prototypes for the purposes of this research, such detail is not required if the aim is to simply record possible improvements. Having a well trained 'note taking observer' (Snyder, 2003) to record these in real time would be faster and easier. An efficient coding scheme is, however needed in advance. Tables 6.3, 6.4 and 6.5 and Figure 6.21 may be of use as starting points for researchers building one. Better still would be to manage sessions with subjects so that prototype development is discussed, agreed and recorded between researchers and subjects as part of the process. The HC technique of affinity diagrams, described in Beyer and Holtzblatt (1997), may be helpful here.

- There has been a large emphasis on real subject data based on copious evidence of its importance to subjects. It might be possible to engage subjects who are very familiar with data and geography more strongly, and delay feelings of fatigue, if the real data was altered by the researcher in one specific way (for example changing two days of the week in the CDR example) and the subjects challenged to 'spot the difference'.

- An observation of a novice subjects' reaction to geovisualization prototype is insightful. When C2 first saw the digital interactive prototype, the reaction was "Ooooh!" When the time came to show the library subjects SomVis for the first time, their reaction was "Wow!" During the free exploration session, a senior library manager briefly entered the testing room and, on seeing SomVis, exclaimed "It’s a bit like Star Trek, isn't it? Warp factor 1!" I think 'Wow!' may be the sound of potential users experiencing overload and possible apprehension at the sight of a data-dense, highly coloured, interactive, multiple component tool. It is perhaps the sound of exploration shutting down. Geovisualization researchers are experienced in the use and representation of multiple tools, but this complexity can undoubtedly act a barrier to subjects. Applications (including prototypes) might benefit from including a pathway for novices who might initially find geovisualization intimidating (this could be by training, helping, or by reducing the tools available at first sight, for example by selectively greying out or otherwise hiding tools. Tidwell (2005) recognises this as a pattern: 'extras on demand').

- There is evidence that the background map is key to the CDR subjects in both user testing and free exploration, and should clearly be chosen with care. One modification might be to tailor background maps to include those elements (and perhaps only those) that these CDR teams regard as significant to their domain. For the CDR team, this would be a 'cartography of crime' and include related attributes such as pubs, taxi ranks, schools, car parks. It would also include material such as CCTV areas, and where they have been crime reduction initiatives recently. It might even be beneficial to distort the geographic map to be a rectangular spatial cartogram of crime. Different domains would have different cartographies.

This concludes this section on prototyping. The work with CDR subjects established many hundreds of possible improvements that could be made to the CDR prototype. How these should be prioritised with human-centred approaches in order to advance the prototypes further towards a fully developed application is the subject of Chapter 7.


PLOT
prototype
comparisons
levels
provide
AHP
C2
C3
One
visualization
COMPARISON
sessions
RYAN
CONSTRAINT
Evidence
ranking
INSPECTION
particular
Quite
data-related
three
SESSION
COSTS
KARLSSON
case
PRIORITISE
COST
POSSIBLE
CHAPTER
group
geovisualization
users
APPROACHES
given
level
order
work
really
tools
see
comments
new
improvement
PRIORITISING
KARLSSON-RYAN
Figure
rankings
constrained
areas
made
may
potential
APPROACH
table
PROCESS
think
new-related
SUBJECT
Two
different
interface
way
interface-related
prototyping
pair-wise
use
consistency
list
number
IMPROVEMENTS
going
first
section
KNAPSACK
high
just
PRIORITIES
research
data
time
difficult
suggestions
context
value
RESULTS
SUBJECTS
DEVELOPMENT
related
choices
might
developments
important
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category
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7 PRIORITISING

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ABSTRACT

I evaluate the use of a human-centred decision-making tool with CDR subjects to prioritise 35 possible improvements that are an output from the geovisualization prototyping work carried out in Chapter 6. These contain a mixture of data-related, interface-related, interaction related and new-related possible improvements, the last of these containing novel geovisualization tools. A geovisualization developer completes the assessment in order to compare priorities with those of the CDR subjects. Results reveal plausible and statistically similar ranking by CDR subjects that are different from the developer. The CDR subjects focus on prototype improvements that have the most bearing on their current activities rather than on innovation. 'New-related' possible improvements are compared significantly less consistently than other categories of possible improvements by all subjects.

Such prioritisation is unconstrained by development costs and may be unrealistic once these are factored in. Costs are established for the 35 possible developments from the geovisualization developer, the process revealing that a one-to-one correspondence between cost and possible improvement is not possible in this case.

Two approaches are employed to prioritise possible improvements under cost constraint. One uses a 'value versus cost' plot inspection technique that requires no further recourse to the CDR subjects. The second is a human-centered approach based on the classic knapsack problem and asks the CDR subjects to elicit their priorities having provided them with their unconstrained priorities and the developer's costs. Both methods produce plausible and similar results. The conclusion is that the additional effort to use a human-centered approach to consult subjects about constrained priorities is not cost effective.

Evidence from questions asked of the CDR subjects after both prioritisation sessions indicate that they need help to understand 'new-related' (including novel geovisualization tools) possible improvements. Communicating information about visualization possibilities through words alone, as happens in these prioritization process, may be inappropriate for such a complex domain. Even after a considerable period spent with these CDR subjects working on the development of a geovisualization application, it is clear that on-going difficulties in communicating geovisualization to these potential users persist.

7.1 INTRODUCTION

RQ6: How well do human-centered approaches concerned with the process of prioritising possible improvements to geovisualization applications work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of prioritising possible improvements to geovisualization applications with prospective users?

The work with prototypes in Chapter 6 generates a great deal of information about the exploration, hypothesis forming, ideation and insight forming by CDR and Libraries users. In the case of the CDR subjects, care was taken to collect, code and classify suggestions from CDR subjects for possible improvements, both explicit and implicit.

The human-centered purpose of prototyping is to elicit improvements that are iterated in order to produce successive prototypes leading to a final application. Such possible improvements will encompass a number of different categories – table 6.5 shows one such categorization into data-related, interaction-related, interface-related, and possible improvements dealing with novel aspects such as new geovisualization tools or interactions. Maguire and Bevan (2002) state that: "Prioritisation of user requirements is important so that development resources can be directed appropriately." This might be particularly problematic where geovisualization novelties vie with other possible improvements for developer time and resources. For this reason, it is useful to consider decision-making approaches and how well they work in the applied geovisualization context of the CDR domain.

The research in this chapter looks at the decision-making approaches available and chooses one to use with the CDR subjects to prioritise the possible improvements in an unconstrained way. Evidence is gathered from the relative ranking of the choices made and from the statistics on consistency and dispersion that are generated as part of the decision-making process. The decision-making technique provides a comparison between the CDR subjects' priorities and those of the CDR-aware geovisualization developer who would generate further iterations of the CDR digital interactive prototype.

Aware that the above results are unconstrained by the practicalities of limited developer resources, development times for each suggested improvement are established by the geovisualization developer. These times are used to generate 'value versus cost' plots which are inspected to obtain priorities for development in an approach suggested by (Karlsson and Ryan, 1997). This approach does not seek further input from CDR subjects. A modified approach is adopted that deals with the complexities arising from generating costs for the possible improvements, some of which include the development of geovisualization tools, and invites CDR subject input to the constrained prioritisation process. CDR subjects have limited funds to purchase developer time, and their choices for suggested improvements are recorded to see how they compare with their unconstrained choices and with the cost constrained choices from the Karlsson and Ryan method, and to see how geovisualization choices featured in all three approaches.

7.2 METHODS

Case No.	ISO 13407 methods	Population	Sample	Units	Objective	Research Design
15	**Prioritising** (analytic hierarchy process (AHP) using possible improvements from results of prototyping plus observations, interviews and transcribed and coded think aloud).	Prospective geovis application users in LCC Research and Planning department	Crime & Disorder reduction (CDR) Team	CDR team members	Evaluate CDR user reactions to using the analytic hierarchy process (AHP) to prioritise improvements to a prototype	(b) Case Study II
16		Geo-visualization experts	Geovis experts	Individual geovis expert / developer	Evaluate Geovis expert / developer reactions to using the AHP to prioritise improvements to a prototype	
17		Prospective geovis application users in LCC Research and Planning department	Crime & Disorder reduction (CDR) Team	CDR team members plus individual geovis expert / developer	Compare CDR and geovis expert experiences to using the AHP to prioritise improvements to a prototype	(d) Cross-sectional
18	Use of 'value v cost' plot inspection and a human-centered approach to determine priorities for possible improvements constrained by cost of development			CDR team members	Evaluate 'value v cost' plot inspection to determine priorities for possible improvements constrained by cost of development	(b) Case Study II
19					Evaluate a human-centered approach to determine priorities for possible improvements constrained by cost of development	
20					Compare 'value v cost' plot inspection and human-centered approach to determine priorities for possible improvements constrained by cost of development	(d) Cross-sectional

Extract from Table 2.2: Prioritising (Research Question 6) - the sections of this research showing case study details by type according to (Gerring 2004).

The case study schema reproduced above outlines the framework for the research in this chapter. The chapter also considers the results of the geovisualization developer's costing of possible improvements for a geovisualization prototype, which yield a number of insights.

7.2.1 DECISION MAKING APPROACHES TO PRIORITISING

From the seven CDR prototyping sessions described in Chapter 6, the three CDR subjects generate verbal transcripts totalling about 120,000 words that yield ~350 explicit and implicit suggestions for improving the prototypes. When coded and grouped, these yield 35 possible improvements (Chapter 6, section 6.2.3.1 and 6.3; Table 6.5). The first 10 are 'data-related' (aggregation, filtering and context related); numbers 11-16 are 'interface-related' (system behaviour, complexity and speed related) ; 17-23 are 'interaction-related' (readability, orientation, scale, legend related); and 24-35 are 'new-related' (novel visualization tools and displays related). The coding of the original ~350 suggestions into these particular categories, and indeed the overall number of categories, is a matter of subjective judgement and emerges inductively (Lewins and Silver, 2007).

Table 6.9 gives counts of instances of suggestions for improvement by type (data-related, interface-related, interaction-related, and new-related) to prototypes during the course of the paper and digital interactive prototyping sessions, by CDR subject, implicit or explicit suggestion, prototype and protocol (user testing or free exploration).

Having elicited a number of possible prototype improvements, the task is then to prioritise them, since development time and resources is a realistic constraint to producing further prototypes or an eventual application. This research is interested in how standard approaches to decision-making work in an applied geovisualization context, how might they be changed and how the nature of geovisualization affects the process of prioritising possible improvements to geovisualization applications with prospective users.

Approaches to decision-making include multi-criteria decision analysis (MCDA) (Dodgson et al., 2000), GIS-based MCDA (Malczewski, 2006), and Analytic Hierarchy Process (AHP) (Saaty, 1977).

The Analytic Hierarchy Process is a well established method used in many fields (Wasil and Golden, 2003). It has even been the target of visualization techniques using a treemap (Asahi, Turo and Shneiderman, 1995). For reasons of its popularity and easy implementation, the AHP was selected as the decision-making approach for this research.

The AHP relies on participants making a large number of pair-wise preference choices from a population of different options. By considering every possible pair-wise combination, it is possible to construct the relative priorities of every member of the population by producing an overall score and hence a ranking. The AHP also allows the calculation of a measure of consistency – the Consistency Ratio (CR) – that gives a quantitative measure of the consistency of the pair-wise scorings relative to each other (Saaty, 1980).

The AHP has been used in the prioritising of software development (Karlsson and Ryan, 1997). Their variant takes the AHP as a starting point and adds the constraining effect of limited development resources. This is explained in more detail in section 7.2.2.

The 35 possible improvements would need 595 (= 35 x 34 /2) pair-wise comparisons in total, but this is an unreasonable number for completion by even the most patient subjects. Karlsson, Olsson and Ryan (1997) comment that:

> "In large-scale developments, requirements are structured in different ways, such as hierarchies, in order to get a better overview of the requirements…Hierarchies are useful in the prioritising process since they reduce the required number of pair-wise comparisons. In a hierarchical structure, only those requirements at the same node are pair-wise compared."

This suggests grouping possible improvements together and make pair-wise comparisons within-group and then between-groups to reduce the number of pairwise comparisons required. Using the four categories (data-related, interface-related, interaction-related, and new-related) in this way reduces the number of pair-wise comparisons to a manageable 153.

The AHP provides a way to prioritise possible improvements to a geovisualization prototype, but the method does not provide a way to constrain the results to fit the development resources available. When resources are constrained, subjects might make different choices from that suggested by their straightforward AHP ranking. This might particularly be the case where a number of different alternative exist to implement a particular improvement, each offering different functionality and each with a different resource implication.

In order to take account of the constraint of limited development resources, Karlsson and Ryan (1997) outline a process that:

- calculates the unconstrained AHP results for subjects,
- ascertains development costs for each possible improvement,
- plots the AHP value for every possible improvement (as a percentage of the sum of all improvements) against the corresponding development cost, and
- inspects the plot to reject high cost/low value items until development constraints can be met.

The methodology for calculating the unconstrained AHP results is covered in section 7.2.2, and for ascertaining costs, in 7.2.3.

The Karlsson and Ryan approach envisages the final stage undertaken 'by inspection' by the developer. Jung (1998) believes that in the situation "with many requirements or closely grouped cost-value points, the inspection method becomes far too complex for human judgment" and proposes a variant on the 0–1 knapsack model to replace the inspection by a computed process. The 0-1 knapsack problem involves filling a hypothetical knapsack with objects of different weights and values to yield the maximum value given a fixed carrying capacity knapsack (see section 2.1.2.5). The point made by Jung (1998) is valid, but an alternative approach that referred the prioritisation issue back to the prospective users would be more human-centered and have advantages. By letting subjects see the results of their AHP, and the costs associated with developing these, it might be possible to establish their priorities under various levels of constraint. This variant has the potential for eliciting how subjects' constrained preferences for 'new-related' (including geovisualization) possible improvements relate to data-, interface- and interactive-related categories. This variation is used with the CDR subjects. Details of the methodology employed are outlined in section 7.2.4.

In summary, there are four separate methodological strands to this part of the research:

- conducting an AHP with CDR subjects and developer 'D' and examining the prioritisation results and their consistency (see 7.2.2)
- ascertaining the costs of developing solutions to possible improvements for the CDR prototype (7.2.3)

- prioritising possible improvements under cost constraint using the plot inspection method of Karlsson and Ryan (1997)
- prioritising possible improvements under cost constraint using the new human-centered approach that uses CDR subjects informed by their AHP results and the development cost constraints (see 7.2.4)

7.2.2 ANALYTIC HIERARCHY PROCESS PROTOCOL TO PRIORITISE IMPROVEMENTS

The CDR subjects were provided with the list of 35 possible improvements with description (Table 6.5) a week before the AHP session with instructions to read them, but not to attempt prioritising them. Only two CDR subjects (C2 and C3) were available to take part in the AHP prioritisation session, as C1 had left LCC at the time of the session.

The origin of the 35 possible improvements was outlined to the subjects and covered the processes of transcription, coding and analysis of the subjects' own think aloud from the prototyping sessions (see Chapter 6). It was explained that the geovisualization developer who had produced the digital interactive prototype ('D') was content – in principle – to spend time implementing some of these improvements, but was limited in the time available. There was therefore a need to prioritise these possible improvements. Choosing between 35 possible improvements is difficult, therefore a selection method that simplified this - the AHP - had been chosen.

After outlining the motivation for the AHP session, the two subjects were reminded about the digital interactive prototype by showing them screen shots of it in action from the prototyping sessions described in Chapter 6, plus a video of the entry of commands via a URL string and the use of SVG controls to zoom and pan. This was necessary as only C3 had used the digital interactive prototype in free exploration mode and had familiarity with command entry and the SVG pan and zoom facility.

Karlsson and Ryan's account of how to calculate the AHP is straightforward and can be implemented in a spreadsheet. For the AHP sessions, the AHP is implemented on a laptop. Subjects see two columns on the left and right of the screen respectively, containing individual possible improvements. Between each pair of suggested improvements are 17 cells running from the left: 9, 8, 7 … to a central '1' then increasing 2,3, 4 … to 9 on the right – an integer divergent scale. Table 7.1 from Karlsson and Ryan (1997) derived from Saaty (1977), shows the meaning assigned to the points on this nine-point scale. A cardboard strip attached beneath the laptop display with this scale information on it, acts as a reminder to the subjects. Subjects also have access to their pre-provided list of the 35 possible improvements along with expanded definitions (Table 6.5) throughout the session. Figure 7.1 shows screenshot of AHP in progress; Figure 7.2 shows a CDR subject in the course of the AHP session.

SCALE FOR PAIRWISE COMPARISONS		
Relative intensity	**Definition**	**Explanation**
1	Of equal value	Two requirements are of equal value
3	Slightly more value	Experience slightly favors one requirement over another
5	Essential or strong value	Experience strongly favors one requirement over another
7	Very strong value	A requirement is strongly favored and its dominance is demonstrated in practice
9	Extreme value	The evidence favoring one over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between two adjacent judgments	When compromise is needed
Reciprocals	If requirement *i* has one of the above numbers assigned to it when compared with requirement *j*, then *j* has the reciprocal value when compared with *i*.	

Table 7.1: AHP scale for pair-wise comparisons, from Karlsson and Ryan (1997)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
2	Display the crime numbers associated with geography, times and crime categories as text						4												Add contextual data to the map view
3	Filter the data shown in the current view to include only certain areas											3							Aggregate selected times on glyphs together into bands
4	Aggregate selected historical time periods to act as the comparison with the current view							3											Add contextual policy data to map view
5	Filter the data shown in the current view to include only crimes greater than a particular number									1									Aggregate selected areas together
6	Filter the data shown in the current view to include only certain crimes or sub-crimes							3											Filter the data shown in the current view to include only crimes greater than a particular number
7	Filter the data shown in the current view to include only certain times						4												Aggregate selected historical time periods to act as the comparison with the current view
8	Aggregate selected times on glyphs together into bands									1									Filter the data shown in the current view to include only crimes greater than a particular number
9	Filter the data shown in the current view to include only certain times							3											Filter the data shown in the current view to include only certain areas

Figure 7.1: Screenshot of AHP in progress.
The series of pair-wise comparisons are in the outer columns, and the relative scores the subject has given each pair are in the central selection. The scale range is at the top (running from the centre to left and right from a central '1' to '9'.

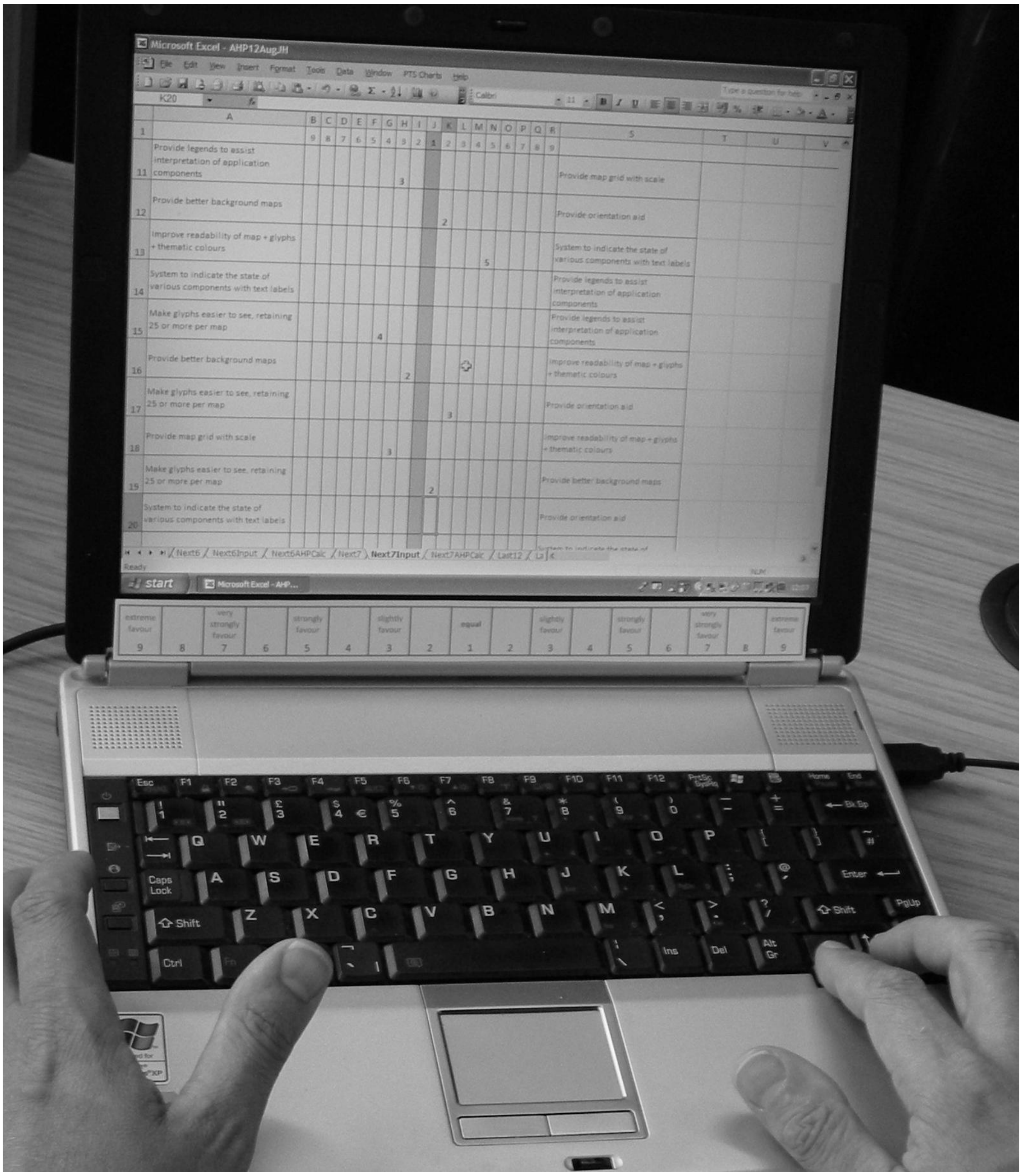

Figure 7.2: AHP pair-wise selection in progress with an LCC CDR user.
Note the cardboard strip below the display with details of the scale.

Subjects are asked individually and separately to consider each pair-wise comparison in turn and to provide their relative preference score in the appropriate cell. The spreadsheet contains cell protection to ensure only the correct column value can be written in each of the 17 data collection columns. The subjects progress through the four categories (data-related, interface-related, interaction-related, and new-related) in order, and finally complete a between-category relative scoring using the AHP. After each category is completed, the entries are examined to see that nothing has been omitted, and that the AHP rankings and consistency ratio have been calculated correctly by the spreadsheet.

The AHP results are shown to the subject at this point to provide an opportunity to discuss their reasonableness, and for the subject to see the measure of consistency, the consistency ratio. If the consistency ratio (CR) is greater than 0.1, "as a general rule, a consistency ratio of 0.10 or less is considered acceptable…in practice, however, consistency ratios exceeding 0.10 occur frequently " (Karlsson and Ryan, 1997), subjects are given the opportunity to revisit any pair-wise scaling, if they wish to, in the light of the CR. The process is iterated until the subject is content, when it moves on to the next group of pair-wise comparisons (regardless of the value of the consistency ratio). Revisiting of pair-wise comparisons is allowed by Karlsson and Ryan (1997) in their protocols with users.

Relevant comments made during the session are recorded (as an alternative to think aloud, given that my ability to facilitate subject sessions and record simultaneously had improved by this time in the research). At the conclusion of the AHP session, each subject is asked summative questions about the process and the results obtained, in order to obtain contextual information about the subjects' choices and the process itself, to see the extent to which the AHP process has succeeded and to establish reasons for any deficiencies.

In section 3.3.4, card sorting is used to understand how CDR subjects and a geovisualization expert categorise CDR tasks, and in section 4.5.1, how CDR subjects and the same geovisualization expert categorise geovisualization tools and interactions. Card sorting provides a way "discover users' mental model of an information space." (Nielsen and Sano, 1995) By asking the geovisualization expert/developer to repeat the same AHP pair-wise comparison as the two CDR subjects, it is possible to compare the results (both the final ranking of preferences and their consistency) with those of the CDR subjects. The AHP can thus act in a similar way to the card sorting – as a way of determining how similar or different these mental models are. This is of interest because a mismatch between subjects' and geovisualization expert/developer's priorities has the capability to take the development in a direction that, while meeting the geovisualization expert's research aims, fails to meet the expectations the subjects might have for the next round of iteration. Ultimately, a continuing mismatch between geovisualization expert/developer and subjects may result in unfulfilling prototypes or applications and/or a breakdown of the relationship between geovisualization expert/developer and the subjects.

Consequently, a geovisualisation expert/developer, 'D', undertakes the AHP test in its entirety in order to see what differences there are, if any, between the results of the CDR subjects and the geovisualisation expert/developer. 'D' was not told the results of the CDR subjects' AHP sessions beforehand. Since 'D' is a geovisualization expert, a developer and has good knowledge of the CDR subject context, it is necessary to agree the role to be adopted when taking the AHP. After negotiation, the role is clarified as 'a geovisualization expert taking this forward' (that is, not as a geovisualization developer). Subjects took approximately the same time to complete the AHP (C2: 75mins; C3: 70 mins; 'D': 82 mins), indicating a consistent application to the task.

7.2.3 ASCERTAINING DEVELOPMENT COSTS FOR POSSIBLE IMPROVEMENTS

In order to progress approaches that include development costs, these have first to be established. The list of possible improvements (Table 6.5) with detailed description of each was provided to the geovisualization expert/developer ('D') who had created the 'digital lightbox' that was used for the CDR digital interactive prototypes. The developer was also provided with the extracts from the transcripts in order see the shades of meaning and shades of strength with which these requirements are stated, the statistics on which CDR subject suggested what, which prototype was being tested and whether comments were explicit or implicit.

In producing the costs, D believed there were potential dependencies between the development of different possible improvements, even though the improvements themselves were different:

> *“Some of these requests are related ... in that if I do one of them, the other one is easy as it relies upon this work…so If A costs $20 whilst B may cost $22, it actually only costs $2…in even more complex cases that I can imagine, B may cost $5 if I have done A for $20."* [D]

Discussion established that a substantial number of possible improvements were capable of being realised in different ways with varying degrees of functionality for different development resources. **There is therefore not a simple one-to-one correspondence between possible improvement and development required**. Consequently, the developer was asked to provide up to three solutions for each of the 35 possible improvements of increasing functionality and cost, with a description of each 'level' of functionality ('basic', 'intermediate' and 'advanced'). The costs produced and the issues raised by this work are given in section 7.4.

It is possible that an unscrupulous geovisualization expert/developer might conceivably reduce the time costs for 'new-related' (containing novel geovisualization tools) possible improvements to favour these in CDR subjects' cost constrained prioritisation. In order to reduce the chance of this, I examined the costings produced for obvious inconsistencies. There were none.

7.2.4 HUMAN-CENTERED PRIORITISATION UNDER COST CONSTRAINTS

In considering how to establish CDR subjects' possible improvement priorities under cost constraint, I found a reference to the knapsack problem (Burg et al., 1999) that offered the possibility of coping with the issue of dependence between items in the rucksack. This is an issue identified by 'D' (see section 7.2.3):

> "We offer a variation of the *Bounded Knapsack Problem* which involves imposing a cost as well as a weight limit, defining the value of each item by a function that is not necessarily a constant, and allowing a value for an item type *i* to depend on the presence or absence of another item type *j* in the knapsack. The idea is taken from the Oregon Trail computer game, where players are asked to imagine preparing for a trek across the Oregon Trail. In order to make it across country, the travellers need to get good value for the supplies they purchase. They have a given amount of money to spend, and the weight of their supplies cannot exceed the capacity of their wagon."

The algorithm proposed by Burg (1999) is too complex for simple implementation but the reference to the Oregon Trail computer game provides the idea of using a board game component metaphor as the protocol for CDR subjects handling the prioritisation process under constraint in a situation where there are dependencies between the possible improvements to the CDR prototype. These might include choosing between different levels of development, each dependent on former levels being completed first; of developments dependent on a completely different development happening first; and developments that are cost-free once a different development has taken place (see section 7.4)

Prospective users were provided with a fixed amount of toy money and offered cards, each representing an improvement they could “purchase”. Cards had different face values corresponding to the cost in hours of developer time, and with different values of development arranged into one of three levels. Successive levels could only be purchased if earlier level(s) had already been acquired. The card system also permitted interaction complexities to be incorporated in simple way – some cards could only be purchased if another card from a different possible improvement has already been purchased; two cards had messages that the purchase of either would purchase both for the price of one.

'Game cards' (see Figure 7.3 for examples) contained multiple pieces of information:

- 'possible improvement' number (1 to 35)
- short description of possible improvement;
- particular development proposed with outcome
- cost of that development
- card level (1, 2 or 3 – level 2 cards were only available for purchase once the same possible improvement numbered level 1 had been purchased; level 3 only available for purchase when levels 1 and 2 cards had been bought. Different level cards could be quickly identified with different card borders)
- 'special instruction' cards indicated unusual conditions that specified that a card could only be purchased once a differently numbered possible improvement card had been bought, or that the purchase of one card would result in another being given free.

In order to provide a mechanism to embody the constraint on available developer time, the 'toy money' provided for CDR subjects to make 'purchases' of developer time was rationed in order to see developer selections under a range of scarcity situations, initially only 20 pounds (equating to 20 hours or about half a week of developer time) was made available, then a further 15 (a cumulative week of developer time), then a final 35, adding to a total of 70 (a cumulative two weeks of developer time). Figure 7.4 shows a 'knapsack' session in progress.

11 (*Interface*) Allow comparison of current view with selected external comparisons

Users will be able to interactively define external comparisons using text

LEVEL 2 / COST=6

11 (*Interface*) Allow comparison of current view with selected external comparisons

Users will be able to interactively define external comparisons graphically

LEVEL 3 / COST=12 (RISKY)

12 (*Interface*) Base thematic map colours on something other than relativity to crimes in display area

In advance, users will be able to predetermine and select basic options for how thematic map should be coloured, e.g. 'global', 'local', 'this year', 'all years'

LEVEL 1 / COST=2

12 (*Interface*) Base thematic map colours on something other than relativity to crimes in display area

Users will be able to select basic range options for how thematic map should be coloured more flexibly, e.g. from a drop-down menu

LEVEL 2 / COST=4

12 (*Interface*) Base thematic map colours on something other than relativity to crimes in display area

Users will be able to select basic range options for how thematic map should be coloured graphically

LEVEL 3 / COST=12 (RISKY)

13 (*Interface*) Retain the paning and zooming position when changing the display

Provide a graphic to show current location when pan / zoom occur

LEVEL 1 / COST=1 **(BUY THIS - GET No.21/1 FREE)**

13 (*Interface*) Retain the paning and zooming position when changing the display

When views are updated, current window extent (zoom / pan) will be retained

LEVEL 2 / COST=2

14 (*Interface*) Reduce complexity of the system

Application redesign will increase functionality but this time will be spent during development attempting to make this accessible, and to make views and view status evident

LEVEL 1 / COST=1

15 (*Interface*) Reduce difficult in comparing 25-odd glyphs

Glyph "leg" with highest value for each of the times in the glyph (e.g 24 for hours of day) will be coloured bright red . 2nd and 3rd highest will be coloured less prominent red hues. All other "legs" stay as grey.

LEVEL 1 / COST=2

15 (*Interface*) Reduce difficult in comparing 25-odd glyphs

Provide another tool in the design that showed the temporal information aspatially but linked to glyphs (e.g. as a small histogram), allowing user's to see concentrations and to locate them spatially on map via linking

LEVEL 2 / COST=3

35 (*New*) Introduce treemap of crime sub-categories into application

Treemap used as interface for selection of crime categories and treemap colours updated to show numbers of crimes in areas selected on map. Note: may slow application

LEVEL 2 / COST=4

17 (*Interaction*) System to indicate the state of various components with text labels.

System will indicate the state of various components with text labels

LEVEL 1 / COST=1

Figure 7.3: Sample 'improvement cards' that could be purchased by subjects with 'toy money'. Numbers refer to one of the 35 possible improvements whose nature and benefit are given; border indicates 'level' of card (1, 2 or 3); level is also shown on the card plus 'cost'. Some costs are qualified as "risky'; some cards have 'specials' such as the card at bottom left that offers 'buy this, get No21/1 free'

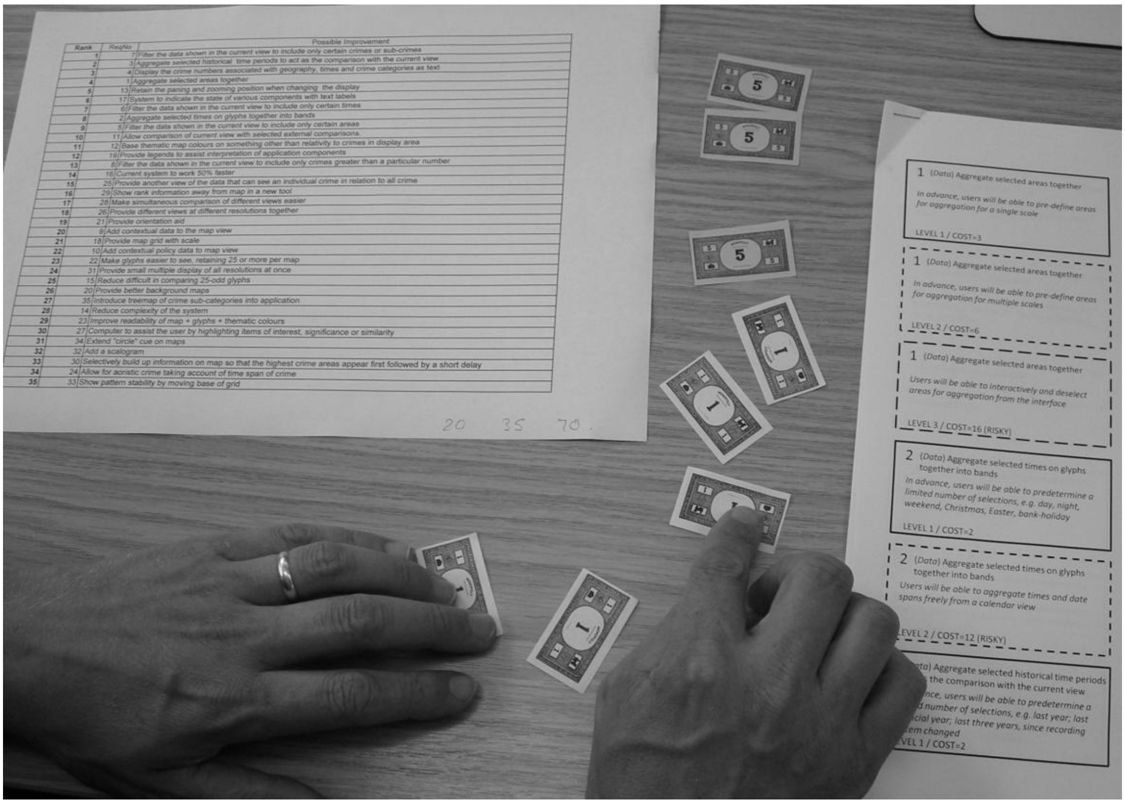

Figure 7.4: Human-centered-modified knapsack selection of development choices in progress. Note (left to right) the list of possible improvements, the 'toy money' and the sheet of 'cards' (Figure 7.3) representing development options.

7.3 RESULTS - ANALYTICAL HIERARCHY PROCESS RESULTS

These results correspond to case numbers 15 – 17 on Table 2.2 (an extract of which is at the start of this chapter).

7.3.1 RESULTS FROM SUBJECT OBSERVATION BEFORE AND DURING AHP

7.3.1.1 CDR SUBJECTS PRE-AHP QUESTIONS

Before starting the AHP exercise, C2 and C3 are invited to ask questions about the process or about the particular possible improvements. Requests for **clarification** of the **meaning** of possible improvements, **terminology** or **capability** dominate. C2 asks about possible improvements 11, 14, 16, 22, 26, 32, 33, 34; C3 about 11, 12, 22, 29, 32. Three queries are common to both users – 11, 22 and 32. 11 concerned the unavailability of external data; 22 concerned the meaning of the word "halo" when describing a technique to surround a feature with a border a few pixels wide to increase contrast over the background; and 32 needed the purpose and use of a "scalogram" to be explained beyond the description given. Neither of the users queried any of the "data related" possible improvements and made only one query each about an "interaction related" one. **New-related** (6 queries from 12 possible improvements) **and in particular**, **interface-related** (5 queries from 6 possible improvements) terms raised the **most queries**, indicating the areas giving the subjects most trouble with understanding. The number of new-related queries resonates with problems communicating geovisualization possibilities to these subjects in the geovisualization lecture (section 4.5).

7.3.1.2 CDR SUBJECTS AND DEVELOPER 'D' DURING AHP SESSION

The researcher recorded comments from CDR users C2 and C3, made as they undertook the AHP. The geovisualization expert developer 'D' was told that his comments would be noted during the course of the AHP but gave a ' think aloud' narrative without being prompted. Comments from D are therefore considerably more voluminous than from the two CDR users and in retrospect, it may have been worth explicitly asking for a 'think aloud' from all the users. Verbal information from users fell into a number of categories related to:

- the AHP **process** itself;
- **privileged knowledge** about development possibilities available to D but not available at the time of the AHP test to the CDR users;
- uncertainties or difficulties in **differentiating** between possible improvements;
- **consistency** or contradiction concerns; and
- **prior preferences** for particular improvements.

AHP Process

D comments at one point that "the whole process depends on interpretation of the words" and at another point that he liked the "first half of the [possible improvement] description, but not the second". While words can be a problematic medium, comments like this and the fact that CDR subjects asked pre-AHP questions about terminology, may point to a fundamental **issue concerning communicating potentially complex notions about visualization in verbal form**. 95% of visualization students are introduced to visualization tools and interaction through practical exercises (Kerren, Stasko and Dykes, 2008). Communicating information about visualization possibilities through words alone - particularly to prospective users who have shown themselves uninterested in visualization per se (see section 4.5.2) - may be inappropriate for such a complex domain. But therein lies a paradox. If a possible improvement can only be conveyed inadequately using words, and requires its realisation before it can be fully understood and appreciated, then visualization-naïve users may not be informed enough to express their preferences, given that the stated problem that resource limitations do not permit all possibilities to be realised. As has been stated in other chapters of this research, alternative approaches to communicating to subjects need consideration.

Privileged knowledge

D is concerned initially about whether he could complete the AHP task by putting aside his knowledge of the time costs of implementing individual possible improvements. At three points during the AHP, D indicates a preference influenced by privileged knowledge of likely development costs. In the first, he says "I think I am reacting against this…I am aware of its development cost – or perhaps [it is because] I don't use it myself." Secondly, when faced with a pairwise choice involving the number of glyphs, he comments "I think 25 [glyphs] is the best I can do, so I`m going for the other [choice]", and finally at the very end of the AHP process: "It is really hard to separate out the development bit – that this is challenging my thinking". showing that developer considerations are playing a part in D`s comparisons.

Differentiating between choices

Both D and C2 appeared to be concerned about being unable to differentiate between a number of pairwise comparisons (that is, giving a "1" as an AHP score) when encountering a 'run' of these. "Quite a few ones" comments D, when three out of a run of seven scores had been a one in the "data-related" group. Two thirds of the way through the "new-related" section of the AHP, C2 described the situation as "not differentiating very much", having just scored the last four pairwise comparisons as a "one". C2 represented the "new-related" group as "like being in a toy shop [wanting] everything, and it was difficult to differentiate". This caused C2 to score within a limited range of numbers on the AHP scale. C2 stated that they completed the "new" group of pair-wise choices" by consciously trying to differentiate more", but in fact the range for the final third of "new" had much the same range as the first two thirds. Despite these apparent difficulties – or perhaps because of them, C2 had the lowest consistency ratio for the "new-related" group between the three users. For one of the interface-related pairwise comparisons, D commented "this is really hard – I have no idea" – but was able to decide on a pair-wise score eventually.

Consistency

As part of the protocol, users are shown their rankings and consistency ratio after each group had been completed both to encourage their on-going participation in the process with instant feedback, and as a check that no errors had been made and comparisons missed. Where the CR was unduly high, users are given the opportunity to review their comparisons scores for errors and amend any discovered. Only one instance of this happened when C3 changed a "five" to a "three" in the "new-related" group. That changed C3' s CR for "new" from 0.70 to 0.69, an insignificant change.

D makes a number of comments about consistency:

- *"I find myself looking back at what I've done before." (data-related)*
- *"I think I'm producing a list in my head and being consistent with it," (data-related)*
- *D enters a pair-wise score and then changes it, "to be consistent" (data-related)*
- *"It is really hard to be consistent" [changing a previous "six" score to a "three"] (data-related)*
- *"I go through phases of liking that and not liking it" (data-related)*
- *"I`m getting more extreme" [in the scores given] (data-related)*
- *"going through the process makes you think and you change your mind" (data-related)*
- *"Surprised I'm that consistent" [on seeing CR of 0.16 for "Data-related" group]*
- *" with the "new" worksheet I'm being more extreme in my marking ("new-related)*

Noticing a tendency to look back at previous pairwise comparisons (that prompted the possibility of thinking about consistency), D adopts the device of scrolling all but the current pair-wise comparison off the screen. This highlights an additional variable in the experiment (with/without access to previous pair-wise comparisons) that had not been adequately controlled for in the protocol. However, since subjects have the opportunity to review their pair-wise comparisons after seeing their AHP rankings and consistency scores in any case, the effect of seeing/not seeing previous pair-wise comparisons is probably small.

Prior preferences

D makes a number of comments during the AHP, some of which are useful in eliciting preferences for the direction of the prototype, and some are indicative of the conflicts inherent in combining the roles of geovisualization researcher and geovisualization developer. Both are interesting as they expose thinking about the building of geovisualization applications by a geovisualization developer that go unrecorded elsewhere in the literature.

- *"I want both of these to score well." (data-related)*
- *"I still think the contextual thing is important." (data- related)*
- *"give people data and let them think about it." [on a "six" scoring] (data-related)*
- *"I think crime’s more important that time…[pause]… probably” (data-related)*
- *"I'm pretty strongly in favour of that one," [on a "six" scoring] (data-related)*
- *"I think select is more important than aggregate." (data-related)*
- *"I think that is really important, but I’d do that in colour" (interface-related)*
- *"sometimes the standard cartographic stuff is important...[musing]… I think we have to do this grid, even though it's boring." (interaction-related)*

- *"I like treemaps" (new-related)*
- *"a scalogram might help them" (new-related)*
- *"I extremely favour that one [in relation to the comparison]" (on a "nine" scoring in favour of treemaps) (new-related)*
- *"I think interface[-related] is less important" (group-related)*
- *"I don`t think interactions are so important" (group-related)*
  - *"some of this filtering, they could do visually so I'm going to give it a low score." (data-related)*
  - *"it's not just the system going faster. I want this to be …usable…I'm going to bank on it being quick enough." (interface-related)*
  - *"I don`t care about this 50% [faster] thing any more" [on a "seven" scoring]*
  - *"I don't want to write a GIS for [CDR] and it doesn't take forward some of these [geovisualization] techniques that we think might be useful" (group-related)*

7.3.2 AHP SESSION RESULTS

In the preface to section 6.3.1, I refer to the necessarily small number of subjects in the study and express a caution about the extent to which results may be generalised (even when statistically significant). This same caution must also apply to the results from this AHP work. As has been said in section 6.3.1, while suggestive, the results below can be more widely generalised only when they form part of a broader consideration, set alongside the work of other researchers conducting similar studies of human-centered approaches for geovisualization (or information visualization) in conjunction with subjects from different domains.

The results of the AHP sessions for CDR subjects C2 and C3 and geovisualization developer D are shown in Table 7.2 giving each possible improvement as a percentage score (out of 100%) and its rank out of the 35 possible improvements. Figure 7.5 shows CDR subjects and geovisualization designer D's rankings as parallel plot multiples, conditioned by improvement group. From Figure 7.5, it is clear that the CDR subjects' priorities are skewed towards 'data related' improvements and against 'new' items. D's priorities are more evenly distributed, and incline towards 'interaction related' and against 'interface related' choices. Comparing the overall ranking produced by the two CDR subjects and developer D, there are marked similarities in the rankings of the 35 possible improvements prioritised by the two CDR subjects (Pearson coefficient 0.50, significant at 0.01 level; 2 tailed, n=35). Developer D does not rank the improvements in a similar way to either C2 or C3 as indicated by non-significant Pearson coefficients (D v C2 coefficient: 0.29; D v C3: 0.25, neither significant at 0.05 level; 2 tailed, n=35).

As the AHP is concluded by undertaking between-category comparisons of the four categories (data-related, interface-related, interaction-related and new-related), it is possible to examine the category consistency ratios (CR) for the three subjects. This is shown in Table 7.3. (Saaty, 1980) considers an AHP 'consistency ratio' of < 0.1 acceptable; "in practice, however, consistency ratios exceeding 0.10 occur frequently" (Karlsson and Ryan, 1997). Those achieved here range from 0.03 to 0.21 for data-, interface- and interaction-related possible improvements, but the **consistency ratio results from the 'new-related' group are noticeably less consistent**, ranging from 0.43 to 0.69. C2 is more consistent than the others throughout.

No	Possible Improvement	C2 %	C2 rank	C3 %	C3 rank	D %	D rank	
1	Aggregate selected areas together	4.57	7	6.60	4	1.05	29	data-related
2	Aggregate selected times on glyphs together into bands	3.84	9	3.45	8	2.12	18	
3	Aggregate selected historical time periods to act as the comparison with the current view	7.04	1	11.16	2	2.73	14	
4	Display the crime numbers associated with geography, times and crime categories as text	2.57	17	9.68	3	5.06	7	
5	Filter the data shown in the current view to include only certain areas	5.06	2	2.97	9	1.69	21	
6	Filter the data shown in the current view to include only certain times	4.78	5	4.91	7	4.53	9	
7	Filter the data shown in the current view to include only certain crimes or sub-crimes	4.84	4	12.31	1	6.23	4	
8	Filter the data shown in the current view to include only crimes greater than a particular number	2.37	20	2.42	13	1.12	27	
9	Add contextual data to the map view	1.45	30	1.77	20	1.38	24	
10	Add contextual policy data to map view	1.44	31	1.71	22	1.33	25	
11	Allow comparison of current view with selected external comparisons.	0.85	34	2.94	10	1.02	30	interface-related
12	Base thematic map colours on something other than relativity to crimes in display area	2.19	23	2.76	11	1.09	28	
13	Retain the paning and zooming position when changing the display	3.65	10	5.08	5	1.60	22	
14	Reduce complexity of the system	1.55	29	0.95	28	2.40	15	
15	Reduce difficult in comparing 25-odd glyphs	3.40	11	1.15	25	0.26	35	
16	Current system to work 50% faster	2.63	15	2.36	14	0.42	34	
17	System to indicate the state of various components with text labels	2.68	14	4.98	6	9.95	1	interaction-related
18	Provide map grid with scale	4.63	6	1.75	21	4.61	8	
19	Provide legends to assist interpretation of application components	2.17	25	2.63	12	8.00	2	
20	Provide better background maps	1.38	32	1.07	26	1.54	23	
21	Provide orientation aid	4.25	8	1.79	19	2.99	13	
22	Make glyphs easier to see, retaining 25 or more per map	4.96	3	1.60	23	3.31	11	
23	Improve readability of map + glyphs + thematic colours	3.14	12	0.82	29	5.50	6	
24	Allow for aoristic crime taking account of time span of crime	2.10	26	0.42	34	0.79	31	new-related
25	Provide another view of the data that can see an individual crime in relation to all crime	2.46	19	2.27	15	2.39	16	
26	Provide different views at different resolutions together	1.56	28	1.81	18	1.78	20	
27	Computer to assist the user by highlighting items of interest, significance or similarity	0.83	35	0.63	30	3.05	12	
28	Make simultaneous comparison of different views easier	2.30	21	1.82	17	6.55	3	
29	Show rank information away from map in a new tool	2.86	13	2.09	16	3.56	10	
30	Selectively build up information on map so that the highest crime areas appear first followed by a short delay	1.07	33	0.43	33	0.49	33	
31	Provide small multiple display of all resolutions at once	1.84	27	1.32	24	1.21	26	
32	Add a scalogram	2.19	24	0.43	32	1.92	19	
33	Show pattern stability by moving base of grid	2.61	16	0.34	35	0.60	32	
34	Extend "circle" cue on maps	2.54	18	0.52	31	2.21	17	
35	Introduce treemap of crime sub-categories into application	2.20	22	1.06	27	5.52	5	

Table 7.2: Results of the AHP sessions for C2 and C3 and geovisualization developer D. Each possible improvement is given as a percentage score (out of 100%) and its rank out of the 35 possible improvements (1=highest; 35=lowest).

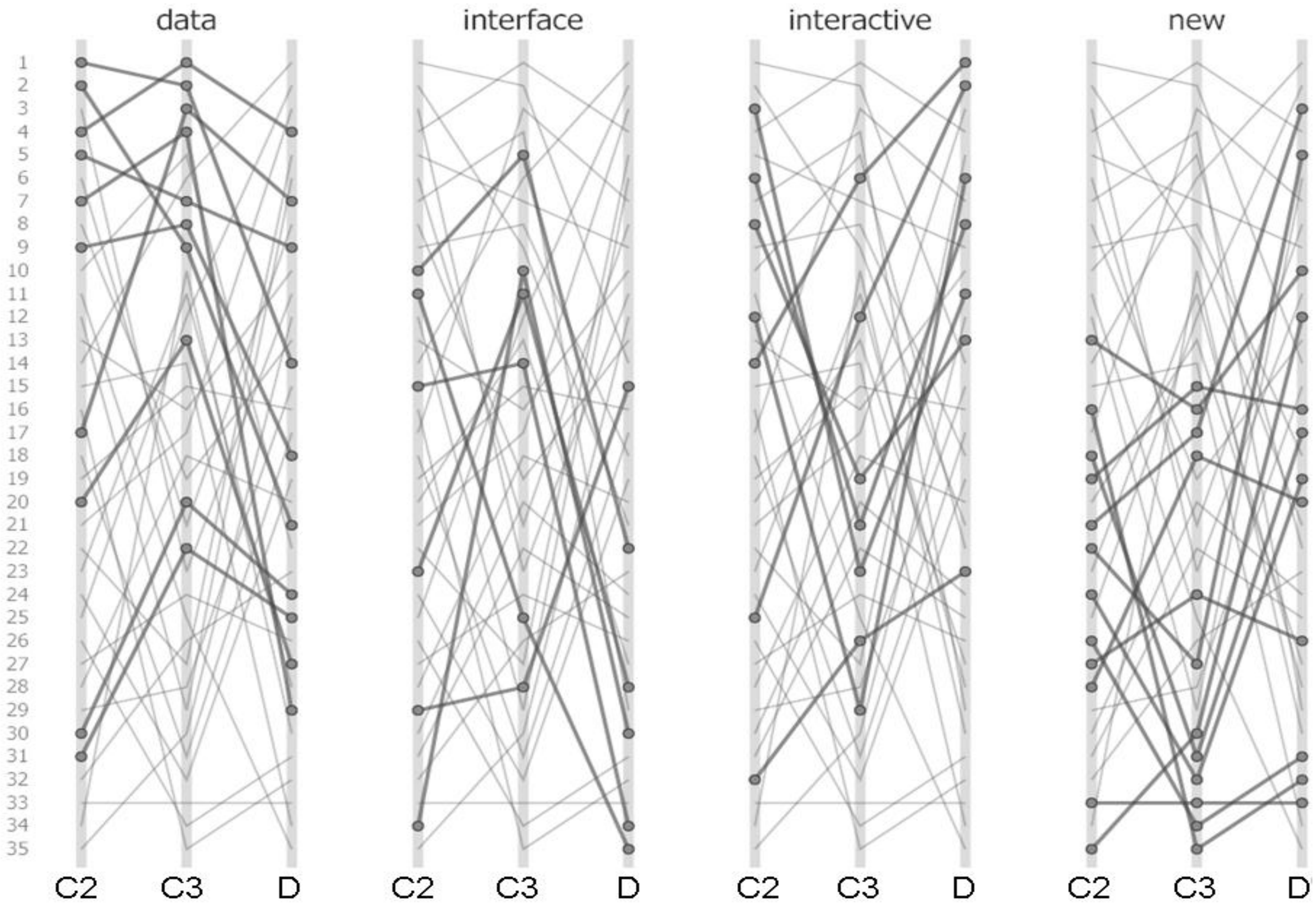

Figure 7.5: Parallel plot multiples of candidate improvements ranked 1 (top) to 35 (bottom), for each category of possible improvement to the CDR prototype: 'data' (10 listed improvements), 'interface' (6), 'interactive' (7) and 'new' (12). AHP rankings for two CDR crime analyst subjects (C2 and C3) and geovisualization expert/developer (D) are shown left to right within each plot. Derived from Lloyd, Dykes and Radburn (2009b)

User \ Group	'data'	'interface'	'interaction'	'new'	between group
CDR subject C2	0.03	0.09	0.04	0.49	0.07
CDR subject C3	0.06	0.20	0.21	0.69	0.06
Developer D	0.16	0.10	0.21	0.43	0.04

Table 7.3: AHP consistency ratios for the four different goups of the 35 possible improvements (data-related, interface-related, interaction-related and new-related) and the final between-group comparison.

It is possible to arrange the percentage scores for the 35 possible improvements in the form of a Lorenz curve (Lorenz, 1905), and then calculate the Gini coefficient (Gini, 1912) to assess the dispersion of each subject's prioritised percentage scores obtained from the AHP. To illustrate this, Figure 7.6 shows the layout of the 35 possible improvements to create the Lorenz curve and indicates how the Gini coefficient is calculated for one of the subjects.

C2's relative preferences across the 35 possible improvements are not as strong as those of C3 and D, as measured by the Gini coefficient - C2: 0.27; C3: 0.48; D: 0.42. That is, C2's dispersion is lower.

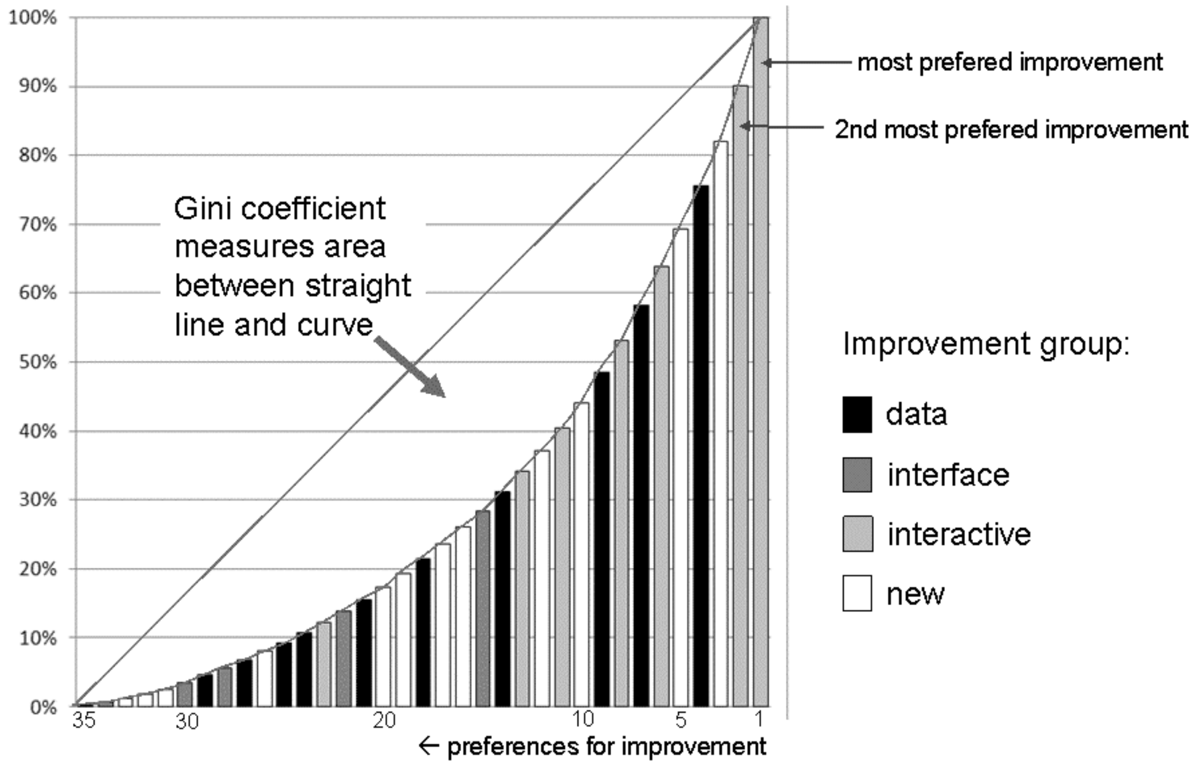

Figure 7.6: Sample layout of the 35 possible improvements to create the Lorenz curve and indicate how the Gini coefficient is calculated for the data for one of the subjects

The 35 possible improvements had their origin in 332 suggestions made by C1, C2 and C3 as part of the prototyping sessions (see section 6.2.4.1). It is useful to explore what kind of link, if any, there is between a particular suggestion made by a subject and the rank the possible improvement based on that suggestion attains in the subject's AHP. This is of interest because if 'often mentioned' suggestions become 'highly ranked' possible improvements, then the AHP process might be wholly or partially redundant. Table 7.4 shows, for C2 and C3, the AHP rank of each of the 35 possible improvements alongside the rank of how often a suggestion that led to that possible improvement was mentioned by the subject during the prototyping sessions described in Chapter 6. Simple scatterplots of one against the other (not reproduced here) reveal that there is no discernable relationship between either subject's AHP ranking and its ranking in number of suggestions made in prototyping. Tellingly, CDR subject C3 ranked new-related possible improvements the lowest in the AHP, but was the highest suggestor of 'new related' improvements in the prototyping sessions (see section 6.3, Table 6.9).

The implications from this are that perhaps subject suggestions during prototyping should be taken as just that – suggestions. **Until they are refined and prioritised in some way, suggestions should not be regarded as requirements for a developer to build into the next iteration**. However, such **refining and prioritisation need not be conducted as the lengthy aggregation of suggestions coupled to a decision-making process such as the AHP**, **but could be more informal**.

No	Possible Improvement	C2 AHP rank	C2 rank of number of suggestions	C3 AHP rank	C3 rank of number of suggestions
1	Aggregate selected areas together	7	18	4	8
2	Aggregate selected times on glyphs together into bands	9	18	8	3
3	Aggregate selected historical time periods to act as the comparison with the current view	1	13	2	22
4	Display the crime numbers associated with geography, times and crime categories as text	17	3	3	3
5	Filter the data shown in the current view to include only certain areas	2	18	9	20
6	Filter the data shown in the current view to include only certain times	5	10	7	10
7	Filter the data shown in the current view to include only certain crimes or sub-crimes	4	18	1	32
8	Filter the data shown in the current view to include only crimes greater than a particular number	20	10	13	15
9	Add contextual data to the map view	30	2	20	3
10	Add contextual policy data to map view	31	18	22	22
11	Allow comparison of current view with selected external comparisons.	34	18	10	32
12	Base thematic map colours on something other than relativity to crimes in display area	23	13	11	22
13	Retain the paning and zooming position when changing the	10	18	5	22
14	Reduce complexity of the system	29	18	28	3
15	Reduce difficult in comparing 25-odd glyphs	11	18	25	10
16	Current system to work 50% faster	15	13	14	15
17	System to indicate the state of various components with text	14	13	6	32
18	Provide map grid with scale	6	18	21	15
19	Provide legends to assist interpretation of application	25	1	12	1
20	Provide better background maps	32	7	26	7
21	Provide orientation aid	8	18	19	15
22	Make glyphs easier to see, retaining 25 or more per map	3	7	23	8
23	Improve readability of map + glyphs + thematic colours	12	4	29	14
24	Allow for aoristic crime taking account of time span of crime	26	18	34	22
25	Provide another view of the data that can see an individual crime in relation to all crime	19	18	15	22
26	Provide different views at different resolutions together	28	18	18	10
27	Computer to assist the user by highlighting items of interest, significance or similarity	35	9	30	20
28	Make simultaneous comparison of different views easier	21	4	17	2
29	Show rank information away from map in a new tool	13	18	16	22
30	Selectively build up information on map so that the highest crime areas appear first followed by a short delay	33	18	33	22
31	Provide small multiple display of all resolutions at once	27	13	24	32
32	Add a scalogram	24	18	32	22
33	Show pattern stability by moving base of grid	16	18	35	22
34	Extend "circle" cue on maps	18	10	31	15
35	Introduce treemap of crime sub-categories into application	22	4	27	10

Table 7.4: AHP rank of each of the 35 possible improvements alongside the rank of how often a suggestion that led to that possible improvement was mentioned by the subject during the prototyping sessions, for subject C2 and C3

7.3.3 SUMMATIVE QUESTIONS AFTER AHP SESSION

After completion of the AHP, the CDR subjects were asked a small number of questions, individually, about their experience of the AHP process and their results, to provide additional evidence. A paper-based questionnaire approach was not used as subjects had spent about two hours in the AHP session and it was possible only superficial or incomplete responses might have resulted due to fatigue. Subject responses to the verbal questions were audio recorded and later transcribed for analysis.

AHP Methodology

The CDR subjects were reasonably content with the descriptions of the 35 possible improvements provided, although **C2 felt that virtually all of the "new-related" group needed** the **additional verbal explanation** that had been offered prior to starting the AHP.

> *"I went through the first three lists [data, interface, interaction] and understood them relatively well, and I highlighted a couple…where I wasn't quite sure… But when it came to the new ones, you needed to explain all of those, just about, to me" (C2)*

Speaking about the AHP process, C3 comments:

> *"You get more confident with it. It helped to start with the more tangible ones - the "Data" ones -you have got tangible outcomes - you know what you are going to get, and you can compare the two more easily.* ***When it came to the "new" developments maybe it would not be that clear how you would apply them - it is a lot more difficult to compare.****" (my emphasis)*

Clearly, both C2 and C3 have had difficulties with the "new-related" possible improvements that include novel geovisualization tools.

During the progress of the AHP, subjects had access to a "crib sheet", sent to them a week in advance that gave a description of each possible improvement. I noticed one CDR subject had placed pencil tick marks, and the other CDR user a number of small pencil dots, against some of the possible improvements. I asked what these ticks and dots meant and whether they influenced the pair-wise comparisons:

> *"I started off by just ticking off the ones I understood your description of the possible improvement….[but] it was a comparison to keep the consistency more than to drive a particular one up above the others. (C2)*
> *"You get a feeling for what you think might be more useful…I didn't refer to that, really. I looked at it [sometimes] and thought 'why did I put a dot by that one?'" (C3)*

The provision of the list of possible improvements in advance does not appear to have led the CDR subjects to manipulate the AHP process in a material way.

There is some evidence that the AHP was tedious for some subjects to complete but not others:

> *"It was about right, and I think the key to it is… the title of [possible] improvement that comes up on the screen… if you get clear on what those mean before you start you can get through it a lot easier. If you were relying on looking at these [descriptions] every time, you would be there forever." (C3)*
> *"when we got to the last [group]…it was quite hard: 1) because you had to explain every single one, and I had to keep all that in my brain; and 2) it was the last [category] - it was all new concepts…It was a little more difficult than the others. But it made me consider each one of them." (C2)*
> *"It is incredibly convoluted, isn't it? …It was painful to do. I didn't enjoy doing it… But I'm glad [I] did that [the AHP exercise], I thought that was an interesting process." (D)*

If the AHP is used in future by geovisualization researchers, a reduced list of possible improvements to the one employed here (and hence reduced pair-wise comparisons) would be less demanding.

These results provide **good evidence** that the AHP process is acceptable to these subjects, if a little too long in the number of pair-wise comparisons required.

AHP Results

Asked whether the subjects felt they were achieving consistency, C2 stated explicitly that achieving consistency was an underlying motivating factor:

> *"I was definitely aware of what had come before, and I liked some things a lot more than others. And I wanted that consistency to be there" (C2)*

C3 claimed to be achieving consistency and was interested in looking at the consistency ratio achieved:

> *"you may be conscious of being consistent with those ones that you don't know about, but at the same time you can't remember what you have put further up the list anyway. Looking at the consistency score at the end was interesting to see whether or not it was." (C3)*

Asked whether their AHP ranking had placed different possible improvements where users would have placed them if left to their own devices, C2, C3 and the D all believed the AHP had put things at the top that they would have put at the top and similarly with improvements at the bottom of the rankings. C3 thought the ranking a "*good reflection*" and commented that *such a ranking without AHP would have taken "a considerably longer period of time".* D expected *"the exciting stuff*" – taken to be the "new-related" possible improvements – to appear "*mid-way down - like 7 to 15 [in D's ranking]*" In fact, they are more dispersed, at ranks

3, 5, 10, 12, 16, 17, 19, 20, 26, and 31-3. D comments that "*The stuff right at the bottom is …related to loads of… different things, or happened implicitly, or I have decided isn't really important...The four or five things that I don't think are worth having are at the bottom of the list.*" The appearance of a number of different possible improvements concerned with filtering at ranks 4, 9, 21 and 27 surprised D who nevertheless thought it "*reflected the ordering of those four filtering techniques that I have decided upon today"* then added "*whether I'd decide upon a different ordering tomorrow, I don't know.*" On another possible improvement theme related to enhanced background maps (numbers 9, 10 & 20) that came out together at ranks 23-25, D related that "*I didn't think very consistently about that, so I can't quite see why those things have come out of this*." Given that these three possible improvements come from different groups within the AHP, this is perhaps an example where D's thoughts about (lack of) consistency are confounded by the workings of the AHP producing results like these.

Differences between C2 and C3 emerge when considering the basis for pair-wise scoring of the four different categories of possible improvements at the conclusion of the AHP. C2 scored based on the overall name given to each group:

> *"the fact that you have given them a label [“Data”, “Interface” etc]… I measured it on the label… rather than maybe completely considering what was underlined that label. …because it categorised it, [it] made it simpler for me to [think] 'if we don't get the “Data” section right… the rest will be a waste of time'. So that has got to be my number one." [C2]*

C3 considers the component possible improvements within the group when scoring and did not rely on the group name. Given that C2 and C3 had statistically similar rankings overall, this difference in approach has not made a difference although the protocol should have emphasised a common approach.

When asked if any particular possible improvements came out unexpectedly high or low. While C2 answered "*no*", both C3 and D commented on "*current system to work 50% faster*" (C3 rank: 14; D rank: 34). Both had clearly found the notion of trading system speed against functionality a difficult one.

> *"system performance is always a trade off of something else. So it would not be a criteria that I would maybe work towards on its own… I would rather have more functionality and have it run a bit slower." [C3]*
> *"the 50% thing is something I was forced to make a decision on….if you said to me: 'Should your system be 50% faster?', I would say “definitely! But I have made an active decision there, that it is fast enough and that it will do, as part of this process. So I don't think that is a surprise, but that is something new." [D]*

The explicit introduction of a system variable such as speed of response as a trade-off for functionality is plainly a useful comparitor for potential users of a visualization application to consider.

Continuing the theme of whether subjects considered any particular possible improvements ranked unexpectedly high or low, D commented that ‘make simultaneous comparison of different views easier’ (ranked third) was '*interpreted that in all sorts of different ways when I have been doing this, so I am a bit uneasy about that one being up there.'* **This echoes the issue concerning communicating potentially complex notions about visualization in verbal form** evident from comments made by the subjects pre- and during-AHP (section 7.3.1.2).

C3 comments on the low ranking (27) given to incorporating the treemap into the application. C3 may perceive the treemap may be as an object of researcher attachment (see Chapter 1.3.1 on this - Cooper (1999) and Cohen et al (2004)). But this lowly ranking is not an error as C3 goes on to emphasise: "*when you start looking at where it is, and maybe what is around it, then, you realise why it is there*."

D highlights a single possible improvement that had appeared "*unexpected low*": 'base thematic map colours on something other than relative to crimes in display area', saying:

> *"I think that is probably something quite important. I don't know why I had a 'downer' on that. I want to be able to do that, really. But it seemed to be covered by one of the other solutions, which was about comparison in the same set of questions." (D)*

This hints at the "fuzzy" nature of the final set of 35 possible improvements, derived as they are from an original 332 suggestions from the CDR subjects, and to consequent overlapping functionality (see section 6.2.41).

I asked subjects if they saw any particular pattern to the possible improvements that they ranked particularly highly or lowly. C3 was emphatic that there was, and that the highly ranked possible improvements were 'data related'. C2 said "*The logic for me is to have a basic system that does the bread and butter well, and then some added gems in there…that is the basis for why I have chosen what I have chosen*." D linked highly ranked items as "*fundamental to interpreting information*".

Subjects were asked how content they were that their final ranking should be the basis on which the developer should prioritise. C2's concern centered around lack of knowledge of the visualization tools: "*I suppose there's some kind of faith to lie with the developer … you have explained how some of these tools might be used…and [you have] to know what you are doing. I have not used any of these, so* ***it is a guess on the back of what you are telling me. So I have to have faith in the developer***." [my emphasis]

C3 was satisfied with the AHP ranking and pragmatic about implementation:

> *"everything has its price… yes, these are based on what I'm going to benefit from, from a working perspective. But there are going to be a limited number of these developments that we can have….I would be happy with this stuff at the top [of the ranking list]….common sense stuff… you couldn't do it without those top few anyway. The bottom ones would be kind of worthless without the basic functionality anyway….if you stuck to the bottom few, you might be able to do some kind of fantastic analysis and delve into the data, but you would not be able to back that up with anything simple or commonsensical, because you wouldn't have the tools to do it."*

D's reply cannot be disentangled from the fact that any development would fall to him, but:

> *"Quite truthfully?… I am reasonably happy with this. But…* ***for the ones that were going to be done I would want quite a lot of discussion over what it really meant****. So I think, that is a difficulty….I might drop a few things down a bit in certain places, but I think it is reasonable. And I think it is very difficult - because these things were related, and they can be interpreted in multiple ways - I think it is a really hard thing to do. And…although this was difficult, and I didn't enjoy it that much, what we have come out with is something that is credible. I never can be perfectly happy with this, because it is a very difficult thing to do."*

D expresses a desire for clarity before starting development work – "*the ones that were going to be done I would want quite a lot of discussion over what it really meant.*" C2 says that the understanding of the proposed tools is "*a guess on the back of what you are telling me"* and "*I have to have faith in the developer*." These are interesting statements given what has gone before in terms of extensive engagement with these CDR subjects over nearly three years to eliciting these possible improvements through many different approaches. The AHP may provide both CDR subjects and D with a ranking that each party considers reasonable, but its apparent ability to prioritise and to capture measures of consistency nevertheless does not provide C2 and developer D with confidence in a concluded dialogue. C2 does not fully understand the tools and comments "*I have to have faith in the developer*"; developer D wants *'quite a lot of discussion'* about what it *really* meant by the list of 35 possible improvements.

After three years, these statements provide **further evidence** to support what appears to be an emerging theme of this research **of the difficulty of communicating geovisualization to potential users, and from these potential users to the geovisualization developer.**

This concludes the work using the AHP and the next section considers the costing of possible improvements by a geovisualization developer.

7.4 RESULTS - COSTING OF POSSIBLE IMPROVEMENTS

The 35 possible improvements that have arisen from considering suggested improvements made during CDR prototyping sessions form the basis for a developer to work up estimates of the time needed to implement these. But these are far from the well-specified, complete and 'signed off' requirements that a professional developer might expect to receive before commencing work. They contain many ambiguities, do not precisely specify outcomes, are not scoped to constrain development to a particular facet or facets of the proposed improvement, and they are vaguely worded. This reflects the reality of the origin of these possible improvements. They do not derive from a standard 'requirements process' – Chapter 4 establishes that a standard approach to establishing requirements, the Volere template, does not work for subjects for whom geovisualization represents 'undreamed of' requirements (Robertson, 2001).

With this in mind, it should not be surprising that the **inputs of ambiguity, vagueness and lack of specificity are manifest in the outputs of the geovisualization developer**. Table 7.5 gives developer D's estimates of cost (in developer hours) to provide functionality for each possible improvement to CDR prototype.

Rather than a neat list of 35 costs for 35 improvements, the developer includes additional elements to indicate the complexities inherent in the process of determining costs, and indicates reservations, possibilities and difficulties in various ways.

Cat	No	Possible Improvement	Level 1	Level 2	Level 3
DATA-RELATED	1	Aggregate selected areas together	3	6	16r
	2	Aggregate selected times on glyphs together into bands	2	12r	
	3	Aggregate selected historical time periods to act as the comparison with the current view	2	12r	
	4	Display the crime numbers associated with geography, times and crime categories as text	1	3	
	5	Filter the data shown in the current view to include only certain areas	3	8	18
	6	Filter the data shown in the current view to include only certain times	2	2	12
	7	Filter the data shown in the current view to include only certain crimes or sub-crimes	3	8	
	8	Filter the data shown in the current view to include only crimes greater than a particular number	1	3	
	9	Add contextual data to the map view	1		
	10	Add contextual policy data to map view	1	4	18r
INTERFACE-RELATED	11	Allow comparison of current view with selected external comparisons.	2	6	12r
	12	Base thematic map colours on something other than relativity to crimes in display area	2	4	12r
	13	Retain the paning and zooming position when changing the display	1x	2	
	14	Reduce complexity of the system	1		
	15	Reduce difficult in comparing 25-odd glyphs	2	3	
	16	Current system to work 50% faster			
INTERACTION-RELATED	17	System to indicate the state of various components with text labels	1		
	18	Provide map grid with scale	1		
	19a	Provide legends to assist interpretation of application components	2		
	19b		1	2	
	20	Provide better background maps	1	6	
	21	Provide orientation aid	1x		
	22a	Make glyphs easier to see, retaining 25 or more per map	1		
	22b		1	2	
	23a	Improve readability of map + glyphs + thematic colours	2		
	23b		3		
NEW-RELATED	24	Allow for aoristic crime taking account of time span of crime	3		
	25	Provide another view of the data that can see an individual crime in relation to all crime	1	4	8
	26	Provide different views at different resolutions together	2	6	18r
	27	Computer to assist the user by highlighting of interest, significance or similarity	2	4	
	28	Make simultaneous comparison of different views easier	4	8	
	29	Show rank information away from map in a new tool			5x
	30	Selectively build up information on map so that the highest crime areas appear first followed by a short delay	1	2	3
	31	Provide small multiple display of all resolutions at once	2		
	32	Add a scalogram	3	6	
	33	Show pattern stability by moving base of grid	1	2	3
	34	Extend "circle" cue on maps	2	4	
	35	Introduce treemap of crime sub-categories into application	2	4	

Table 7.5: Developer 'D' estimates of cost (developer hours) to provide functionality for each possible improvement. 'r' = risky' 'x'=dependency on another possible improvement

The developer tackles much of the complexity by offering to provide different 'levels' of development for the majority of the possible improvements – ten have three possible levels; another fifteen have two levels (in discussion with the developer prior to the work beginning when this issue was raised, we agreed that options would be confined to a maximum of three levels). Additional elements incorporated by the developer include:

- offering two different ways to achieve the possible improvement that implies two different development pathways for three possible improvement 19, 22 and 23. These are split into two as a consequence – 19a and 19b, 22a and 22b; 23a and 23b.
- identifying 'risky' developments – ones with less certainty of achieving the desired outcome, indicated by an 'r' as an indication of uncertainty
- indicating a dependency on another potential improvement – shown with an 'x':
  - possible improvement 29 is dependent on the development of the first two levels of development of potential improvement 20
  - possible improvement 21 is achieved if the first level of possible improvement 13 is developed beforehand (or *vice versa*)
- not providing a cost for possible improvement 16 "Current system to work faster" as this would entail a move to lower level coding with new learning required and a very large investment in time and therefore cost. Essentially, this possible improvement is not achievable within the current architecture and the 'cost' would be prohibitive.

The geovisualization literature is silent about the process of design (section 5.2.1). The geovisualization literature is also silent about the process of iterative development in the face of vague and ambiguous subject input on possible improvements. **I commend geovisualization developers to expose such processes where possible for the benefit of other researchers**.

7.5 RESULTS – USING KARLSSON & RYAN PLOTS TO DETERMINE PRIORITIES

These results correspond to case number 18 on Table 2.2 (an extract of which is at the start of this chapter).

The ambiguity in the developer output creates challenges for the use of the Karlsson and Ryan method of plotting value versus cost and inspecting it to lead to a prioritisation of AHP results without returning to the subjects for further input. With the cost information from the geovisualization developer provided as a series of levels and with various complexities (dependencies, uncertainties, joint and multiple development pathways), decisions need to be taken as to how to present this information on the cost axis of the Karlsson and Ryan plot. Pragmatically, the approach is to:

- ignore the expressions of risk
- ignore the joint development that permits one improvement to be developed at no cost if another is developed first
- split possible improvements where there are multiple development pathways (from 19 to 19a and 19b, for example)
- provide for multiple levels by including them as the cumulative cost of developing them on the plot
- do the same where there are dependences on another possible improvement.

This enables the Karlsson and Ryan plots of value (the percentage each possible improvement is of the total 100%, derived from the AHP (Table7.2)) versus cost (in developer hours) (Table 7.5) to be drawn. For C2, Figure 7.7 shows the AHP-derived Value v Cost plot emphasising the different levels of development, and Figure 7.8 AHP-derived Value v Cost emphasising the category of possible improvement. For C3, the corresponding plots are Figure 7.9 and 7.10, respectively. For geovisualization developer D, the corresponding plots are Figure 7.11 and 7.12, respectively. Karlsson and Ryan's inspection method to determine priorities consists of drawing lines from the origin in order to delineated three areas. These are high value/low cost (= 'High' potential for development), low value/high cost (= 'Low' potential for development), plus an intermediate area (= 'Medium' potential for development). These lines are drawn on Figures 7.7 to 7.12 to delineate the three areas so each contains an equal number of possible improvements (including ones at multiple level). The lines do not extend to the crowded origin area to aid clarity. Note that some over-plotting for symbols occurs.

C2's and C3's plots are similar, and D's different, as would be expected given the similarities in the rankings of the 35 possible improvements prioritised by the two CDR subject, but not between D and the two CDR subjects, established by the Pearson product moment correlation coefficient (section 7.3.2). The lines delineating the three areas of high, medium and low potential for development are placed very differently for C2 compared to C3's and D's, which are similarly placed. This is an effect of different dispersions, calculated by the Gini coefficient (see section 7.3.2).

Reading the symbols from within the 'High' areas for C2, C3 and D gives an indication of what Karlsson and Ryan's method would suggest the development priorities were for the subjects. They are:

- For all three, they would predominantly comprise 'level 1' developments, with a few 'level 2' developments (three for C2, four for C3, and five for D) and no 'level 3' developments.
- For C2, a near equal mix of data-related and interaction-related categories with less than half that number made up of interface- and new-related categories.
- For C3, predominantly the data-based category, with about a third that number made up of interface- and interaction-related categories, and just one new-related category.
- For D, a three-way split between interaction-related, data-related and new-related, with just one interface-related category.

The above readings from the plots are not exact – over-plotting being the main reason, and the imprecision of the exact delineation of the lines. However the broad trends are robust enough, and C2 and C3's AHP value choices are similar as evidenced by the Pearson rank correlation. **The optimal development route for C2 and C3 – according the Karlsson-Ryan method – would embrace mainly level 1 with a sprinkling of level 2 and no level 3 developments, and focus – in order: data-related, interaction-related, interface-related developments, and new-related developments**. This is a significant conclusion as the 'new-related ' category contain all the geovisualization possible improvements. **This implies that, even after considerable time spent with these subjects communicating geovisualization to them in a number of ways, and gaining an increasing understanding of their context of use, the conclusion of the Karlsson-Ryan method is that they would wish to see little geovisualization development to the CDR prototype.**

The development priorities for developer D would similarly focus on mainly level 1 with a sprinkling of level 2 and no level 3 developments, **but the focus would be near equal on interaction-related, data-related and new-related developments**.

This concludes the section on the results of the Karlsson-Ryan plot inspection method to determine development priorities for the CDR subjects.

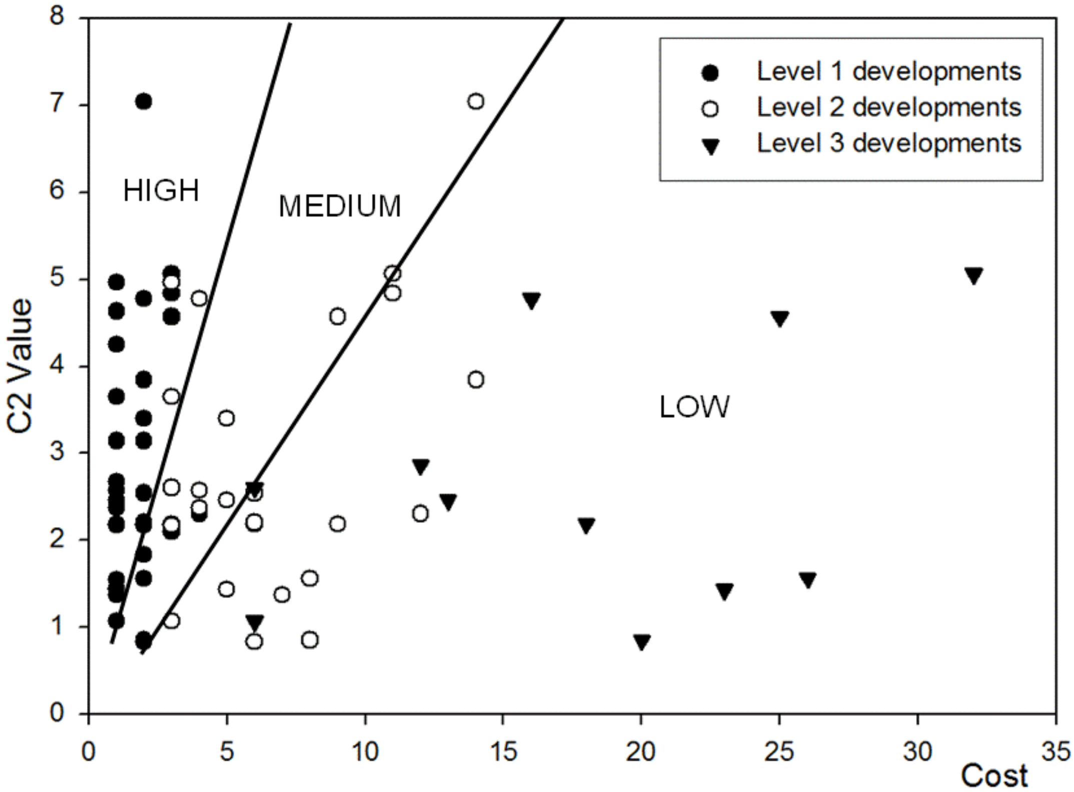

Figure 7.7: AHP-derived Value v Developer cost plot for C2 with Karlsson-Ryan inspired partitioned areas corresponding to equal numbers of high, medium and low potential for development. Symbols refer to different 'levels' of development.

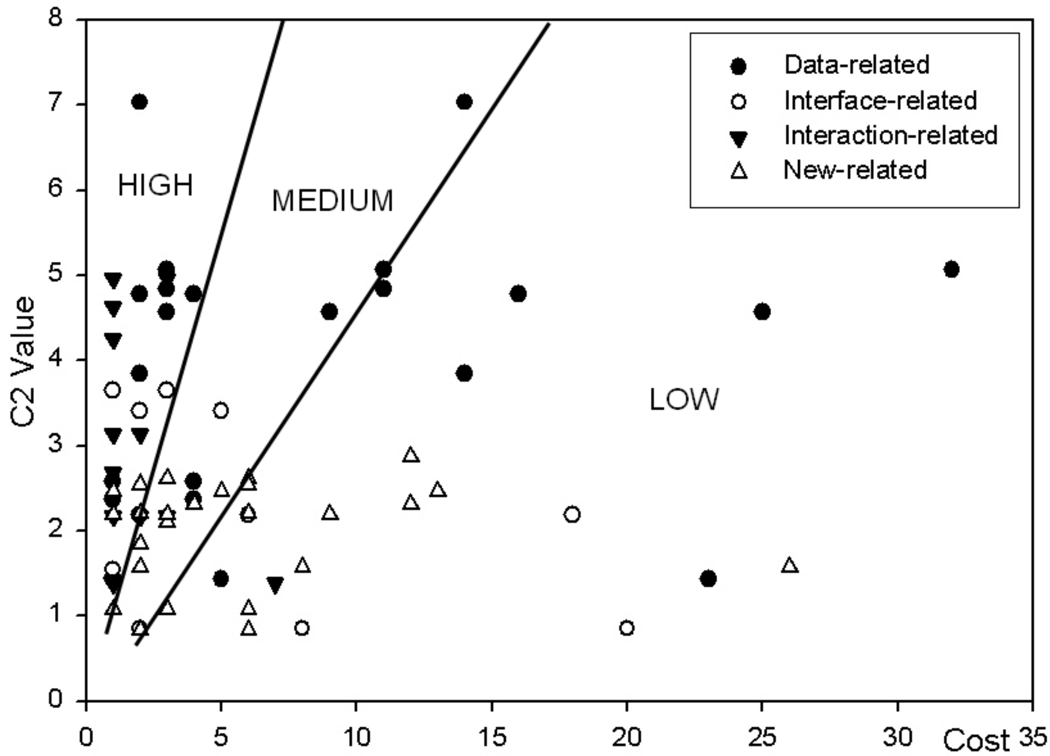

Figure 7.8: AHP-derived Value v Developer cost plot for C2 with Karlsson-Ryan inspired partitioned areas corresponding to equal numbers of high, medium and low potential for development. Symbols refer to different categories of possible improvement.

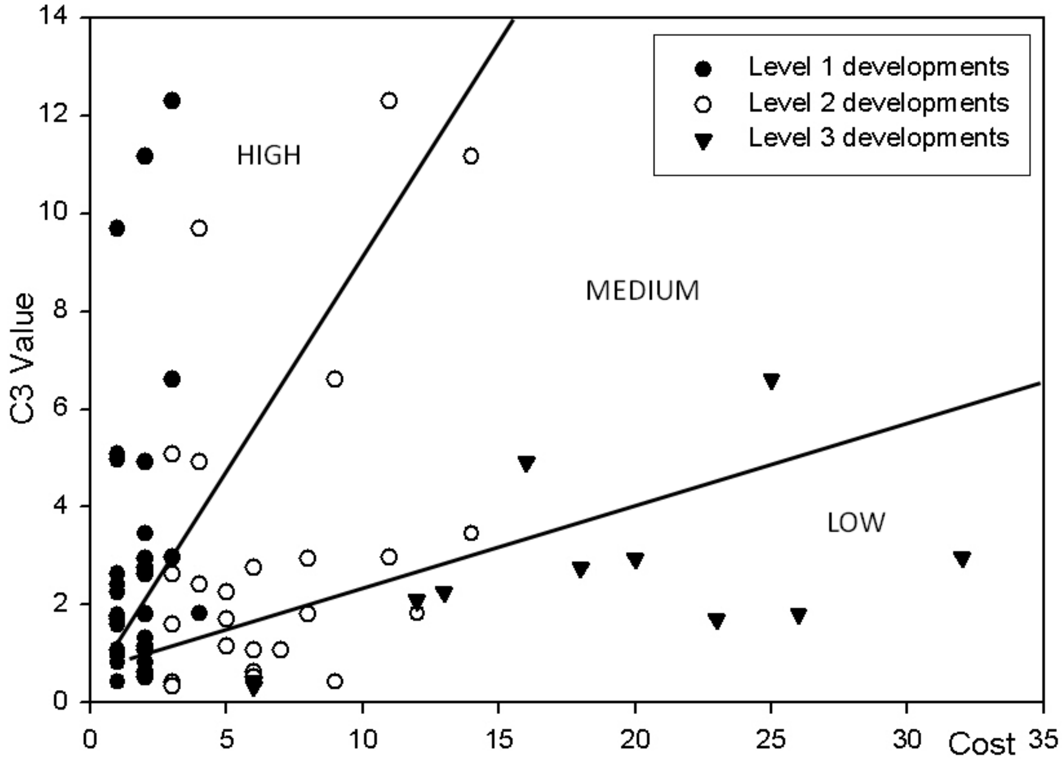

Figure 7.9: AHP-derived Value v Developer cost plot for C3 with Karlsson-Ryan inspired partitioned areas corresponding to equal numbers of high, medium and low potential for development. Symbols refer to different 'levels' of development.

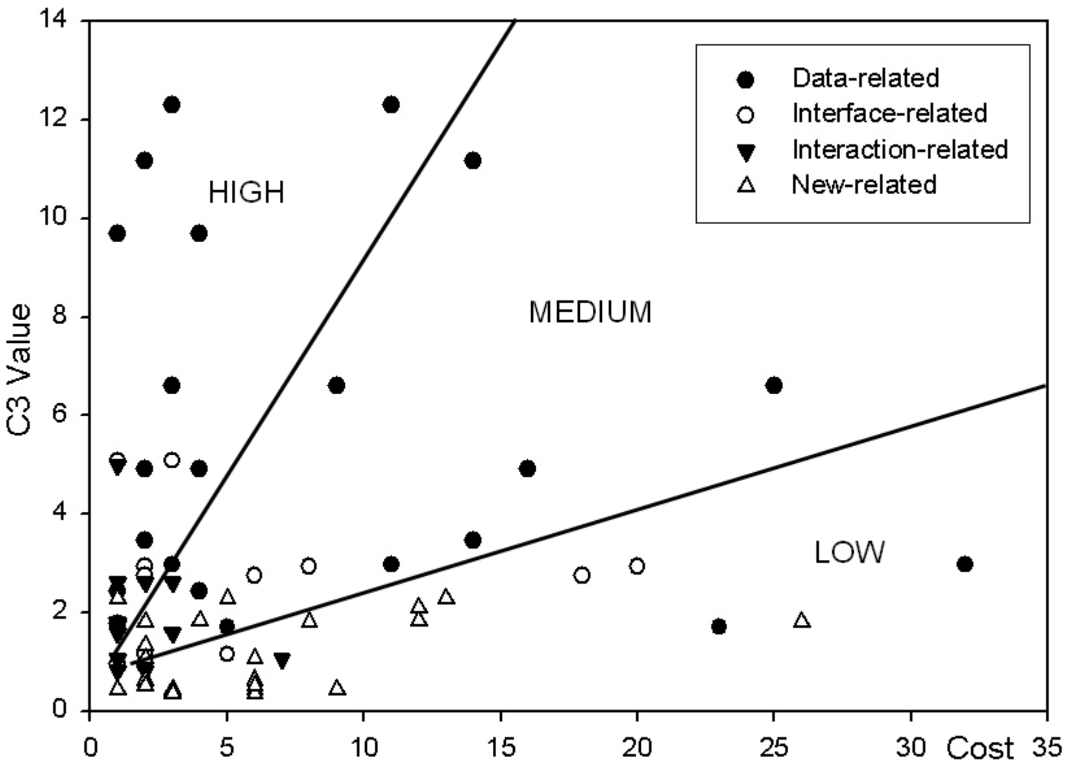

Figure 7.10: AHP-derived Value v Developer cost plot for C3 with Karlsson-Ryan inspired partitioned areas corresponding to equal numbers of high, medium and low potential for development. Symbols refer to different categories of possible improvement.

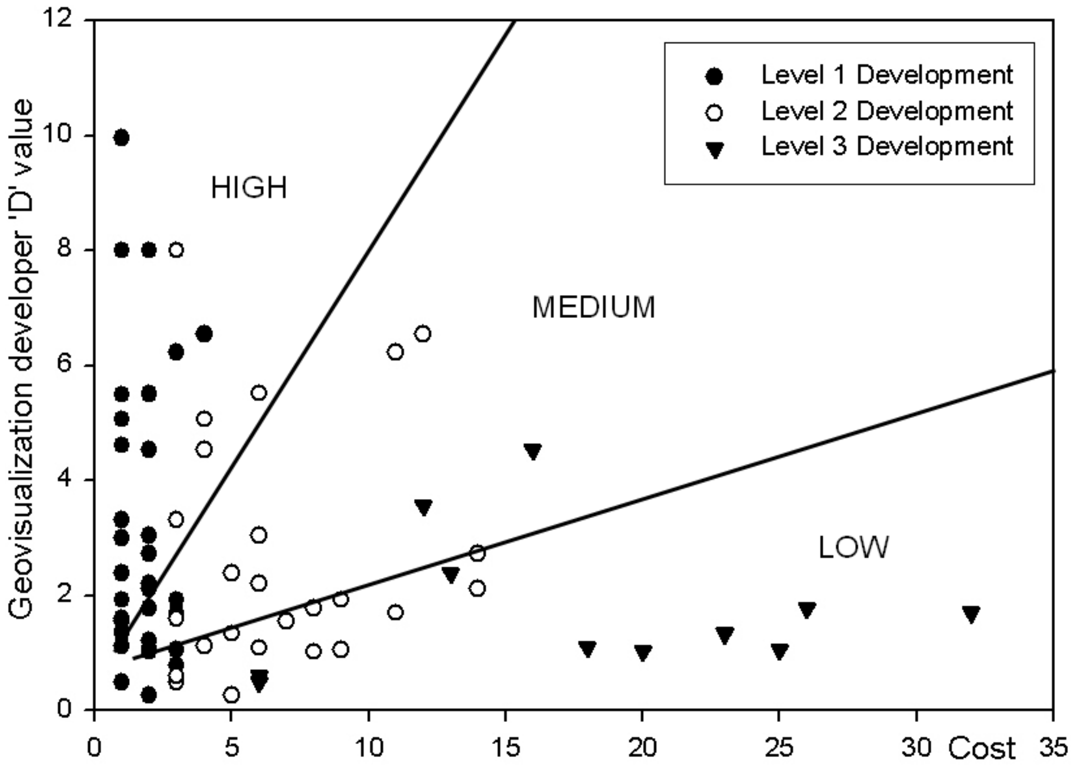

Figure 7.11: AHP-derived Value v Developer cost plot for developer D with Karlsson-Ryan inspired partitioned areas corresponding to equal numbers of high, medium and low potential for development. Symbols refer to different 'levels' of development.

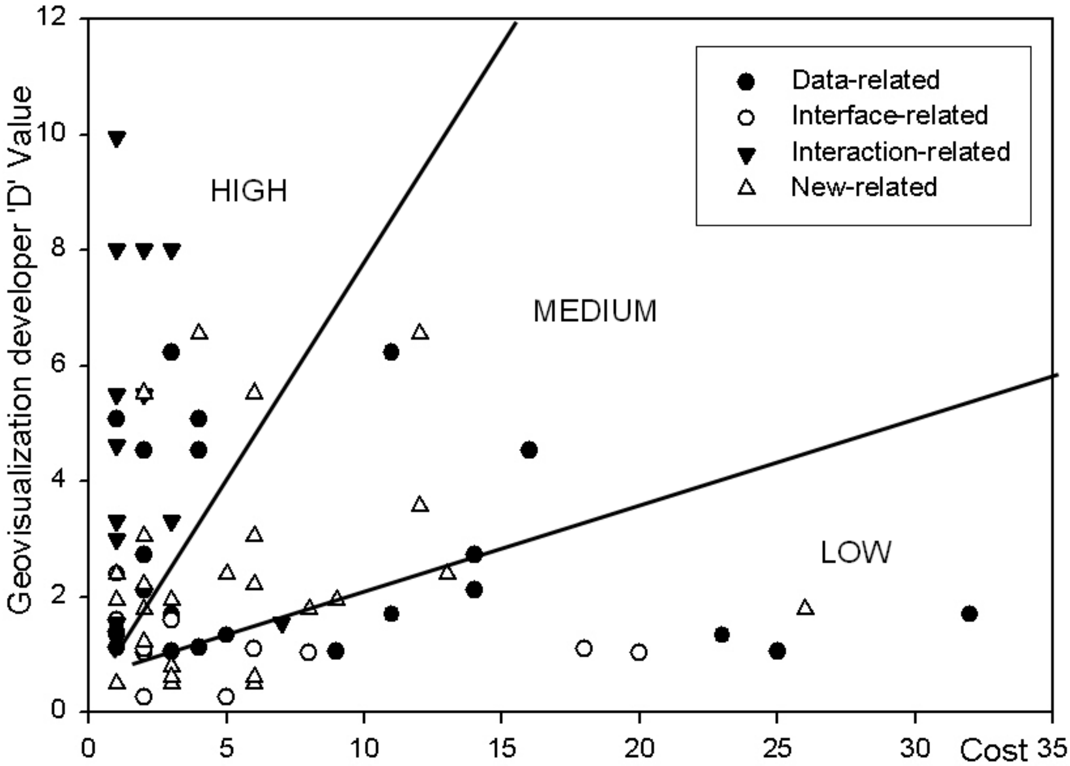

Figure 7.12: AHP-derived Value v Developer cost plot for developer D with Karlsson-Ryan inspired partitioned areas corresponding to equal numbers of high, medium and low potential for development. Symbols refer to different categories of possible improvement.

7.6 HUMAN-CENTERED KNAPSACK APPROACH TO PRIORITISING

7.6.1 CHOOSING PRIORITIES UNDER CONSTRAINT

These results correspond to case number 19 on Table 2.2 (an extract of which is at the start of this chapter). The Karlsson-Ryan plot inspection methodology produces different development pathways for the two CDR subjects on the one hand, and the geovisualization developer D on the other. However, the method is deterministic and does not incorporate subject input of their AHP rankings with knowledge of the range of development costs. This section examines an alternative approach that uses simple 'game' cards containing development costs (and different options), toy money and subjects' knowledge of their own AHP rankings to determine if materially different development decisions are made. In particular, it seeks to determine if CDR subjects really do not wish to prioritise developments that are 'new-related' and which contain geovisualization tool developments as suggested by the Karlsson and Ryan plot inspection method used in section 7.5.

Tables 7.6 and 7.7 show the results from the alternative approach for C2 and C2 respectively. The 'rank' column shows how the subjects ranked each of the 35 possible improvements during the AHP. The 'No' column gives the number of the possible improvements from 1 to 35. The 'order of purchase' shows just that with the three different 'levels' of development that can be purchased separately indentified. So for example, subject C2 selected the first level of possible improvement No 3 first, then the first level of No 5, and so on.

Colour hues relate to the three separate tranches of expenditure allowed the subjects; the first allowed 20 units (pink hue), the second a further 15 units (orange hue), and the third a further 35 units (green hue). Subsequent columns show the cost and cumulative cost of each 'expenditure' by subjects, and are similarly colour coded. The divisions between the different categories of possible improvement – data-related, interface-related, interaction-related and new-related, are also indicated. From Tables 7.6 and 7.7, it can be seen that C2 and C3 have slightly different purchasing tactics when it comes to buying from the different levels of development. C2 buys 21 level 1, seven level 2 and no level 3 possible improvements. This indicates a spreading of the funds available in a "wide but shallow" approach. C3 spends in much the same proportion in levels 1 and 2 (15 and 4 times, respectively) but has funds for one level 3 development purchase – so "wide and shallow" coupled with one possible improvement developed "in depth".

			Order of purchase			Cost			Cumulative expenditure			
Rank	No	Possible Improvement	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	
7	1	Aggregate selected areas together	7			3			15			DATA-RELATED
9	2	Aggregate selected times on glyphs together into bands	27			2			68			
1	3	Aggregate selected historical time periods to act as the comparison with the current view	1			2			2			
17	4	Display the crime numbers associated with geography, times and crime categories as text	10			1			18			
2	5	Filter the data shown in the current view to include only certain areas	2	17		3	8		5	41		
5	6	Filter the data shown in the current view to include only certain times	5			2			11			
4	7	Filter the data shown in the current view to include only certain crimes or sub-crimes	4	18		3	8		9	49		
20	8	Filter the data shown in the current view to include only crimes greater than a particular number										
30	9	Add contextual data to the map view										
31	10	Add contextual policy data to map view										
34	11	Allow comparison of current view with selected external comparisons.										INTERFACE-RELATED
23	12	Base thematic map colours on something other than relativity to crimes in display area	15			2			31			
10	13	Retain the paning and zooming position when changing the display	8b	19		0	2		16	51		
29	14	Reduce complexity of the system										
11	15	Reduce difficult in comparing 25-odd glyphs	16	20		2	3		33	54		
15	16	Current system to work 50% faster										
14	17	System to indicate the state of various components with text labels	9			1			17			INTERACTION-RELATED
6	18	Provide map grid with scale	6			1			12			
25	19a	Provide legends to assist interpretation of application components	23			2			59			
	19b		24	25		1	2		60	62		
32	20	Provide better background maps										
8	21	Provide orientation aid	8a			1			16			
3	22a	Make glyphs easier to see, retaining 25 or more per map	3			1			6			
	22b											
12	23a	Improve readability of map + glyphs + thematic colours										
	23b											
26	24	Allow for aoristic crime taking account of time span of crime										NEW-RELATED
19	25	Provide another view of the data that can see an individual crime in relation to all crime	11	12		1	4		19	23		
28	26	Provide different views at different resolutions together										
35	27	Computer to assist the user by highlighting of interest, significance or similarity										
21	28	Make simultaneous comparison of different views easier	13			4			27			
13	29	Show rank information away from map in a new tool										
33	30	Selectively build up information on map so that the highest crime areas appear first followed by a short delay										
27	31	Provide small multiple display of all resolutions at once	22			2			57			
24	32	Add a scalogram										
16	33	Show pattern stability by moving base of grid	21			1			55			
18	34	Extend "circle" cue on maps										
22	35	Introduce treemap of crime sub-categories into application	14	26		2	4		29	66		

Table 7.6:Analysis of order of development purchases by CDR subject C2

Rank	No	Possible Improvement	Order of purchase Level 1	Order of purchase Level 2	Order of purchase Level 3	Cost Level 1	Cost Level 2	Cost Level 3	Cumulative expenditure Level 1	Cumulative expenditure Level 2	Cumulative expenditure Level 3	
7	1	Aggregate selected areas together										DATA-RELATED
9	2	Aggregate selected times on glyphs together into bands	8			2			20			
1	3	Aggregate selected historical time periods to act as the comparison with the current view	4			2			15			
17	4	Display the crime numbers associated with geography, times and crime categories as text	5	16		1	3		16	35		
2	5	Filter the data shown in the current view to include only certain areas	17	18	19	3	8	18	38	46	64	
5	6	Filter the data shown in the current view to include only certain times	3			2			13			
4	7	Filter the data shown in the current view to include only certain crimes or sub-crimes	1	2		3	8		3	11		
20	8	Filter the data shown in the current view to include only crimes greater than a particular number										
30	9	Add contextual data to the map view	15			1			32			
31	10	Add contextual policy data to map view										
34	11	Allow comparison of current view with selected external comparisons.										INTERFACE-RELATED
23	12	Base thematic map colours on something other than relativity to crimes in display area										
10	13	Retain the paning and zooming position when changing the display	6a			1			17			
29	14	Reduce complexity of the system										
11	15	Reduce difficult in comparing 25-odd glyphs										
15	16	Current system to work 50% faster										
14	17	System to indicate the state of various components with text labels	7			1			18			INTERACTION-RELATED
6	18	Provide map grid with scale	14			1			31			
25	19a	Provide legends to assist interpretation of application components	9			2			22			
	19b		10	11		1	2		23	25		
32	20	Provide better background maps										
8	21	Provide orientation aid	6b			0			17			
3	22a	Make glyphs easier to see, retaining 25 or more per map										
	22b											
12	23a	Improve readability of map + glyphs + thematic colours										
	23b											
26	24	Allow for aoristic crime taking account of time span of crime										NEW-RELATED
19	25	Provide another view of the data that can see an individual crime in relation to all crime	12			1			26			
28	26	Provide different views at different resolutions together										
35	27	Computer to assist the user by highlighting of interest, significance or similarity										
21	28	Make simultaneous comparison of different views easier	13			4			30			
13	29	Show rank information away from map in a new tool										
33	30	Selectively build up information on map so that the highest crime areas appear first followed by a short delay										
27	31	Provide small multiple display of all resolutions at once										
24	32	Add a scalogram										
16	33	Show pattern stability by moving base of grid										
18	34	Extend "circle" cue on maps										
22	35	Introduce treemap of crime sub-categories into application										

Table 7.7: Analysis of order of development purchases by CDR subject C3

Tables 7.8 and 7.9 summarise the amount of development 'purchased' in each of the three tranches by development category by subject C2 and C3, respectively.

Group	**Tranche 1 (20)**	**Tranche 2 (+15 = 35)**	**Tranche 3 (+35 = 70)**	Total
Data	14	0	18	32
Interface	0	4	5	9
Interaction	4	0	5	9
New	0	11	7	18
Total	18	15	35	**68**

Table 7.8: Summary analysis of development purchases by group for subject C2

Group	**Tranche 1 (20)**	**Tranche 2 (+15 = 35)**	**Tranche 3 (+35 = 70)**	Total
Data	18	4	29	51
Interface	0	1	0	1
Interaction	1	6	0	7
New	0	5	0	5
Total	19	16	29	**64**

Table 7.9: Summary analysis of development purchases by group for subject C3

Notice that the subjects did not quite keep to the expenditure rules – both under spending in tranche 1, and C3 overspending by 1 unit in tranche 2 and under spending by 6 in tranche 3.

Both C2 and C3 are heavy purchasers of data-related possible improvements in tranche 1, buying no interface- or new-related improvements and few interaction-related.

In the second tranche, their purchasing patterns are different. C2 reverses the pattern of the first tranche buying mainly new-related and some interface-related improvements, and no data- and interaction. C3 spreads purchases more evenly between interaction-, new- and data-related possible improvements.

Tranche 3 sees a return to the pattern of purchasing in the first tranche. C3 buys nothing but 'data-related'; C2 buys predominantly 'data-related' (spending 18 units) with about a third of that spent on each of the other three categories.

7.6.2 COMPARISON WITH KARLSSON-RYAN PLOT INSPECTION APPROACH

These results correspond to case number 20 on Table 2.2 (an extract of which is at the start of this chapter).

Table 7.10 compares the results from section 7.6.1 with those from the Karlsson-Ryan plot inspection approach from section 7.5.

Karlsson-Ryan plot inspection result	**HC 'knapsack' approach with subjects**
C2 and C3 both to have predominantly 'level 1' developments, with a few 'level 2' developments (three for C2, four for C3) and no 'level 3' developments.	C2 and C3 bought predominantly 'level 1' developments, with a few 'level 2' developments (seven for C2, four for C3) and just one 'level 3' development by C3
C2 to have a near equal mix of data-related and interaction-related categories with less than half that number made up of interface- and new-related categories.	C2 bought 9 data-related and 7 interaction-related developments; 5 interface-related and 7 new-related developments.
C3 to have predominantly data-based category, with about a third that number made up of interface- and interaction-related categories, and just one new-related category.	C3 bought 11 data-related possible improvements at a cost of 51 (out of 64 spent in total). C3 also bought 6 interaction-related, 1 interface-related and 2 data-related possible improvements.

Table 7.10: Comparison of Karlsson-Ryan plot inspection results with those from the HC 'knapsack' approach with CDR subjects 'buying' costed developments knowing their AHP results.

The comparison may be easier to see graphically. Figures 7.13 and 7.14 show the HC knapsack approach with CDR subjects results superimposed on the Karlsson-Ryan plot for C2 and C3, respectively. Possible improvements selected in different tranches (1, 2 and 3) are shown circled in different colours (red, orange, green, respectively). Annotation refers to order of selection and (in parentheses) the number of the possible improvement, for example '1(7)' in red refers to the first purchase (the '1') of possible improvement 7 (the '(7)') which is a level 1 development (red colour).

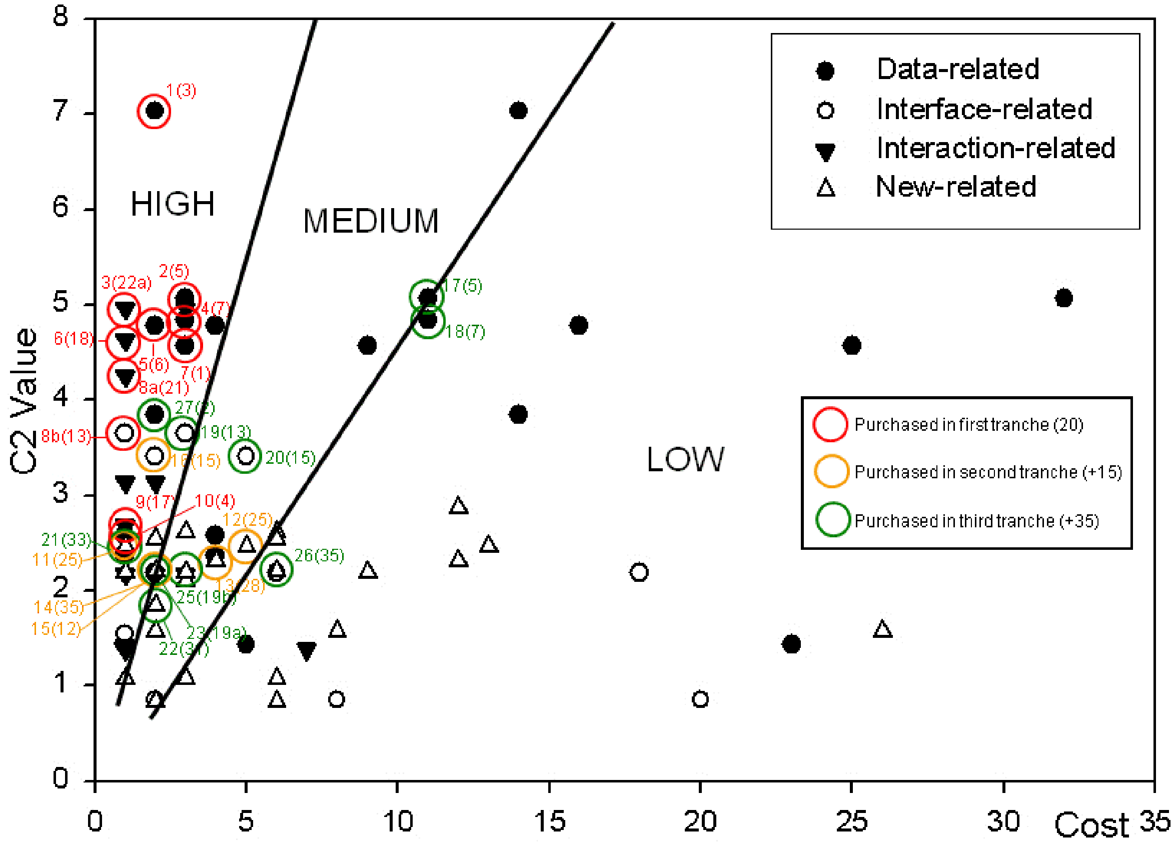

Figure 7.13: Karlsson-Ryan 'Value versus Cost' plot with results of C2 'knapsack' session.

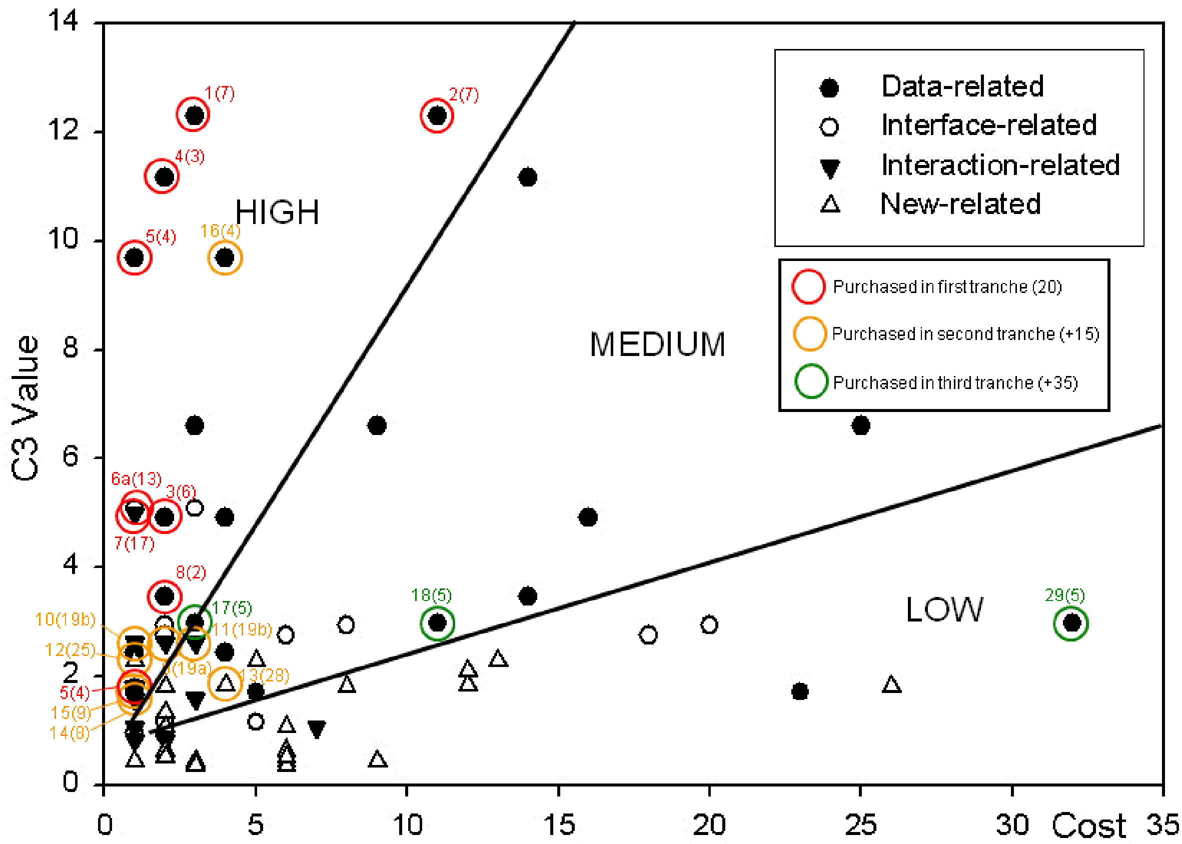

Figure 7.14: Karlsson-Ryan 'Value versus Cost' plot with results of C3 'knapsack' session.

The Karlsson-Ryan plot inspection method that relies only on the subjects' AHP results and the costs of each possible improvement development, provides a good match with the human-centered 'knapsack' approach that involves the CDR subjects making development purchasing decisions under constraint after completing the AHP.

There is **good evidence** that in this case, **the Karlsson-Ryan plot inspection method suffices as a way of prioritising possible improvements under the constraint of development costs with only the AHP as the only subject input**. **The additional effort required to conduct an additional 'knapsack' approach is not justified**, in this case.

The conclusions from this section echo the majority of the findings from section 7.5, as might be expected given the conclusion in the last paragraph. **C2 and C3 choose level 1 with a sprinkling of level 2 and just one level 3 developments, and focus – in order - data-related (20 out of 48 purchases), interaction-related (13), new-related developments (9), and interface-related developments (6).** The order of the last two of these change (interface- and new-related) from the Karlsson-Ryan result, and the Karlsson-Ryan plot inspection result did not include a level 3 purchase, but the results from the two different approaches are otherwise much the same. C2 spent most on new-related possible improvements in tranche 2, but C3 was focused throughout on data-related possible improvements (51 units of expenditure out of a total of 64).

The HC knapsack approach with the CDR subjects shows the focus on data-related possible improvements at the expense of the three other categories, including new-related developments. Again, this is a significant conclusion as the 'new-related ' category contain all the geovisualization possible improvements. **This implies that, even after considerable time spent with these subjects communicating geovisualization to them in a number of ways, and gaining an increasing understanding of their context of use, the conclusion of their results from the HC knapsack approach is that they would wish to see data-related possible improvements prioritised over other categories including 'new related', and hence little geovisualization development to the CDR prototype.**

7.6.3 SUMMATIVE QUESTIONS AFTER CHOOSING PRIORITIES UNDER CONSTRAINT

C2 and C3 were asked a number of summative questions about the HC knapsack approach in order to provide addition evidence. These are gathered together in this section under headings relating to the usefulness (or otherwise) of a constrained prioritising process; the HC knapsack process itself; the influence of each the subject's AHP ranking on prioritising under constraint; and the differences experienced between unconstrained and constrained prioritising.

Usefulness of the constrained process

> *"in terms of making us aware of how much each of the developments would take, [it was] very useful. In terms of a prioritising exercise, useful" (C2)*
>
> *"it makes you have to go through the criteria and think about what you're actually suggesting you want. So yes, useful for me, in terms of understanding." (C2)*
>
> *"it makes you think about the trade-off…[and] the cost involved based on the priorities." (C3)*
>
> *"you're not making a clear-cut decision on anything here. You are ordering and prioritising. I think whenever you are doing that, it is very difficult to do that without implementing some kind of system or method to what you're doing. So, in that sense, I think it works really well." (C3)*
>
> *"you go through a whole process of "here are all of the options"; "order your options regardless of cost" - because that's how you should do it - then you bring your cost element in, and then maybe you think twice about it." (C3)*
> *"[what worked well was] introducing the element of how much it would cost…as an important constraint. Putting it in that context brought it home to you that again, **we have to "play safe" and go for the basic fundamentals.**" (C2) [my emphasis]*

C2 and C3 understand and appreciate the nature of constrained choice and welcome a systematic way of approaching it. C2's last quote is important. In spite of the time spent with these subjects, attempting to communicate geovisualization to them, the priorities of C2's day-to-day work are paramount and mean that C2 turns away from the prospect of new-related opportunities including novel geovisualization tools, "*plays safe*" and goes for "*the basic fundamentals*".

Human-centered 'knapsack' process

> *"the [toy] money is fine, it just keeps a track of where you are going with it, rather than just keep continually having to add it up." (C2)*
>
> *"you start with [AHP] list, and you start going through [the costed version], and you have made your selection, maybe out of three choices, but then it is quite hard to then remember that you didn't make your final decision, even though you liked it. You've still got this list to work through. So **I did find it quite difficult**." (C2) [my emphasis]*

*"I don't know whether it was possible, maybe, to have a checklist of what I had ticked here, just to make it simpler for me…**It was quite cumbersome**"(C2) [my emphasis]*

Although the mechanism of the toy money helped, C2 found parts of the process "quite difficult" and "quite cumbersome". Fewer possible improvements would help improve matters (as suggested in section 7.3.3).

*"I think my criticism would be if the final part of it [**the constrained selection] should warrant more time**, because [that's] the real crux… but at the same time, it would be useful to do it quickly. And then reflect back on what you did quickly and maybe amend it, rather than spending a lot of time going "oh maybe I'll change that"." (C3) [my emphasis]*

*"I think that was **not enough time to do it as effectively, maybe as I would have like…there is an awful lot of information there.**" (C2) [my emphasis]*

Both C2 and C3 believe that the process needed more time. However this is difficult to square with the other demands on these subjects' time:

*"despite thinking "oh no**, I have not got time to do this**", it has been very enjoyable." (C2) [my emphasis]*

Once again, having fewer possible improvements would shorten the time taken for both the AHP and the HC knapsack process.

Influence of the AHP ranking

*"in terms of systematically going through, then **the [AHP rankings] list did influence quite strongly**. And that obviously would have an impact on the ones near the top, the ones that you have decided are interesting in that way. But I did go back through, and I did reassess…as I went along to some degree…not rigorously, but it did influence [it]."(C2) [my emphasis]*

*"in general terms, **you do get to a point down the list and think "no", whatever the cost** (C3) [my emphasis]*

*"**Even if it's really cheap, you're not that bothered**…So there's the black and white element to it - those things that you would consider buying, and those things which you definitely would not consider buying as your first rule. And after that, it is going through it and deciding. **I did almost go down my [AHP] rank [list], but I didn't stick to it**." (C3) [my emphasis]*

Both C2 and C3 indicate that the AHP ranking was a factor in their choices, but that it was by no means rigorously adhered to. C3 clearly feels that some improvements are not worth pursuing at any cost.

Unconstrained AHP versus HC knapsack constrained differences

> *"I've got my [AHP-derived] list of priorities, and it is adding a further dimension to it. Which has, in some ways, changed my rankings on the list. [Because] with* ***the fact that you have got potentially three levels of development for one particular improvement… you want all or nothing. Some I have learned that you can scrape by with the bare essentials.*** *It is going through it and* ***deciding which you only need the bare essentials, and which ones are the be all and end all …with the full development****."(C3) [my emphasis]*

> *"There were maybe a couple of occasions, where even though they had ranked [reasonably highly]…when you started putting it in the context of the others, …because you brought the element of cost into it, that put a whole different slant on it." (C2)*

> *"Number 2 [aggregating times on glyphs into bands] is ranked ninth, but… I don't think I stuck it in anywhere…realistically,* ***you could make sense of the dates yourself rather than pick "All Easter dates" or "All bank holiday dates", and therefore it wasn't a priority compared to the others****."(C2) [my emphasis]*

> *"the thing about aggregating selected areas together (Number 1) is I get a bit hung up with anything that is predefined, because predefined areas wouldn't really work very well, because you might not be interested in grouping a load of grid squares together….which is why I have kind of left that one and I haven't bought it yet. I realised for a cost of 9, it is a lot… so does it warrant [it]?* ***The fact that, if I was really interested, I've [already] bought the numbers to go on the screen, I could do it in my head. So what am I getting for the money at the end of the day?****" (C3) [my emphasis]*

These four quotations embody two strands of thinking about prioritising possible improvements under cost constraint. The first is **satisficing** - that a less than wholly satisfactory outcome due to resource constraint, for example, is sufficient. The second is the notion of **'all or nothing**' – that some possible improvements are not worth having at all, and those that are worth having should be developed fully.

> *"you spot things and think 'well, actually, because it's only [a cost of] one' you could get quite a lot of basic functionality for your 20 hours, but there is always the trade-off isn't there? Just things like [adding] a scale [No.18]. I have not bought it until later on…* ***if you were producing maps of the areas and it was of interest, you could just take a screen dump. And you have not got to do anything with it. Those kind of things are quite important if you're going to pass them on to other people****. (C3) [my emphasis]*

This quotation from C3 relates to the context of these subjects and their need to present data to the CDRPs. With many customers, for these subjects saving time in converting exploration output into presentation is important. C3 cannot divorce presentation from exploration, which geovisualization practitioners see as at the opposite end of the spectrum (DiBiase, 1990).

*"The other one that stood out was "filter the data shown in the current view to include only certain areas" (No 5). You see, the cost of that is eight [for the second piece of development] and again, why would you only want to filter one area out? You could do it… on the screen, or in your head. So I couldn't really see the benefits of that in the end. So I talked myself out of that…**Or actually, no. On that one - tell a lie - to be able to do it by CDRP is quite important. But it is [a cost of] 29... But that will be probably be where my last load of money went in the end** [the difference between 35 and 70 hours]."(C3) [my emphasis]*

Recall that C3 bought one level 3 possible improvement (in fact, by the nature of the development level, bought levels 1, 2 and 3). This was Possible improvement No 5 'Filter the data shown in the current view to include only certain areas'. In the first part of this final quotation, C3 explains why this is a poor purchase:

"You see, the cost of that is eight [for the second piece of development] and again, why would you only want to filter one area out? You could do it… on the screen, or in your head. So I couldn't really see the benefits of that in the end. So I talked myself out of that." [C3]

In the session this was followed by a long pause, followed by an extraordinary turnaround:

"Or actually, no. On that one - tell a lie - to be able to do it by CDRP is quite important. But it is [a cost of] 29... But that will be probably be where my last load of money went in the end." [C3]

And so it proves. C3 bought levels 2 and 3 to develop this possible improvement. This may have been a reaction to time pressure. But it shows at the very least how fine the decision can be between "all or nothing". The Karlsson-Ryan plot inspection approach would not have prioritised the higher levels of this particular possible improvement.

7.7 CONCLUSIONS

RQ6.1: How well do human-centered approaches concerned with the process of prioritising possible improvements to geovisualization applications work in an applied geovisualization context?

1 Analytical Hierarchy Process

With the limited number of subjects available, the AHP produces results that are rich in detail (rankings, consistency, dispersion) and indicate plausible results. CDR subjects' priorities are skewed towards ‘data-related’ improvements and against ‘new-related’ items. D's priorities are more evenly distributed, and incline towards ‘interaction related’ and against ‘interface related’ choices . There are marked similarities in the rankings of the 35 possible improvements prioritised by the two CDR subjects (Pearson coefficient 0.50, significant at 0.01 level; 2 tailed, n=35). Developer D's rankings are different from both CDR subjects' rankings as indicated by non-significant Pearson coefficients (see Figure 7.5) despite the high levels of engagement between the CDR subjects and the geovisualization expert/developer throughout the development process. Geovisualization applications are predominantly ‘expert’ driven (Fuhrmann et al., 2005) and so **the discrepancies in terms of priorities are a finding that should be explored further to see if it is replicated with other subjects and geovisualization tool developers**.

From Table 7.3, the AHP consistency ratios for C2, C3 and D range from 0.03 to 0.21 for data-, interface- and interaction-related possible improvements, but the **consistency ratio results from the ‘new-related’ group (which contains novel geovisualization tools) are noticeably less consistent**, ranging from 0.43 to 0.69. C2's dispersion as measured by the Gini coefficient, is lower than C3's and D's - C2: 0.27; C3: 0.48; D: 0.42. **While the two CDR subjects have very different dispersions and different consistency ratios, their rankings are indistinguishable**.

There is **good evidence** (section 7.3.3) that the AHP process is acceptable to the CDR subjects, but less so by the developer D, who found it somewhat tedious to complete. If the AHP is used in future by geovisualization researchers, **a reduced list of possible improvements to the one employed here (and hence reduced number of pair-wise comparisons) will be less demanding.**

If 'often mentioned' suggestions from individual CDR subject's implicit and explicit suggestions made during prototyping (see section 6.2.4.1) become 'highly ranked' possible improvements in the AHP, then the AHP process might be wholly or partially redundant. However, there is **no evidence** of this (section 7.3.2, Table 7.5). The implications from this are that subject suggestions during prototyping should be taken as just that – suggestions. **Until they are refined and prioritised, suggestions should not be regarded as 'requirements' for a developer to build into the next iteration**. However, such **refining and prioritisation need not be conducted as the lengthy aggregation of suggestions coupled to a decision-making process such as the AHP**, **but could be more informal**. For example in collaborative sessions with many subjects, suggestions could be captured as they arise (perhaps on sticky notes attached to a board) and later in the same session categorised, discussed and prioritised by participants (perhaps by subjects and geovisualization expert/developers together) until a consensus on priorities emerges. A human-centered technique - **affinity diagramming** (Beyer and Holtzblatt, 1997) - could be used for the categorisation aspect, and has already been employed in a geovisualization context (Marsh, 2007).

The explicit introduction of a system variable such as speed of response as a trade-off for functionality is plainly a useful comparison for potential users of a visualization application to consider. As Andrienko et al (2005) point out, the development of geovisualization applications and tools is partly driven by "New technology [that] continues to appear and…often enables us to do things that were not possible before." But the speed-functionality trade-off is likely to remain an issue, especially where - as in the case of the digital interactive prototype –a remote server is interrogated for temporal, spatial and attribute data that must be recalculated before display. Clearly, subjects in this case were prepared to forego a 50% speed increase for some functionality, but **visualization researchers may wish to probe at what point what functionality *is* traded for speed**.

2 Costing possible improvements for a geovisualization prototype

The 35 possible improvements that form the basis for a developer to work up estimates of the time needed for implementation are far from well-specified, complete and 'signed off' requirements. They contain many ambiguities, do not precisely specify outcomes, are not scoped to constrain development to a particular facet or facets of the proposed improvement, and they are vaguely worded, reflecting the reality of the origin of these possible improvements. As a consequence, these **inputs of ambiguity, vagueness and lack of specificity are manifest in the outputs of the geovisualization developer** (Table 7.6). **The developer includes additional elements to indicate the complexities inherent in the process of determining costs, and indicates reservations, possibilities and difficulties in various ways**.

I have made the point that the geovisualization literature is silent about the process of design (section 5.2.1). The geovisualization literature is similarly silent about the process of iterative development in the face of ambiguous subject input on possible improvements. **I commend geovisualization developers expose such processes where possible for the benefit of other researchers**.

3 Karlsson-Ryan Value v Cost plot inspection

The Karlsson-Ryan value v cost plot inspection approach yields plausible prioritised possible improvements for the CDR prototype although visual readings from the plots can be inexact where there is over-plotting.

The optimal development route for C2 and C3 – according the Karlsson-Ryan method – would embrace mainly level 1 with a sprinkling of level 2 and no level 3 developments, and focus – in order - data-related, interaction-related, interface-related developments, and new-related developments. This is a significant conclusion as the 'new-related ' category contains all the geovisualization possible improvements. **This implies that, even after considerable time spent with these subjects communicating geovisualization to them in a number of ways and gaining an increasing understanding of their context of use, they do not prioritise geovisualization development to the CDR prototype.** Recall that this result is derived without reference to the CDR subjects (but see RQ6.2 below).

RQ6.2: How might human-centered approaches concerned with the process of prioritising possible improvements to geovisualization applications be changed?

There is **good evidence** that **the novel human-centered 'knapsack' approach generates prioritised potential developments that are plausible** given CDR subjects' individual AHP ranks and costs of each potential development (Tables 7.7 and 7.8). C2 and C3 choose level 1 with a sprinkling of level 2 and just one level 3 developments, and focus - in order - on data-related (20 out of 48 purchases), interaction-related (13), new-related developments (9), and interface-related developments (6).

The HC knapsack approach with the CDR subjects shows (section 7.6.1, Tables 7.8 – 7.10) the **focus on data-related possible improvements at the expense of the three other categories, including new-related developments**. Again, this is a significant conclusion as the 'new-related' category contains all the geovisualization possible improvements. **This implies that,**

even after considerable time spent with these subjects communicating geovisualization to them in a number of ways, and gaining an increasing understanding of their context of use, the conclusion of their results from HC knapsack approach is that they would wish to see data-related possible improvements prioritised over other categories including 'new related', and hence little geovisualization development to the CDR prototype.

There is **good evidence** (section 7.62, Table 7.11) that the Karlsson-Ryan plot inspection method (that relies only on the subjects' AHP results and the costs of each possible improvement development), provides a good match with the human-centered 'knapsack' approach involving CDR subjects. In this case, **the Karlsson-Ryan plot inspection method suffices as a way of prioritising possible improvements under the constraint of development costs with only the AHP as the only subject input**. In this case, **the additional effort required to conduct an additional human-centered 'knapsack' approach is not justified**.

The summative questions about the HC knapsack process (section 7.6.3) provides:

- **Some evidence** that in spite of the time spent with these subjects, attempting to communicate geovisualization to them, the priorities of C2's day-to-day work are paramount and mean that C2 turns away from the prospect of new-related opportunities including novel geovisualization tools, "*plays safe*" and goes for "*the basic fundamentals*".
- **Some evidence** that C2 found parts of the process "quite difficult" and "quite cumbersome". Fewer possible improvements would help improve matters (as suggested in section 7.3.3).
- **Good evidence** from both C2 and C3 that the HC knapsack process needs adequate time and, where this is not possible, having fewer possible improvements would shorten the time needed.
- **Good evidence** from C2 and C3 that, in thinking about prioritising possible improvements under cost constraint, embrace notions of **sufficing** (that a less than wholly satisfactory outcome due to resource constraint, for example, is nevertheless, sufficient), and of **'all or nothing**' (that some possible improvements are not worth having at all, and those that are worth having should be developed fully).
- **Some evidence** from C3 about the context of these subjects and C3's need to present data to the CDRPs. With many customers, for these subjects saving time in converting exploration output into presentation is important. C3 cannot divorce presentation

from exploration, which geovisualization practitioners see as at the opposite end of the spectrum (DiBiase, 1990).

> *"if you were producing maps of the areas and it was of interest, you could just take a screen dump. And you have not got to do anything with it.Those kind of things are quite important if you're going to pass them on to other people." (C3)*

RQ6.3 How does the nature of geovisualization affect the process of prioritising possible improvements to geovisualization applications with prospective users?

There is strong evidence (Table 7.3) from the high consistency ratios recorded by each of the CDR subjects and developer D with 'new-related' possible improvements (that contain novel geovisualization tools) that some aspect of these **'new-related' possible improvements** leads to far less consistent results with the AHP, and by implication **uncertainty about their relative benefits**. The fact that this effect is noticed in developer D as well as in both CDR subjects, indicates that the effect is not solely due to a lack of understanding on their part.

However, there is **strong evidence** of initial lack of understanding of the **meaning of possible improvements**, **terminology** or **capability** before the AHP session (section 7.3.1.1). **New-related** and **interface-related** terms raised the **most queries**, indicating the areas giving the subjects most trouble with understanding. At one point in the pre-AHP session (section 7.3.1.1), C2 represents the "new-related" group as "*like being in a toy shop [wanting] everything, and it was difficult to differentiate*". In the summative questions after the AHP, C3 comments "*When it came to the "new" developments maybe it would not be that clear how you would apply them - it is a lot more difficult to compare*" and C2 recalls "*when it came to the new ones, you needed to explain all of those, just about, to me*" (section 7.3.3). **Clearly, both C2 and C3 have had difficulties with the "new-related" possible improvements that include novel geovisualization tools**. This echoes the evidence from section 4.5.1, Table 4.8, where C2 (and the other CDR subjects) were unable to differentiate between geovisualization tools/interactions for their work after a geovisualization lecture.

The number of new-related queries resonates with problems communicating geovisualization possibilities to these subjects in the geovisualization lecture (section 4.5). This may point to a fundamental **issue concerning communicating potentially complex notions about visualization in verbal form**. Communicating information about visualization possibilities through words alone - particularly to prospective users who have shown themselves uninterested in visualization *per se* (see section 4.5.2) - may be inappropriate for such a complex domain. As has been stated in other chapters of this research, **alternative approaches to communicating geovisualization to subjects need consideration**.

Developer D expresses a desire for clarity before starting development work in this quotation: "*the ones that were going to be done I would want quite a lot of discussion over what it really meant.*" C2 says that the understanding of the proposed tools is "*a guess on the back of what you are telling me"* and "*I have to have faith in the developer*." (section 7.3.3) These are interesting statements given what has gone before in terms of extensive engagement with these CDR subjects over nearly three years eliciting these possible improvements after many different approaches. The AHP may provide both CDR subjects and D with a ranking that each party considers reasonable, but its apparent ability to prioritise and to capture measures of consistency nevertheless does not provide C2 and developer D with confidence in a concluded dialogue. C2 does not fully understand the tools and comments "*I have to have faith in the developer*"; developer D wants *'quite a lot of discussion'* about what is *really meant* by the list of 35 possible improvements. After engagement with the CDR subjects over a considerable period of time, these statements provide **some further evidence** to support what appears to be an emerging theme of this research **of the difficulty of communicating geovisualization to these potential users, and from them to the geovisualization developer.**

RECOMMENDATIONS

I recommend visualization researchers use the AHP as a human-centred approach to determined unconstrained priorities with subjects.

I recommend that visualization researchers use the Karlsson-Ryan 'value versus cost' plot inspection method in conjunction with the AHP as a systematic way of prioritising developments under cost constraints.

7.8 DISCUSSION

Raw suggestions arising from prototyping sessions with subjects are simply too numerous and intractable a form of information for a developer to work on to iterate a geovisualization prototype. Some form of process that concatenates and categorises suggestions is needed so that prioritisation can begin.

The pair-wise comparison process of the AHP works for the CDR subjects and the geovisualization expert/developer as a way to produce individual priority lists.

The fact that the rankings by C2 and C3 are statistically similar shows the AHP is robust. The priorities of the geovisualization expert/developer are different despite the high levels of engagement between analyst and expert throughout the human-centred application development process outlined in this research. The fact that the geovisualization expert/developer's AHP ranking is different shows the power of the AHP as a tool to discover – like the card sorting that took place in sections 3.3.4 and 4.5.1 – a "users' mental model of an information space" (Nielsen and Sano, 1995). The difference in priorities raises the question of how future development should proceed and how the differences between subject and developer can be reconciled, especially as geovisualization applications are predominantly 'expert' driven (Fuhrmann et al., 2005). This finding is one that should be explored further with other subjects and other visualization developers.

As well as yielding the ranking of possible improvements, the AHP contributes measures of how consistently the process has been conducted and, by extension using Lorenz curve (Lorenz, 1905) and the Gini coefficient (Gini, 1912), measures of dispersion, of the possible improvements. These are further enhanced by splitting the possible improvements into categories relating to groups of similar possible improvements – data-related, interface-related, interaction-related and new-related - so that inferences can be made about the different measures within and between each of these. The 'new-related' include novel geovisualization tool possible improvements.

There is poor consistency in ranking 'new-related' improvements from all subjects, and such rankings clearly cannot be relied upon to indicate priorities within this category. But the fact that 'new' candidate improvements are ranked inconsistently by all subjects suggests particular uncertainty about their nature and/or possible benefits. The issue may be one of communication and interpretation - unfamiliar improvements are more difficult to describe, communicate and interpret consistently with the coding, grouping and succinct descriptions required for pair-wise comparison in the context of 332 possibilities. Including the kinds of complex novel visual features typical of geovisualization as possible improvements may thus affect the working of the AHP. This is despite efforts to expose the CDR analysts to geovisualization techniques and prototypes over an extended period and providing detailed descriptions prior to and during the AHP process. The time spent by the CDR subjects at the outset and the qualitative data lend weight to this conclusion, confirming findings on difficulties in communicating geovisualization to these users (sections 4.5.4 and 4.5.5).

Establishing costs of each possible improvement from a geovisualization developer reveals that the imprecision and ambiguity inherent in the descriptions of the possible improvements results in the developer being unable to produce a one-to-one mapping of cost to possible improvement. The developer's response is to create multiple choices of level of development, to flag up risky developments, identify dependencies, common pathways to achieve more than one development, and so forth. Given that these aspects are not confined to 'new-related' possible improvements, this cannot be ascribed to the novel geovisualization tools envisaged, but relates to the overall complexity of a geovisualization application – data-, interface-, interaction-related as well as new-related. Such a conclusion is likely to extend to the development of most complex visualization applications.

Both the Karlsson-Ryan 'value versus cost' plot inspection and the human-centered 'knapsack' approach yield plausible and similar results for ranking the possible improvements under cost constraint. Results reveal that the CDR subjects focus just as strongly on known functionality when development resources are limited, even when current tasks provide opportunity for beneficial geovisualization. Given the similarity in results obtained from the two approaches, there is no merit in pursuing the more expensive 'knapsack' option.

One aspect that comes through clearly in the narratives of the CDR subjects in and around the AHP and knapsack sessions is the reaction to new-related possible improvements (that include novel geovisualization tools). CDR subjects initially lack of understanding of the meaning of possible improvements, terminology or capability. They require extended explanation. They evoke comments from the CDR subjects that conveys uncertainty about their benefits. They do not feature high on the list of CDR subjects unconstrained or constrained prioritisation choices. There seem to be a number of processes at work here: memory, the use of text to describe something that is essentially visual, and the interest these subjects have in exploring their data.

Firstly, several months had passed between the prototyping sessions and the AHP/knapsack sessions. Evidence from the recall questions after the geovisualization lecture (section 4.5.2) indicates that these subjects do not retain information about geovisualization tools and interactions. That is clearly a factor here, and the measures taken to provide lists of possible improvements a week in advance of the AHP session plus discussion and help in advance of that session were all designed to overcome this. But at the very end of the last knapsack session, C2 is saying that the understanding of the proposed tools is "*a guess on the back of what you are telling me"* and "*I have to have faith in the developer*."(section 7.3.3).

Secondly, there is another example of what I termed the 'nomenclature problem' in section 4.5.2. The AHP and the knapsack processes are essential textual. In order for the AHP to work, pair-wise choices must be made between a series of two possible improvements. The exact description and benefits of many of these **fundamentally visual** possible improvements are difficult to render in words.

Thirdly, there is evidence from both CDR subjects that their day-to-day jobs require them to focus on their customers whose requirements for support and presentational material places a premium on the possible improvements that deliver those benefits. While both CDR subjects see the promise of being able to explore their crime data, C2 "*plays safe*" and goes for "*the basic fundamentals*" (section 7.6.3) and C3 reconsiders a previously rejected possible improvement: " *On that one … to be able to do it by CDRP is quite important. But it is [a cost of] 29... But that will be probably be where my last load of money went in the end."*(section 7.6.3). While it may be understandable for the CDR subjects to focus on prototype improvements that have the most bearing on their current activities rather than on innovation, this may be another limitation of the AHP, as these subjects have been more open to innovation when not asked to prioritise - indeed all 332 suggestions for improvements originated from them when working with geovisualization prototypes (section 6.2.4.1).

Consequently, future application of AHP in geovisualization might variously:

- involve all parties in the AHP concurrently so that concepts can be discussed and interpretations clarified - AHP as a collaborative process to communicate shared understanding of priorities
- provide visual descriptions/stimuli with demos, videos or presentations prior to and during the process so that the candidate improvements are agreed

- use fewer, more specific, candidate improvements - sampling rather than aggregation
- run the AHP against different scenarios to establish (for example) current and future priorities
- weight the results by analyst based on criteria such as consistency (from the consistency ratio) or dispersion (from the Gini coefficient)

Whilst showing how a decision support technique can be successfully employed, I suggest that the nature of geovisualization may cause difficulties for those seeking to differentiate between candidate improvements, and may not provide an unambiguous development roadmap. Approaches to developing prototypes rapidly in collaboration with prospective users through 'patchwork prototyping' (Jones, Floyd and Twidale, 2007), or establishing requirements in ways that involve creativity (Maiden, Gizikis and Robertson, 2004) may be beneficial in resolving the different perspectives identified here.

8 CONCLUSIONS

This chapter brings together the conclusions and recommendations from other chapters of the thesis.

8.1 RESEARCH QUESTION 1

Research Question 1 asks: **How well do human-centered approaches concerned with establishing context of use work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of establishing context of use from prospective users?**

RQ1.1 How well do human-centered approaches concerned with establishing context of use of prospective users of a geovisualization application work in an applied geovisualization context?

The Contextual Inquiry master/apprentice model works well in practice and the roles are easily assumed in both **interviewing** and **observation** (section 3.3.1 and 3.3.2). **I commend** this approach to geovisualization researchers.

There is **good evidence** from both CDR (section 3.3.1.2) and Library (see section 3.3.1.3) subjects that **interviews** provide useful insights from subjects on skills, experience, tools, aims, inputs and outputs that would be of use to a geovisualization designer in understanding their context of use. (See section 2.1.4 for outline of how the strength of evidence is classified)

There is **good evidence** from analysis of both CDR (section 3.3.1.2) and Library (see section 3.3.1.3) subject interviews that **word frequency counts** from interview transcriptions yield useful quantitative information about subjects context in use, highlighting key concepts.

There is **good evidence** from analysis of both CDR (section 3.3.1.2) and Library (see section 3.3.1.3) subject interviews that **keyword-in-context analysis** is a particularly rich and valuable approach as it provides greater insight into subjects' motivations.

I commend both the **word frequency count** and **in particular the keyword-in-context approach** as offering the potential for significant insight into subject context for geovisualization researchers.

There is **good evidence** from one observation session of a CDR subject, and one with Libraries senior managers, that **observation** provides a less systematic approach to gathering contextual information, and a smaller coverage, than interviews. But it can lead to avenues of inquiry and to important insights that it is hard to imagine surfacing in an interview, and it can lead additional weight to evidence uncovered in interviews (section 3.3.2).

There is **good evidence** from considering both CDR and Libraries (section 3.3.3.1) that **studying internal documents** is an effective way of learning about a subjects' context without taking up their time. As well as explicit information about the work, it can provide insights into approach, presentation, data use, analysis methods and the breadth of insight subjects achieve, and can confirm information from other methods such as interviews and observation. **I commend** this approach to geovisualization researchers.

There is **good evidence** from considering both CDR and Libraries (section 3.3.3.2) that **studying external documentation** can provide corroboration (or otherwise) of insights obtained from subjects, and contrast their context to the generality of similarly situated individuals or teams. **I recommend** the study of external documentation to supplement internal documentation and provide a context for generalisation.

RQ1.2 How might human-centered approaches concerned with establishing context of use of prospective users of a geovisualization application be changed?

ISO13407 on human-centred approaches to context in use refers only to "users, tasks and the organizational and physical environment." An important aspect of applications designed for exploration (such as geovisualization applications) is to **understand and acquire subjects' data and their relationship with it** (section 3.3.5). This has significant implications for the relationship with subjects and **requires a focus on data in context** (section 3.3.5) as well as subject context in use. However data in context is not a substitute for context of use. Subject data needs to be studied explicitly in a process akin to the process of 'studying documentation' - an off-line process, disconnected from subjects, who provide the raw data (section 3.3.5).

I strongly recommend other researchers concerned with exploratory application development (such as information visualization and geovisualisation designers) to recognise explicitly their need to collect information about data and metadata from prospective users, and to engage with, and study, subject data themselves.

Card sorting is typically employed is to determine the optimal way of including items in a series of drop-down menus . It also offers a quantitative way of gaining access to subjects' conceptual worlds to assess their categorisation of tasks. I find that:

- It enables tasks that include spatiality (that are important to geovisualization) to be set alongside other tasks.
- a geovisualization expert can perform the same card sort as subjects and thus permit comparisons between subjects' and a geovisualization expert's conceptual views of subject tasks (section 3.3.4).
- there is **some evidence** card sorting reveals differences and similarities when category headings given by subjects to their sorted cards are compared. One subject categorises tasks without reference to spatiality, whereas colleagues have extensive spatial categorisation. Such an individual might reflect their aspatial view of tasks in other approaches such as interviews (section 3.3.4).
- clustering analysis of card sorting (that takes no heed of subject headings) produces subjectively sensible task tree diagrams. The clustering of tasks provides an indication of where a geovisualization application would have most coverage and therefore be of most use to prospective users (section 3.3.4). The cluster analysis of the CDR subjects' card sort, for example, shows a cluster comprising domestic crime, racial crime, crime affecting persons living alone, crimes affecting the Islamic community and crime associated with, and/or committed by, recent migrants.
- a card sorting difference distance matrix highlights differences between the way that different users cluster tasks and therefore provides both a check of consistency with a group of subjects, and also a comparison between subjects and a geovisualization expert. This enables a quantitative assessment the similarity between such a geovisualization expert's concept of the subjects' task domain and that of the subjects themselves (section 3.3.4).

I commend card sorting as a useful quantitative technique for geovisualization application designers to explore the conceptual worlds of the prospective users and their own understanding of prospective user domains.

RQ1.3 How does the nature of geovisualization affect the process of establishing context of use from prospective users?

Prospective users who have access to and work with spatial data, have skills in its manipulation, and/or whose tasks involve data exploration, clearly represent better prospective users of a geovisualization application. I develop a set of criteria to differentiate the groups within LCC in order to assess their potential to benefit from geovisualization. These relate to aspects of geovisualization's character - concern with data availability and scope, groups' spatial skills and the extent to which data exploration is part of groups' work. These criteria are obvious and, 'spatial skills' excepted, would be as applicable to information visualization or even exploratory data analysis. A less obvious, human-centered, criterion is the 'enthusiasm' of subjects, which I see as a conflation of rapport, motivation and aspiration (section 3.2.2).

8.2 RESEARCH QUESTION 2

Research question 2 asks: **How well do human-centered approaches concerned with establishing requirements work in an applied geovisualization context? How does the nature of geovisualization affect the process of establishing requirements from prospective users?**

The nature of geovisualization (novelty, complexity, interactive, exploratory nature, its spatial and multiple components) may mean that e**stablishing requirements using a template** - a standard HC approach to bridging the gap (van Wijk, 2006) between the domain experts such as the CDR team, and application designers – may be problematic.

RQ2.1 How well do human-centered approaches concerned with establishing requirements work in an applied geovisualization context?

The direct approach to establishing requirements is by asking prospective users with a template such as Volere, that have been created to facilitate that process. There is **strong evidence** that CDR subjects are unable to contribute answers to direct questions from the Volere about the content or the motivation for such an application. Where 'tangential' Volere questions are asked, then some, limited, insight is obtained, but insufficient to inform a geovisualization designer. The results are similar across all three CDR team members (section 4.3). When one of the CDR subjects has the Volere questions repeated after 18 months of learning about geovisualization, and experience with geovisualization wireframes and prototypes (section 4.3.1 and especially 4.3.2) the Volere template still cannot elicit useful requirements about a future geovisualization application's content.

I recommend that geovisualization researchers avoid the Volere template approach to establishing requirements from subjects. There is good evidence (section 4.3.1.1) that the proposition of a geovisualization application does not elicit requirements from subjects, whose responses indicate its "undreamed of" nature. Nevertheless, the Volere template might help researchers by providing a long 'check list' of issues, and yielding additional context of use information. The kind of information a designer needs to build a geovisualization application depends on an understanding of the characteristics of subject s' data and associated metadata – spatial and attribute (and possibly temporal). This is not implicit in the Volere template and needs to be gathered as a separate exercise.

RQ2.2 How might human-centered approaches concerned with establishing requirements work in an applied geovisualization context be changed?

Volere lacks any clear thrust towards asking about subject data, and by extension, using it as a way to get subjects to talk about the ways to visualize it, which is a particular weakness in the context of geovisualization.

RQ2.3 How does the nature of geovisualization affect the process of establishing requirements from prospective users?

The findings obtained and outlined in section 4.3 are a combination of the CDR domain, the nature of geovisualization, and the approach employed by the Volere template. Since Volere enjoys success elsewhere, and the crime and disorder domain benefits from successful commercial and open source applications, **it is probable** that it is the particular nature of geovisualization that is the issue. The failure of Volere to establish substantive geovisualization requirements means that alternative methods of elicitation are needed to move forward to the design of a geovisualization application, which are addressed in the responses to research question 3.

8.3 RESEARCH QUESTION 3

Research question 3 asks: **How well do human-centered approaches concerned with mediating between the geovisualization domain and prospective users work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of mediation between the geovisualization domain and prospective users?**

The response to this research question focuses on two approaches. The first attempts to communicate the context of the CDR subjects to geovisualization experts with a scenario in the expectation that their collective suggestions would form a basis for alternative requirements – a way forward for the designer of a geovisualization application for these subjects. The second attempts to inform the subjects about geovisualization through a lecture so that they have sufficient knowledge to be able to suggest what tools and interactions might be useful for the exploratory work.

RQ3.1 How well do human-centered approaches concerned with mediating between the geovisualization domain and prospective users work in an applied geovisualization context?

Geovisualization experts and a scenario

Creating a scenario based on the CDR context and using it with nine geovisualization experts to elicit their tool and interactions suggestions yields **strong evidence** from transcribed interviews and from questionnaires, of prioritised, concise, coherent and compatible suggestions for which geovisualization tools and interactions to employ (section 4.4.1). The top ranked interactions and tools suggested by the geovisualization experts are: aggregating, zooming, filtering, clustering, linking, comparing, symbolising and classifying. (interactions); map, density/hot spots, cartograms, spreadsheet/table/grid, animation, parallel coordinate plot, small multiples and histograms (tools).

Many of these have a wider scope than other, less lowly ranked suggestions, and it is possible that experts' suggestions may be for that reason rather than the particular needs of the CDR team. There is also the possibility that the suggestions might favour those that have a historical connection with use in a crime context. This needs further research to untangle these factors. With these caveats in mind, it is nevertheless possible to combine the advice of multiple geovisualization experts into a coherent and concise statement that might be useful advice to a designer (if the designer was a different person from the one carrying out the enquiry with the geovisualization experts).

I recommend that geovisualization designers should consider the use of scenarios to describe subject context of use, as they usefully concentrate such information in an accessible way.

I commend novice geovisualization designers use scenarios as a way to convey context-of use information to one or more geovisualization experts as a prelude to using them to suggest context-appropriate geovisualization tools and interactions

I recommend that **further research** is conducted to see if multiple geovisualization experts' suggestions for particular tools and interactions are focused on subject needs, or on simply popular and/or widely scoped tools and interactions.

Geovisualization lecture

There is **good evidence** that delivering a lecture on geovisualization to subjects and immediately asking them to identify possible useful tools and interactions for domain exploratory work using a card sort **fails** to do so (section 4.5.1). Subjects appear overwhelmed by the possibilities of geovisualization and cannot differentiate usefully between them. The card sorting approach does have merit in eliciting information on the effectiveness of communicating geovisualization.

There is **good evidence** that delivering a lecture on geovisualization to subjects and asking them to sketch domain-related applications to identify possible useful tools and interactions for specific domain tasks **fails** to produce meaningful results (section 4.5.1). The technique itself, allied to a count of tools and interactions within sketches, does have merit as a way of eliciting information on the effectiveness of communicating geovisualization in this way.

There is **good evidence** that asking subjects to recall geovisualization tools and interactions after a fortnight from the lecture (section 4.5.2) **fails** to elicit more than a very small number of tools, indicating that communication of geovisualization via a lecture format does not work in the case of these subjects and the particular lecture given to them. Nevertheless, the recall approach does have merit in eliciting information on the effectiveness of communicating geovisualization.

I recommend that researchers be cautious in attempting to bridge the gap between themselves and domain experts by using a lecture format to educate domain experts in geovisualization tools and interactions.

I recommend that researchers use card sorting on domain tasks, domain task sketches and recall interviews as useful techniques to understand the success or otherwise of communication efforts.

RQ3.2 How might human-centered approaches concerned with mediating between the geovisualization domain and prospective users be changed?

Geovisualization experts and a scenario

While the scenario was useful in aiding geovisualization experts' understanding of many aspects of the subjects' context of use, there is **strong evidence** from the summative questions asked of the nine geovisualization experts (section 4.4.3) and from comments made by at least one geovisualization expert during the interviews (section 4.4.2) that indicate the importance of supplemental information such as maps and a geovisualization tools and interactions 'crib sheet', but in particular subject data and metadata. There is particularly **good evidence** (section 4.4.3.2) that data/metadata is important to the geovisualization experts as they **all** consult it to supplement the scenario.

This suggests that **when used in a geovisualization context, the HC scenario approach should be modified** to include this supplemental information, especially domain data and metadata. The scenario, by itself, is not as effective a vehicle to help geovisualization experts make suggestions that might lead to a application for the CDR team as the scenario plus the interview process that provided additional opportunities for interaction and supplemental information in the form of data/metadata, maps, and a tools and a techniques 'crib sheet'.

I strongly recommend that the use of scenarios in a geovisualization context should be supplemented with information on subject data and metadata, and where appropriate, spatial data on subjects local geography structure. Having a list of tools and techniques used successfully in the past can be a useful aid to memory and to nomenclature.

RQ3.3 How does the nature of geovisualization affect the process of mediation between the geovisualization domain and prospective users, and vice versa?

There is **good evidence** (section 4.4.3.3) that geovisualization experts express their ideas differently and have different starting points when addressing a geovisualization problem – some data-centred, some task and data-centred, and some tool-centred. Some experts also have a strong preference for communicating ideas in the form of sketches whereas others are content with speech alone. This suggests that awareness of personal styles might be important in interactions when experts work with each other or with subjects with other experts or domain subjects (sections 4.4.2 and 4.4.3)

There is **some evidence** (section 4.4.1.3) that geovisualization experts do not tend to recommend the use of existing applications.

I **recommend** that geovisualization experts should take account of their personal styles of approaching the creation of geovisualization applications and/or communicating information about them, when interacting with other experts or subjects.

8.4 RESEARCH QUESTION 4

Research question 4 asks: **RQ4: How well do human-centered approaches concerned with design work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of design of geovisualization applications with prospective users?**

RQ4.1: How well do human-centered approaches concerned with design work in an applied geovisualization context?
The breadth and multi-disciplinary nature of both the human-centred and geovisualization domains makes design guidance hard to assimilate and to apply (section 5.2.2)

There is **strong evidence** that the CDR subjects interacted effectively with the wireframes given the quantitative (section 5.3) and qualitative (sections 5.3.1 – 5.3.3) evidence of their verbal commentaries containing approving remarks, ideas, limitations identified, opinions about, and queries on, the wireframes.

Another indicator of how CDR subjects could interact with the wireframes might be the extent to which they made amendments, additional sketches, or the like when encouraged to do so on the paper wireframes, as this is indicative of the 'preliminary' and 'throw away' nature of wireframe prototypes. While subjects were encouraged to do this verbally and by the provision of pencils 'for scribbling', there is **good evidence** (section 5.3.4) that they did not interact with the wireframes in this way as not one of them wrote anything on the wireframes at any time during the sessions. This indicates that perhaps the wireframes were 'too finished' and their production values discouraged emendation, or perhaps the CDR team may be similar to some of the geovisualization experts of section 4.4 who prefer to communicate their ideas exclusively verbally, and not like those who prefer to sketch their ideas. Certainly, the CDR subjects found the sketching exercise they undertook themselves (section 4.5.4) difficult and fatiguing.

When choosing which wireframe design they wished to pursue, two of the CDR subjects gave reasons for their choices that indicated how strongly their choices were rooted in their context and current tool use. Hence there is **good evidence** that geovisualization design is situated firmly in potential user context of use and data in context (see section 5.3.3.3).

Wireframe 2 generated twice as many ideas from the CDR subjects as Wireframe 1. While this could be a learning effect (Wireframe 2 sessions followed Wireframe 1 sessions), some other aspects of Wireframe 2 may account for this large difference. These could be that it:

- employed a means of exploring data temporally using a novel tool in the form of the time glyphs
- enabled exploration of a wider range of data, spatially, temporally and by crime attribute
- integrated tools for space, time and attribute more densely by superimposing these elements within a strong spatial framework

These are all plausible factors that contribute a number of different, confounding aspects. It would be possible to conceive of experiments that could tease out which individual factors – such as data density, strong spatiality, inclusion of novel tools, inclusion of temporal data - are more important in eliciting engagement and response from domain experts. **I commend** this work for future researchers to pursue.

RQ4.2: How might human-centered approaches concerned with design in an applied geovisualization context be changed?

I found it necessary to modify the wireframe design concept as outlined from the typical human-centred approach to create a 'geovisualization-modified' wireframe design, comprising a typical state for a design in an initial wireframe on a large sheet of paper, supplemented by adding additional sheets containing stand-alone multiples of tool components and of possible tool states.

I commend this 'geovisualization-modified' wireframe design approach to other researchers. However**, I caution** that the 'finished' look of such adapted wireframes may be an inhibiting factor in getting subjects to fully critique designs, evidenced by the reluctance of the CDR subjects to draw/scribble on the wireframe prototype (section 5.3.4). Consequently, additional effort should be expended with subjects to emphasise the provisional and 'throw away' nature of the wireframes.

However, the need for real data in a geovisualization context leads to contradictions in some of the characteristics of wireframes. Real data wireframes take longer to produce than simulated data wireframes, contradicting their 'quick production' nature. Longer production times contradict their 'throw away' and 'unfinished' natures. A wireframe with higher production values may mislead a subject as to its 'finished' state and discourage criticism and interaction. Such a wireframe may lead to a greater degree of attachment in the designer, who may be reluctant to discard it. Clearly, a 'geovisualization-modified' wireframe is different from its unmodified cousin. Yet for all of those differences, there is copious **strong evidence** from many parts of section 5.3 that it nevertheless succeeds in eliciting a rich body of information, of creativity and of understanding, from a group of subjects who have not engaged substantially with the geovisualization possibilities they have been exposed to up to this point in the geovisualization lecture session. Wireframes *do* work in a geovisualization context. However, **I commend that** more work is done in other domains with other assemblages of tools to refine 'geovisualization-modified' wireframes and determine what works well, and what does not.

It is questionable whether the success of the sessions is wholly due to the changes made to the wireframes to reflect the nature of geovisualization. It is likely that a large part is down to the nature of wireframes in general. From the subjects' point of view, they had a small numbers of tools and their possible states explained to them in an interactive, and hopefully supportive, environment. The context of use was their own (crime and disorder reduction), the setting was a familiar spatial area (Loughborough) and they were afforded a long period of time (nearly two hours) to understand and comment. This 'wireframe experience' is a distinct contrast to the 'geovisualization lecture' approach to communication (section 4.2.3) where the same subjects had a very short time to understand an individual tool or interaction, and the context was more abstract. **Some evidence** of the importance of longer exposure to geovisualization within a context that is domain-specific comes from subject C2's complete change of mind on the use of glyphs between the lecture and the wireframe sessions (section 5.3.2.5):

> *"to be honest - now you have reminded my memory - I looked at those [the glyphs] a fortnight ago [at the geovisualisation lecture] and I hated them…I really hated them. I thought they were inelegant, and I thought that they were hard to interpret. But…I mean, [now] I really do like it, because you've got the interaction of it here, I do like it." (C2)*

The comparative success of 'geovisualization-modified' wireframes with subjects suggests that some form of focus on specific tools in the form of early designs and envisaged interactions may be appropriate even earlier in the process of engagement with domain experts – in the requirements phase - given the general failure of the methods used to elicit geovisualization requirements (templating, and a lecture on geovisualization) in this research (see Chapter 4). By extension, the success of 'geovisualization-modified' wireframes bodes well for other collaborative and artefact-rich processes such as different forms of prototyping, which are explored in Chapter 6.

RQ4.3: How does the nature of geovisualization affect the process of design of geovisualization applications with prospective users?

Consideration of the process of creating an outline design for a geovisualization application (section 5.2.3) leads me to conclude that It would be advantageous to the visualization community if application designers were to expose more of the process that led to the final design to help the learning of others. **I commend** this course of action to them.

Good evidence from section 5.3.4 states that CDR subjects took time to listen to and to understand the tools and their possibilities within each of the wireframes before commenting freely about them. **I recommend** that wireframe sessions with prospective users of an eventual application be of sufficient length to overcome the initial novelty and complexity of geovisualization tools and possible tool states, and permit subjects to query, engage, ideate and criticise the design fully.

Good evidence from two CDR subjects (section 5.3.2.4) reveals the crucial importance of using real data. I found that geovisualization wireframes need to represent the spatial correlation inherent in real data to subjects, who otherwise experience confusion, are puzzled by the absence of known patterns in the data, and as a consequence do not engage well with designs if they are presented with dummy data, as this important quote shows:

> *" one of the things that is perhaps hampering my limited imagination is because it is random data…I immediately try and make sense of it, kind of thing. 'Ah, theft from vehicles is very similar to…oh no it isn't - it's just random'. I immediately start to try to interpret it instead of just trying to leave it at the level of [an example]… (C1)*

It is not clear from this current research whether data has to be the subjects' own real data, or simply real data from the domain in general (for example crime data from another part of the UK). But it is clear it must be real data. Only real data carries the subtle but important spatial correlation artefacts of the First Law of Geography (Tobler, 1970) that these subjects expect to find in thematic maps of real data, and, by extension, the spatial patterns they expect to see that reflect temporal correlations in the glyphs of real data.

A **key finding** is therefore that the use of real user data is important to attract user engagement in geovisualization wireframe prototyping and **I strongly recommend** that researchers use real and not dummy data in their interactions with subjects from the earliest possible point. This implies gaining access to subject data as close to the beginning of the relationship between geovisualization designers and domain experts (see also section 3.5.3).

The striking difference in response from subjects between the geovisualization lecture (section 4.5) and the wireframing raises the question of which factors are responsible. For example, whether it is because the wireframes had more detail, less abstraction, more spatiality or presented fewer but more relevant images to subjects. **I commend** this as **useful work for future researchers to pursue**.

8.5 RESEARCH QUESTION 5

Research question 5 asks: **How well do human-centered approaches concerned with prototyping work in an applied geovisualization context; how might they be changed? How does the nature of geovisualization affect the process of prototyping of geovisualization applications with prospective users?**

The results from the user testing with active intervention in CDR, free exploration with the digital interactive prototype in CDR, and free exploration with SomVis 'as a digital interactive prototype' in LCC Libraries are given in sections 6.3.4, 6.3.7 and 6.3.9, respectively, along with the references to the evidence. These voluminous results will not be repeated in as much detail in this concluding section, which highlights the main findings and recommendations.

RQ5.1 How well do human-centered approaches concerned with prototyping work in an applied geovisualization context?

1 Paper prototype with user testing, active intervention and chauffeured interface (CDR subjects) – case number 8

Speed , and the presence of **the treemap** are the **perceived strengths of the paper prototype; Inflexibility** of the paper prototype is **a weakness** (**some evidence** from section 6.3.3),

The paper prototype in this case produces more than twice as many suggestions for improvement that are related to 'new' features (a category that includes novel geovisualization elements) (**good evidence** from section 6.3.1.3, Table 6.19 and from the details of the user testing think aloud transcripts (section 6.3.2)).

There is **some evidence** from individual subjects that:

- the paper prototype is **capable of driving spontaneous desire to explore data (**section 6.3.2.1),
- the paper prototype **promotes reflection on current work practices (**section 6.3.2.3),
- paper prototyping can **replicate the shortage of screen 'real estate'** that would occur with a computer-based application (section 6.3.2.1),
- subjects use and integrate both the piece of paper bearing the thematic map/glyphs and the piece of paper bearing the treemap/glyphs, demonstrating **the flexibility of**

the paper prototype to handle multiple tool representations (sections 6.3.2.1 and 6.3.2.1)

- **subjects' sometimes need knowledge about areas on the map and additional attribute data** (such as initiatives to reduce crime and disorder) to create hypotheses of what are the causes of a pattern of crime (sections 6.3.2.1 and 6.3.2.1),
- what is learned from the prototype is **data-dependent** – that is, it is a combination of prototype *and* data (section 6.3.2.2).
- **different subjects have different responses in a geovisualization situation as they hold different (tacit) spatial knowledge** (section 6.3.2.3)

The relative success of paper prototyping in user testing is in line with the findings of Virzi, Sokolov and Karis (1996), Catani and Biers (1998), Walker, Takayama and Landay (2002) and Lim et al (2006). It does not support of work of Liu and Khooshabeh (2003) who found that "interactive prototype captured the same usability issues that the paper prototype studies did and more" (see section 6.2.1.1). Snyder (2003) cautions "complex or subtle interaction usually can't be simulated perfectly" with paper prototyping. But by using real subject data, high quality graphics and by confining subjects to a limited number of screens with realistic tasks, paper has not been at a disadvantage.

2 Digital interactive prototype with user testing, active intervention and chauffeured interface (CDR subjects) – case number 9

Digital interactive prototyping is successful at engaging subjects, eliciting exploration activity, hypothesis forming and establishing possible improvements with a user-testing with active intervention protocol, and with a free exploration protocol (**good evidence** from sections 6.3.2.1 – 6.3.2.3)

The digital interactive prototype's strong points over the paper prototype are its **ease**, **clarity** and **excitement/appearance** (**some evidence** from section 6.3.3).

Some evidence, in this case, C3's familiarity with Loughborough shows, that **the general process of exploration is influenced by prior knowledge**, so this plays a part in changing the subject's interaction with the digital interactive prototype (section 6.3.2.1)

3 Paper and digital interactive prototypes with user testing, active intervention and chauffeured interface (CDR subjects) – case number 10

There is **strong evidence** from individual subjects that in this case both paper and digital interactive prototypes generate **considerable breadth of engagement, hypothesis formation, exploration, ideation/insights and for expectations to be confirmed or confounded** (evidence from counts of coded think aloud and from the details of the user testing think aloud transcripts, sections 6.3.2.1 to 6.3.2.5),

Subjects indicate an overall **positive view of the prototypes** using words such as **interesting, insightful, useful, exciting, enjoyable, thought provoking** and **inspiring** (**good evidence** from section 6.3.3)

Subjects' main negative response to the prototyping sessions are related to tiredness and fatigue, partially due to the length and intensity of sessions, and partly to the repetitive nature of the tasks (**good evidence** from section 6.3.3).

Paper and digital interactive prototypes yield similar numbers and types of exploratory information within an 'active intervention' user-testing protocol (evidence from section 6.3.1.1, Table 6.10)

Within an 'active intervention' user-testing protocol, the **paper prototype yields more suggestions for improvement than the digital interactive prototype except for interface-related improvements** (statistically significant at 0.05 significance level) (evidence from section 6.3.1.2, Table 6.15 and section 6.3.1.3, Tables 6.19 and 6.20).

User testing with active intervention is particularly poor at producing implicit suggestions for improvement (evidence from section 6.3.1.2, Table 6.17, for both paper and digital interactive prototypes)

All CDR subjects have 'data-related' suggestions for improvement as a predominant category. The other three categories (interface-, interaction- and new-related) have more of a range (evidence from Table 6.21, section 6.3.1.3).

Subjects' perception is that the **paper prototype had the edge over the digital interactive prototype in terms of speed** (**good evidence** from section 6.3.3),

The process of being exposed to geovisualization prototypes has led to changes in thinking about the approach to the work of this team (**some evidence** from section 6.3.3).

Hands-on experience of working with prototypes enables **requirements to be established** (**some evidence** from section 6.3.3),

The user testing protocol limits subjects to tools and tasks and interferes with the exploration process (**some evidence** from section 6.3.3)

4 Digital interactive prototype with free exploration (CDR subject C3) – case number 11
There is good evidence from a large number of quotations from the free exploration (section 6.3.5.1) show **a significant depth of interaction, engagement, exploration and fluidity and rapidity with the digital interactive prototype with a free exploration protocol**.

There is some evidence from the summative questions (section 6.3.6) to using the digital interactive prototype in a free exploration way is that it is **flexible**, **enjoyable** and **engaging,** and that **the tutorial and controls crib sheet were adequate to operate the digital interactive prototype**.

5 Digital interactive prototype with user testing, active intervention, chauffeured interface v free exploration (CDR subjects) – case number 12
The overall **level of exploration in free exploration is over twice the level observed in user testing** in a session that lasted about the same time as the user testing with active intervention session (**good evidence** from section 6.3.1.1, Table 6.13)

There is a difference in C3's geovisualization exploration of the digital interactive prototype with the two different protocols, with **more possible improvements emerging in the free exploration, and markedly more implicit suggestions** (statistically significant at 0.05 significance level; **good evidence** from section 6.3.1.2, Table 6.18). While statistically significant, this finding must be bear a caveat given C3's role in the CDR team as the GIS expert, and possessing a good knowledge of the geography of the area featured in the prototypes.

In **some evidence** from the summative questions (section 6.3.6), C3 believes **the main differences between the user-testing and free exploration protocols are speed, control/flexibility, realism and less constraint on what the user wants to do**. The enabling of browser zoom and pan in the free exploration clearly plays a part in this.

6 Digital interactive prototype with free exploration in collaborative session (Library subjects) – case number 13

There is **some evidence** from their free exploration think aloud and from the questionnaire, that such r**ecording of findings by subjects is a bottleneck to exploration** (section 6.3.8.1.2).

The free exploration session with three **collaborating** subjects has strengths and weaknesses. The **strengths** include evidence from the free exploration think aloud of:

- **untested assertions made by one subject that can be challenged or corrected by others** (**good evidence** from sections 6.3.8.1.2 and 6.3.8.1.3)
- **systematic approaches** to the session are articulated and made explicit by one subject for the benefit of the team (**some evidence** from section 6.3.8.1.2)

The **weaknesses** include **some evidence** from the free exploration think aloud of:

- **the disjointed nature of subjects' narratives** for the purposes of attribution and analysis (section 6.3.8.1.2)
- **the need to articulate and agree aspects that would not occur with a solo subject** (for example, whether a line or circle is referenced by everyone as 'red', as occurred in section 6.3.8.1.2)

A number of responses to the summative group questions illustrate **aspects of the library subjects context in use that were not apparent earlier in the process**. **This demonstrates that such context information is not just disclosed at an early stage of the ISO 13407 process**. These include **some evidence** of:

- **the need for buy-in by subjects' management**, as they can switch resources away from exploration unless they are convinced of the benefits (section 6.3.8.3.3),
- **the practical difficulties of introducing radically new methods in a team resourced on the basis of current, periodic tasks** (section 6.3.8.3.3).

- a **contextual factor that determines how subjects respond to prototypes is their perception of how these might contribute to a positive change to their work situation**. (section 6.3.8.3.6)

There is **good evidence** from individual questionnaires (section 6.3.8.2) that **the subjects find SomVis fast, easy to learn and use, easy to select variables, weightings and SOM size with, and easy to interpret the component tools. All subjects believe the use of real data is very important.**

In the summative group question session, there is **good evidence** of further **indications of the extent to which the library subjects are engaging with a geovisualization 'prototype' -** two quotes (sections 6.3.8.3.1 and 6.3.8.3.3) indicate that **the library subjects value the ability to combine multiple tools and display results simultaneously** – an essential interactive feature of a geovisualization application.

L1 had the expectation before the data session that preceded the SomVis session that any clusters found would be spatial in nature. However, during the SomVis exploration, such instances occurred only twice, as evidenced by the free exploration think aloud (some evidence from 6.3.8.1.1 and 6.3.8.3.3). During the summative group questions (section 6.3.8.3.4) L1 believes no spatiality was discovered at all.
This shows **the importance of triangulating evidence from multiple sources,** and in particular**, not relying on summative evidence alone.**

As well as evidence from subjects' use of SomVis from the free exploration, the summative group questions give an insight into the understanding of, and learning from, SomVis. There is **some evidence** that L1 demonstrates **an understanding the exploratory nature of the SomVis 'prototype'** (section 6.3.8.3.3) - that it is not a tool for presenting results and that a different process is needed to communicate discoveries. There is also **good evidence** from the same source and the individual questionnaires that **the subjects feel confident in being able to run SomVis themselves in the future**, and are clear about the scale of the on-going exploration task (section 6.3.8.3.6)

For the library subjects, the **components of success include working with their own, real data, on a highly focused task, with simple outcomes** (discovering clusters). There is **good evidence** for this comes from summative group questions (section 6.3.8.3.6). To get to this point, **it was not necessary to provide a lecture on geovisualization, or work with subjects over an extended time period** (as with the CDR subjects).

7 Digital interactive prototypes with free exploration (CDR subject C3 and Library subjects) – case number 14

In spite of large differences of subjects, number of participants, prototypes and tasks, there are a good number of similarities between the free exploration of the crime digital interactive prototype and the SomVis 'prototype' used by the libraries subjects:

Methodologically there were problems with think aloud in both C3 and L123 sessions. In the CDR session, there is **some evidence** that **the think aloud struggles when the subject is focused intently** (section 6.3.3.5). In the libraries session, there is **some evidence** that think aloud suffers from **the disjointed nature of subjects' narratives** (section 6.3.8.1.2).

The count of exploration recorded by the three library subjects ('L123') is statistically indistinguishable from the 'free exploration' conducted by C3 with the CDR digital interactive prototype (see Table 6.14)

The need for structure is noted in **some evidence** from subject C3's comments during free exploration that **the almost endless exploration possibilities need discipline to conduct explorations in a systematic way** (section 6.3.5.2). This need for structure is also noted in **some evidence** from the libraries free exploration think aloud and from the questionnaire, that **recording of findings by subjects is a bottleneck to exploration** (section 6.3.8.1.2).

There is **good evidence** from both the CDR (sections 6.3.5.2 and 6.3.5.4) and libraries (sections 6.3.8.1.2 and 6.3.8.1.3) free explorations that **detailed domain knowledge is needed to make hypotheses about, and extract meaning from, the patterns observed in the data**.

There is **good evidence** from both the CDR and libraries of examples of the situated context of these subjects that may affect their response to geovisualization prototypes. In the case of CDR it is how the **choices made in geovisualization exploration may have a real impact on decisions that affect policy** (section 6.3.5.1 and 6.3.5.2). In the libraries case, **the need for buy-in by subjects' management** (section 6.3.8.3.3), the **practical difficulties of introducing**

radically new methods in a team resourced on the basis of current, periodic tasks (section 6.3.8.3.3 and 6.3.8.3.6) and **their perception of how these might contribute to a positive change to their work situation** (section 6.3.8.3.6).

There is **good evidence** from a large number of quotations from the CDR free exploration (section 6.3.5.1) that show **a significant depth of interaction, engagement and exploration** with the CDR digital interactive prototype with the free exploration protocol. Similarly, there is **good evidence** from a large number of quotations from the libraries free exploration (sections 6.3.8.1.1, 6.3.8.1.2 and 6.3.8.1.3) of **exploration, hypothesis forming, confirming expectations, rich ideation** and **insight** with the SomVis 'prototype' with the free exploration protocol. The libraries team finds and names clusters of library borrowers.

There is **good evidence** that both the libraries subjects (section 6.3.8.1.3) and CDR subject C3 (section 6.3.51) **gain fluency and speed** with their respective free exploration prototypes.

In **some evidence** from the CDR free exploration, **geovisualization possibilities generate data exploration possibilities** (section 6.3.5.1):*"I have been drawn into these [areas] by being able to manipulate the resolution of the data…"* Similarly (section 6.3.6) C3 **when engages with a spatial pattern in free exploration the effect is to focus the attention** ("*the more you go on with it, the more you get sucked into particular areas*"). In the libraries case, there is **some evidence** showing **deep engagement with the patterns of clusters** (section 6.3.8.1.3), although these are not spatially based, as in the CDR case.

There is **good evidence** that both C3 (section 6.3.6) and the libraries subjects (section 6.3.8.2) believe it is important to use real data in the prototypes.

The positive and (where given) negative feelings about the two free exploration prototyping sessions are shown in Table 6.18. Feelings recorded in the CDR user testing sessions are also included. Both free exploration sessions contain far fewer negative adjectives than occur in **the user testing sessions,** which **were clearly more taxing and intimidating**.

RQ5.2 How might human-centered approaches concerned with prototyping work in an applied geovisualization context be changed?

The paper and digital interactive prototypes work well in producing both suggestions for improvements and a rich subject involvement with copious examples of exploration, hypothesis forming, ideation/insight, and confirming and confounding expectations.

However, while the success of the paper prototype in eliciting both exploratory activity and suggested improvements from the CDR subjects is encouraging, it is important to recall that it relies on a system to produce multiple paper representation containing real subject data. In practice, this has meant that the paper prototype relies on the prior existence of the digital interactive prototype. While this is acceptable in a test situation, it is impractical for wider use as a technique, unless it brings some special advantages over presenting essential the same material as a digital interactive prototype. These might include its less intimidating nature with subjects. However, this advantages makes a poor case for 'real data paper prototyping' as a viable 'real world' approach.

The user testing protocol with active intervention requires task construction by the researcher. Understanding of subject context of use has been shown in Chapters 4 and 5 and in this chapter to be a communications process that is not finalised in the first ISO 13407 phase. There is a possibility that tasks may not be fully understood and lead to problems in prototype user testing. User testing also requires more resources to administer especially where a 'Computer' undertakes interface control, and this also affects speed of operating the prototype for the subject and places a barrier between the subject and the prototype.

Free exploration yields the same quantity of result (section 6.3, Table 6.9) but without interposing the experimenter between the subject and the prototype, and needs fewer resources to administer. The task can be selected by the subject within parameters selected by the researcher). While it is necessary to tutor the subject in operating the interface to the prototype this was not a problem in practice in either the CDR or the Libraries cases.

The free exploration protocol is perceived to have advantages of fluidity, rapidity and less constraint over the user-testing with active intervention protocol for CDR. There is a difference in C3's geovisualization exploration of the digital interactive prototype with the two different protocols, with **more 'possible improvements' emerging in the free exploration, and markedly more implicit suggestions** (statistically significant at 0.05 significance level; evidence from Table 6.18)

The results from the library users show that they generate considerable exploratory activity in a free exploration protocol with the SomVis 'prototype', and succeed in identifying (non-spatial) clusters of borrowers they consider meaningful. Understanding context and explaining tailored geovisualization tool approaches in the context of subjects' data is sufficient for these subjects to use even sophisticated visualization tools in a free exploration environment. This is dependent on providing adequate support and may indicate that it is the **quality** of the communication between researcher and subject that is important, and not necessarily communication over a **long period**.

RQ5.3 How does the nature of geovisualization affect the process of prototyping of geovisualization applications with prospective users?

Work with prototypes in a user-testing environment with active intervention, and free exploration in two domains, produces further evidence for conclusions drawn in earlier chapters on:

- **the importance of real data**.
- **the importance of domain knowledge** (especially as tasks become more complex)
- **the emerging context of subjects and their data**

There is now **very strong evidence** to support **the importance of real data** to subjects from different subjects, in different domains, with different prototypes and different protocols (see RQ5.1 for evidence sources).

There is now **strong evidence** from frequent instances that **detailed domain knowledge is needed to make hypotheses about, and extract meaning from, the patterns observed in the data** (see RQ5.1 for evidence sources).

There is **good evidence** from section 6.3.3 that **not all crimes are equally important to subjects** and some categories are relatively unexplored. Some crimes are more interesting than others, but this is not tacit knowledge (see RQ5.1 for evidence sources).

Methodologically, the work with both CDR prototypes and both protocols reveals:

- **the importance of the attribute information conveyed by the background map**
- subject behaviour in arguing from pattern to map

And the work in both domains reveals:

- **think aloud limitations when thoughts are sharply focused**
- **the influence of prior knowledge on exploration**

(see RQ5.1 for evidence sources).

Examining Table 6.18 (section 6.3.9.2) highlights two negative aspects experienced by the CDR subjects around the user testing. These are that the tests were tiring/fatiguing, and that they were daunting/induced apprehension.

The first of these implies the user tests were too long. I consider that this is a problem that stems from using domain experts in a protocol that typically uses recruited subjects (see my analysis of visualization literature with human-centered approaches in section 1.3.2). Such subjects are expensive to recruit but are essentially interchangeable - the clock is reset with each new subject. But the domain experts are not interchangeable. A long sequence of interviews, questions, observations, geovisualization wireframe and prototyping sessions, even over a long period span of time, places a large burden on these domain expert subjects. Most of the interactions with these domain expert subjects are 'one shot' – the act of showing a wireframe or a prototype changes subjects' perceptions. They cannot be taken back and become 'unseen'. Consequently, there is going to be a balance between trying to extract as much as possible from these unique subjects, and exhausting them, perhaps to the point of them withdrawing their cooperation.

The second of these points refers to apprehension of, and being daunted by, the user testing. My view on this is that in choosing user testing as an approach, even with active intervention as a 'helpful' protocol, I had not given enough thought to the nature of user testing. As I have said above, it is a protocol that typically uses recruited subjects. To motivate such recruits often payment or (for students) credits are offered as inducements. I was expecting the domain expert subjects to undertake user testing encouraged by nothing more than my assumption of their motivation to contribute to my research questions. To compound matters, they were not permitted to control the interface to the prototypes. Contrast this experience to the free exploration with both C3 and the libraries subjects. Here both were allowed to choosing the data/task, and control the interface to their prototypes themselves.

I believe that user testing as an approach may be fundamentally at odds with the notion of 'partnering' with domain experts and attempting to understand their context of use over a long period of time. This touches on a wider theme of the power balance between the subject and the researcher that I discuss in Chapter 9.

RECOMMENDATIONS

I strongly recommend visualization researchers use **real subject data.** However, **I caution** that the use of real subject data in a paper prototype entails an effort that may negate its usefulness as a 'real world' technique.

I recommend that geovisualization researchers should consider the use of both paper and digital interactive prototypes in both user testing with active intervention, and free exploration protocols, subject to considering (a) the impact of the need for real user data on paper prototypes, and (b) the appropriateness of user testing with domain expert subjects.

I recommend both paper and digital interactive prototyping in user testing with an active intervention protocol as a way to communicate geovisualization ideas to subjects and elicit exploratory responses from them in a user-testing environment with an active intervention approach. Both prototypes have advantages, and both can contribute to the process of iterating towards a final geovisualization application. However, this is subject to the caveats concerning (a) the impact of the need for real user data on paper prototypes, and (b) the appropriateness of user testing with domain expert subjects.

I particularly recommend paper prototype in user testing with an active intervention protocol for improvement suggestions. However, this is subject to the caveats concerning (a) the impact of the need for real user data on paper prototypes, and (b) the appropriateness of user testing with domain expert subjects.

I particularly recommend the paper prototype in user testing with an active intervention protocol for improvement suggestions related to novel tools/interactions for use in geovisualization. However, this is subject to the caveats concerning (a) the impact of the need for real user data on paper prototypes, and (b) the appropriateness of user testing with domain expert subjects.

I recommend that researchers should be mindful of the impact of interfaces to geovisualization prototypes that are not under the control of users, as the perception of a prototype will be a composite of the prototype itself plus its interface.

I recommend that researchers would be advised to ask future subjects at the 'Context of Use' stage whether they find different parts of their domain data more interesting than others, and if so, why. **I further recommend** that researchers expect, look out for, record and consider new contextual information from their subjects during prototyping sessions, as such information arises not just in the initial Context of Use phase.

I recommend future geovisualization researchers should note that transcription of audio is arduous and that having a well trained 'note taking observer' to record pertinent subject commentary in real time will be faster and far less effort.

I recommend that geovisualization researchers consider the ways they can effectively persuade prospective subjects' stakeholders of the benefits of exploration and 'exploration through visualization' to gain commitment by learning what subjects and their managers value from contextual dialogues with them.

I recommend future researchers working with domain experts take care to ensure that the origin of freely available software employed is concealed to ensure subjects do not access it directly outside any experimental sessions.

I caution that user testing results are valid **only within an active intervention protocol** as part of prototyping an application, and **not as a summative evaluation** of a final application.

I propose that it would be an instructive piece of research to compare subject use of a geovisualization prototype with 'real, own data' and with 'real, other people's same-domain data' to understand better the relative importance of these factors.

8.6 RESEARCH QUESTION 6

RQ6.1: How well do human-centered approaches concerned with the process of prioritising possible improvements to geovisualization applications work in an applied geovisualization context?

1 Analytical Hierarchy Process

With the limited number of subjects available, the AHP produces results that are rich in detail (rankings, consistency, dispersion) and indicate plausible results. CDR subjects' priorities are skewed towards 'data-related' improvements and against 'new-related' items. D's priorities are more evenly distributed, and incline towards 'interaction related' and against 'interface related' choices . There are marked similarities in the rankings of the 35 possible improvements prioritised by the two CDR subjects (Pearson coefficient 0.50, significant at 0.01 level; 2 tailed, n=35). Developer D's rankings are different from both CDR subjects' rankings as indicated by non-significant Pearson coefficients (see Figure 7.5) despite the high levels of engagement between the CDR subjects and the geovisualization expert/developer throughout the development process. Geovisualization applications are predominantly 'expert' driven (Fuhrmann et al., 2005) and so **the discrepancies in terms of priorities are a finding that should be explored further to see if it is replicated with other subjects and geovisualization tool developers**.

From Table 7.3, the AHP consistency ratios for C2, C3 and D range from 0.03 to 0.21 for data-, interface- and interaction-related possible improvements, but the **consistency ratio results from the 'new-related' group (which contains novel geovisualization tools) are noticeably less consistent**, ranging from 0.43 to 0.69. C2's dispersion as measured by the Gini coefficient, is lower than C3's and D's - C2: 0.27; C3: 0.48; D: 0.42. **While the two CDR subjects have very different dispersions and different consistency ratios, their rankings are indistinguishable**.

There is **good evidence** (section 7.3.3) that the AHP process is acceptable to the CDR subjects, but less so by the developer D, who found it somewhat tedious to complete. If the AHP is used in future by geovisualization researchers, **a reduced list of possible improvements to the one employed here (and hence reduced number of pair-wise comparisons) will be less demanding.**

If 'often mentioned' suggestions from individual CDR subject's implicit and explicit suggestions made during prototyping (see section 6.2.4.1) become 'highly ranked' possible improvements in the AHP, then the AHP process might be wholly or partially redundant. However, there is **no**

evidence of this (section 7.3.2, Table 7.5). The implications from this are that subject suggestions during prototyping should be taken as just that – suggestions. **Until they are refined and prioritised, suggestions should not be regarded as 'requirements' for a developer to build into the next iteration**. However, such **refining and prioritisation need not be conducted as the lengthy aggregation of suggestions coupled to a decision-making process such as the AHP**, **but could be more informal**. For example in collaborative sessions with many subjects, suggestions could be captured as they arise (perhaps on sticky notes attached to a board) and later in the same session categorised, discussed and prioritised by participants (perhaps by subjects and geovisualization expert/developers together) until a consensus on priorities emerges. A human-centered technique - **affinity diagramming** (Beyer and Holtzblatt, 1997) - could be used for the categorisation aspect, and has already been employed in a geovisualization context (Marsh, 2007).

The explicit introduction of a system variable such as speed of response as a trade-off for functionality is plainly a useful comparison for potential users of a visualization application to consider. As Andrienko et al (2005) point out, the development of geovisualization applications and tools is partly driven by "New technology [that] continues to appear and…often enables us to do things that were not possible before." But the speed-functionality trade-off is likely to remain an issue, especially where - as in the case of the digital interactive prototype –a remote server is interrogated for temporal, spatial and attribute data that must be recalculated before display. Clearly, subjects in this case were prepared to forego a 50% speed increase for some functionality, but **visualization researchers may wish to probe at what point what functionality *is* traded for speed**.

2 Costing possible improvements for a geovisualization prototype

The 35 possible improvements that form the basis for a developer to work up estimates of the time needed for implementation are far from well-specified, complete and 'signed off' requirements. They contain many ambiguities, do not precisely specify outcomes, are not scoped to constrain development to a particular facet or facets of the proposed improvement, and they are vaguely worded, reflecting the reality of the origin of these possible improvements. As a consequence, these **inputs of ambiguity, vagueness and lack of specificity are manifest in the outputs of the geovisualization developer** (Table 7.6). **The developer includes additional elements to indicate the complexities inherent in the process of determining costs, and indicates reservations, possibilities and difficulties in various ways**.

I have made the point that the geovisualization literature is silent about the process of design (section 5.2.1). The geovisualization literature is similarly silent about the process of iterative development in the face of ambiguous subject input on possible improvements. **I commend geovisualization developers expose such processes where possible for the benefit of other researchers**.

3 Karlsson-Ryan Value v Cost plot inspection

The Karlsson-Ryan value v cost plot inspection approach yields plausible prioritised possible improvements for the CDR prototype although visual readings from the plots can be inexact where there is over-plotting.

The optimal development route for C2 and C3 – according the Karlsson-Ryan method – would embrace mainly level 1 with a sprinkling of level 2 and no level 3 developments, and focus – in order - data-related, interaction-related, interface-related developments, and new-related developments. This is a significant conclusion as the 'new-related ' category contains all the geovisualization possible improvements. **This implies that, even after considerable time spent with these subjects communicating geovisualization to them in a number of ways and gaining an increasing understanding of their context of use, they do not prioritise geovisualization development to the CDR prototype.** Recall that this result is derived without reference to the CDR subjects (but see RQ6.2 below).

RQ6.2: How might human-centered approaches concerned with the process of prioritising possible improvements to geovisualization applications be changed?

There is **good evidence** that **the novel human-centered 'knapsack' approach generates prioritised potential developments that are plausible** given CDR subjects' individual AHP ranks and costs of each potential development (Tables 7.7 and 7.8). C2 and C3 choose level 1 with a sprinkling of level 2 and just one level 3 developments, and focus - in order - on data-related (20 out of 48 purchases), interaction-related (13), new-related developments (9), and interface-related developments (6).

The HC knapsack approach with the CDR subjects shows (section 7.6.1, Tables 7.8 – 7.10) the **focus on data-related possible improvements at the expense of the three other categories, including new-related developments**. Again, this is a significant conclusion as the 'new-related' category contains all the geovisualization possible improvements. **This implies that,**

even after considerable time spent with these subjects communicating geovisualization to them in a number of ways, and gaining an increasing understanding of their context of use, the conclusion of their results from HC knapsack approach is that they would wish to see data-related possible improvements prioritised over other categories including 'new related', and hence little geovisualization development to the CDR prototype.

There is **good evidence** (section 7.62, Table 7.11) that the Karlsson-Ryan plot inspection method (that relies only on the subjects' AHP results and the costs of each possible improvement development), provides a good match with the human-centered 'knapsack' approach involving CDR subjects. In this case, **the Karlsson-Ryan plot inspection method suffices as a way of prioritising possible improvements under the constraint of development costs with only the AHP as the only subject input**. In this case, **the additional effort required to conduct an additional human-centered 'knapsack' approach is not justified**.

The summative questions about the HC knapsack process (section 7.6.3) provides:

- **Some evidence** that in spite of the time spent with these subjects, attempting to communicate geovisualization to them, the priorities of C2's day-to-day work are paramount and mean that C2 turns away from the prospect of new-related opportunities including novel geovisualization tools, "*plays safe*" and goes for "*the basic fundamentals*".
- **Some evidence** that C2 found parts of the process "quite difficult" and "quite cumbersome". Fewer possible improvements would help improve matters (as suggested in section 7.3.3).
- **Good evidence** from both C2 and C3 that the HC knapsack process needs adequate time and, where this is not possible, having fewer possible improvements would shorten the time needed.
- **Good evidence** from C2 and C3 that, in thinking about prioritising possible improvements under cost constraint, embrace notions of **sufficing** (that a less than wholly satisfactory outcome due to resource constraint, for example, is nevertheless, sufficient), and of **'all or nothing**' (that some possible improvements are not worth having at all, and those that are worth having should be developed fully).
- **Some evidence** from C3 about the context of these subjects and C3's need to present data to the CDRPs. With many customers, for these subjects saving time in converting exploration output into presentation is important. C3 cannot divorce presentation

from exploration, which geovisualization practitioners see as at the opposite end of the spectrum (DiBiase, 1990).

> *"if you were producing maps of the areas and it was of interest, you could just take a screen dump. And you have not got to do anything with it.Those kind of things are quite important if you're going to pass them on to other people." (C3)*

RQ6.3 How does the nature of geovisualization affect the process of prioritising possible improvements to geovisualization applications with prospective users?

There is strong evidence (Table 7.3) from the high consistency ratios recorded by each of the CDR subjects and developer D with 'new-related' possible improvements (that contain novel geovisualization tools) that some aspect of these **'new-related' possible improvements** leads to far less consistent results with the AHP, and by implication **uncertainty about their relative benefits**. The fact that this effect is noticed in developer D as well as in both CDR subjects, indicates that the effect is not solely due to a lack of understanding on their part.

However, there is **strong evidence** of initial lack of understanding of the **meaning of possible improvements**, **terminology** or **capability** before the AHP session (section 7.3.1.1). **New-related** and **interface-related** terms raised the **most queries**, indicating the areas giving the subjects most trouble with understanding. At one point in the pre-AHP session (section 7.3.1.1), C2 represents the "new-related" group as "*like being in a toy shop [wanting] everything, and it was difficult to differentiate*". In the summative questions after the AHP, C3 comments "*When it came to the "new" developments maybe it would not be that clear how you would apply them - it is a lot more difficult to compare*" and C2 recalls "*when it came to the new ones, you needed to explain all of those, just about, to me*" (section 7.3.3). **Clearly, both C2 and C3 have had difficulties with the "new-related" possible improvements that include novel geovisualization tools**. This echoes the evidence from section 4.5.1, Table 4.8, where C2 (and the other CDR subjects) were unable to differentiate between geovisualization tools/interactions for their work after a geovisualization lecture.

The number of new-related queries resonates with problems communicating geovisualization possibilities to these subjects in the geovisualization lecture (section 4.5). This may point to a fundamental **issue concerning communicating potentially complex notions about visualization in verbal form**. Communicating information about visualization possibilities through words alone - particularly to prospective users who have shown themselves uninterested in visualization *per se* (see section 4.5.2) - may be inappropriate for such a complex domain. As has been stated in other chapters of this research, **alternative approaches to communicating geovisualization to subjects need consideration**.

Developer D expresses a desire for clarity before starting development work in this quotation: "*the ones that were going to be done I would want quite a lot of discussion over what it really meant.*" C2 says that the understanding of the proposed tools is "*a guess on the back of what you are telling me"* and "*I have to have faith in the developer*." (section 7.3.3) These are interesting statements given what has gone before in terms of extensive engagement with these CDR subjects over nearly three years eliciting these possible improvements after many different approaches. The AHP may provide both CDR subjects and D with a ranking that each party considers reasonable, but its apparent ability to prioritise and to capture measures of consistency nevertheless does not provide C2 and developer D with confidence in a concluded dialogue. C2 does not fully understand the tools and comments "*I have to have faith in the developer*"; developer D wants *'quite a lot of discussion'* about what is *really meant* by the list of 35 possible improvements. After engagement with the CDR subjects over a considerable period of time, these statements provide **some further evidence** to support what appears to be an emerging theme of this research **of the difficulty of communicating geovisualization to these potential users, and from them to the geovisualization developer.**

RECOMMENDATIONS

I recommend visualization researchers use the AHP as a human-centred approach to determined unconstrained priorities with subjects.

I recommend that visualization researchers use the Karlsson-Ryan 'value versus cost' plot inspection method in conjunction with the AHP as a systematic way of prioritising developments under cost constraints.

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9.1 MAJOR FINDINGS AND THEIR SIGNIFICANCE

Broadly, the major findings of this research are:

- Subjects respond to their **own real data** in early and later designs (wireframes and paper/digital interactive prototypes, respectively)
- Subjects have **'undreamed-of' requirements** that cannot be effectively established from standard HC approaches (Volere template) or modified approaches (communication via geovisualization lecture)
- Subjects do not respond well to textual or verbal descriptions of geovisualization, but **respond very well to tangible visual artefacts** such as wireframe, paper and digital interactive prototypes, containing real user data.
- Some **HC approaches work well** – useful techniques for understanding subject context of use; for prioritising improvements to a geovisualization prototype; for comparing subjects' and a geovisualization expert/developer's conceptual worlds.

9.1.1 SUBJECTS' REAL DATA

A key finding from chapter 3 is that geovisualization researchers working with subjects to understand their context of use should recognise explicitly that they must understand both the context of prospective users *and* their data in context. Work with the CDR subjects on wireframes in Chapter 5, corroborated in Chapter 6, shows the crucial importance of real domain data. The value of using real data has been noted by Plaisant (2004): "Using real datasets with more than a few items, and demonstrating realistic tasks is important" and more recently by Todd et al (2008): "Real data testing is not for every project. It requires more time and effort from the team (and sometimes even from the participants). The cost-benefit ratio can be compelling, however…" The significance of my research is to provide extensive subject corroboration for the importance of real subject data in working with subjects to build a geovisualization application.

There is good evidence that CDR subjects believe that not all crimes are equally important, some categories are relatively unexplored, and some crimes are more interesting than others. Domain experts can have favourite datasets. The significance of this finding is that datasets used with subjects should be chosen with care, mindful not to accept subjects' preconceptions about 'uninteresting' categories of data.

9.1.2 'UNDREAMED-OF' REQUIREMENTS

In order to be able to communicate geovisualization effectively to subjects, it is clear from this research that approaches such as a requirements template and geovisualization lectures (Chapter 4) do not succeed. Literature studies of human-centered approaches in information visualization and geovisualization (Table 1.2) show that only Marsh (2007) has considered the requirements phase. The significance of my research is to demonstrate a negative finding –the lack of success of standard and modified HC requirements approaches with the CDR subjects when the focus is a geovisualization application.

These and additional results from Chapter 6 and 7 suggest that verbal and text based communications of geovisualization are inferior to visual representations. Subjects become engaged when tangible visual artefacts such as wireframe, paper and digital interactive prototypes of increasing sophistication are presented to them for interaction. Such visual realisations cannot be matched to subjects' requirements, without establishing those requirements beforehand. The paradox of building requirements into visualizations for subjects with 'un-dreamed of' requirements needs another approach. I conjecture it may be by producing successive visual artefacts, based on intelligent guesses, grounded in experience and learning from the visualization community, for iterative discussion with subjects. Iteratively refining these until subjects' 'un-dreamed of' requirements become clearer may provide a pathway to a final application.

9.1.3 TANGIBLE VISUAL ARTEFACTS

There is copious evidence from Chapters 5 and 6 that domain experts interact with wireframe, paper and digital interactive prototypes within different protocols and succeed in completing exploratory activities, hypothesis forming, ideation and making insights, confirming known facts, and confounding others. The CDR subjects generate many hundreds of suggestions for improving their prototype. The engagement with these visual artefacts is in contrast to the failure to communicate geovisualization requirements using standard and non-standard HC approaches.

The significance of this work is to show the range and depth of these domain experts' engagement and interactions with prototypes:

- with a range of different prototypes (paper and digital interactive), protocols (user testing with active intervention and free exploration), across two user domains, and which also encompassed solus and collaborative forms of subject working.

- with subjects who are neither leaders in their field nor professionals, the typical subjects for visualization research to date.

9.1.4 HC APPROACHES THAT WORK

9.1.4.1 CONTEXT OF USE

The context of use of potential users is the first phase of ISO13407, but one of the findings of this research has been the extent to which additional information about context of use arises whenever there is contact between researcher and subjects. The flow of contextual information is greatest at the start of a relationship, but occurs at all points in the process of creating a geovisualization application. Therefore, researchers need to be alert to this and have ways to respond flexibly to new contextual information as it arrives.

Context of Use approaches that yield positive results are:

- ways to determine promising possible candidates with whom to engage to build a geovisualization application, including such factors as their motivation.
- the master-apprentice way of gathering information recommended in Contextual Design (Beyer and Holtzblatt, 1997),
- obtaining feedback from subjects on findings (Miles and Huberman, 1994),
- the usefulness (and limitations) of subject interviews and observation,
- the particular strengths of word frequency/concordance and keyword-in-context analysis (Luhn, 1959) in addressing a corpus of subject textual information,
- the usefulness of internal and external documentation to supplement interviews and observation,
- the value of card sorting as a technique to understand subjects' conceptual models of tasks (see section 9.1.4.3).

The significance of this research is to have appraised these approaches in a geovisualization context in a part of the ISO13407 that is unrepresented in the visualization literature.

9.1.4.2 PRIORITISING POSSIBLE IMPROVEMENTS

The Analytic Hierarchy Process has proved to be successful both in prioritising subjects' possible improvements for a geovisualization application, and in giving insights into the consistency with which 'new-related' possible improvements are prioritised. The significance of this work is in the application of the AHP to prioritise competing improvements to a geovisualization application, and in the use of measures of consistency and dispersion to draw conclusions about the difficulties experienced by subjects and geovisualization design alike when faced with prioritising 'new-related' possible improvements (that contain geovisualization tool innovations).

The work to cost development options highlights the ambiguities inherent in even a systematically described and built list of possible improvements, and the ambiguous responses this engenders from a geovisualization developer. The significance of this is in exposing this aspect of geovisualization development, which has hitherto been unremarked upon in the visualization literature.

The application of a novel HC approach to prioritising CDR subjects' possible improvement choices under cost constraints shows that cheaper results can be obtained using the standard method of Karlsson and Ryan (1997). The significance of this work is in its validation of the standard approach.

9.1.4.3 UNDERSTANDING CONCEPTUAL WORLDS

One of the strands to emerge from this research is how HC approaches can be used to compare a subject's conceptual world with that of a geovisualization researcher. The approaches include card sorting of subject tasks, card sorting of geovisualization tools and interactions, and the analytic hierarchy process. The significance of this work is both in the usefulness of such comparisons and that the use of HC approaches to make this comparison is unreported in the visualization literature.

A further advantage of card sorting is that it showed that an individual's conceptual sorting of crime tasks did not include any spatial aspect (section 3.3.4). Such a finding could be material in subsequent geovisualization research with that individual.

9.2 CONSEQUENCES OF THE MAJOR FINDINGS

The major findings interlink and have dependencies that have wider implications and consequences. These are considered in detail in this section.

The need to understand domain subjects' context and to understand and acquire their data and metadata implies subjects' cooperation to achieve these ends. In order to obtain subjects' cooperation, researchers need to think through the features of the research that will keep subjects motivated, communicate those effectively to subjects and generate trust and confidence in the subjects. Clearly, a degree of interpersonal skill is involved. A key aspect is to establish 'what's in it for the subjects.' This in turn entails thinking about **subjects' roles in the research**, and the **balance of power between researcher and subjects**.

The situated nature of subjects has a number of consequences, one of which is their ability to **translate progress in geovisualization into change in the workplace**.

Subjects do not respond well to geovisualization when expressed in verbal or textual form, but do respond to visual artefacts containing real subject data. Subjects cannot articulate requirements for a geovisualization application in advance of seeing visual artefacts. These two findings imply a need to expose subjects to visual artefacts with their own real data as soon as possible in the process of mediation between researcher and subjects. This in turn implies that **real data is available in a form that is tractable** to the researcher, and that the researcher can create geovisualization designs quickly. The latter in turn implies having:

- **geovisualization design skills** or the wherewithal to assemble them
- access to **examples of geovisualization tool elements** that can be deployed rapidly
- access to, and facility with, **fast, flexible tools** or applications that can build visual artefacts, with varying degrees of fidelity
- access to, or **facility with, proven human-centered approaches** to communicate visual artefacts to subjects

The dependencies highlighted in bold above are considered in greater depth in the sections that follow.

9.2.1 THE ROLE OF 'SUBJECTS'

I indicate in section 3.4 that portraying domain experts as 'subjects', while good for academic objectivity, is perhaps a poor description, given the engagement required of them through context of use, requirements and design stages. To achieve results, a relationship has to be forged based on building understanding and confidence. I suggest that 'co-discovers' or 'colleagues' might be more appropriate terms by the end of the process.

Shneiderman and Plaisant (2006) refer to this in defining an aspect of multi-dimensional in-depth long-term case studies (MILCs) that seek to study the context of use of subjects intensely: "The in-depth aspect is the intense engagement of the researchers with the expert users to the point of becoming a partner or assistant." Shneiderman and Plaisant (2006) go beyond this and propose that "HCI and information visualization researchers accept responsibility for a second outcome: the achievement of users' goals within their domain of work. This is a substantial increase in expectations for researchers, which raises the responsibility of researchers for the successful work of their subjects/collaborators." Recent work by Valiati, Freitas and Pimenta (2008) adopt multi-dimensional in-depth long-term case studies approach for information visualization evaluation and outline the results obtained.

The significance of the work in this thesis is two-fold. Firstly to concur with Shneiderman and Plaisant in their expectations of researcher-subject engagement in MILCs. My experience with LCC subjects is that early design exposures build naturally into prototyping, and that process can be likened to a conversation about a topic of mutual interest – subject data, subject context, researcher tools, subject *and* researcher eyes. Secondly, this work goes beyond the context of use/ethnographic involvement envisaged by Shneiderman and Plaisant, to work with the same subjects through requirements, design, prototyping and prioritising phases. Working with LCC libraries subjects indicates that a long time may not be necessary, but that the intensity of the engagement is what matters. Shneiderman and Plaisant in fact define the long-term aspect of MILCs as "longitudinal studies that begin with training in use of a specific tool through proficient usage that leads to strategy changes for the expert users". 'Long-term' may be a *non sequitur*.

9.2.2 THE BALANCE OF POWER BETWEEN RESEARCHER AND SUBJECT

Discussing the role of subjects along a continuum that leads to co-discoverers, touches on another aspect of this research that has not been explicit. This is the balance of power between subjects and the researcher at various stages. There are a number of indications that certain parts of the research may have been uncomfortable for subjects, for example parting with, and losing control over, their data, and most notably in the user testing protocol during prototyping, where there were indications of tension from some LCC CDR subjects:

> *"I was definitely confused earlier on" [C2]*
> *"There might have been a bit of apprehension in there" [C3]*
> *"Quite daunting in some respects" [C3]*

There were other moments when subjects were apparently overwhelmed by seeing digital interactive prototypes with all tools displayed simultaneously - the so-called "Wow!" moments.

Some of the metaphors used to describe major visualization domain applications have a nomenclature with words like 'workbench' and 'toolkit' that have associations with technical expertise. These include [my emphasis] "GeoVISTA Studio – A Computational **Workbench**" (Gahegan et al., 2000), "prefuse – a **toolkit** of interactive information visualization" (Heer, Card and Landay, 2005), "Visual Inquiry **Toolkit**" (Chen, MacEachren and Guo, 2006), "The GAV **Toolkit** for Multiple Linked Views" (Jern et al., 2007) and "The Infovis **toolkit**" (Fekete, 2004).

Kelman (1972) writes that:

> "Ethical problems arise because …individuals, groups and communities that provide data for social research are deficient in power relative to the other participants in the research process…The research subject's position within the research situation itself generally places him at a disadvantage. The investigator usually defines and takes charge of the situation on his own terms and in line with his own values and norms, and the subject has only limited opportunity to question the procedures."

It is instructive to consider the relative balance of power between the subjects and the researcher for each of the major HC approaches used, and this is shown in Figure 9.1. The positioning of approaches along the axis is somewhat subjective, but takes into account:

- the novelty of what the subjects were faced with;
- its difficulty;
- whether they were in their own environment;
- whether it took place with subjects alone, in the presence of their colleagues but individually, or collaboratively with colleagues;
- whether the nature of the approach was one where a 'model' of the power balance was already established (for example, the researcher observing subjects and asking questions in a 'master/apprentice' arrangement or, on the other hand, a lecture delivered by a geovisualization expert);
- the balance of the approach between formal or fun;
- whether or not sessions were tiring for subjects.

Also important was whether the subjects had control of what portion of their data space they examined – as happened in the CDR and libraries free exploration prototype protocols, or had constraints imposed by the researcher – as happened with the user testing protocols.

Figure 9.1 illustrates which approaches might have put domain expert subjects into an uncomfortable power situation – those towards the right of the figure.

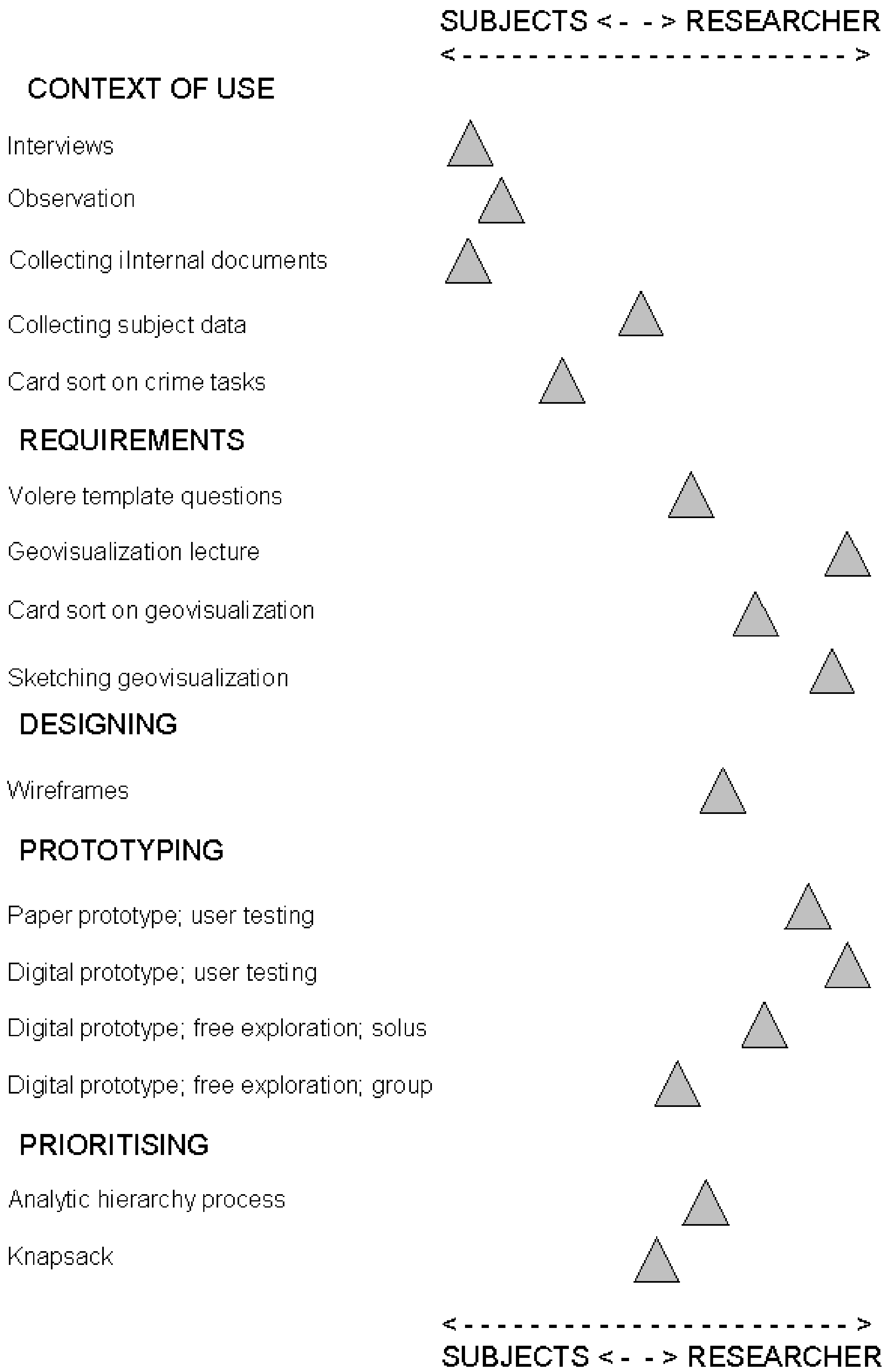

Figure 9.1: Illustrative power axis between subjects and researcher showing where the power balance lies (approximately) for the human-centred processes used in this research

Card sorting appears twice in different positions due to the nature of the topic sorted – (familiar) crime tasks in one, (unfamiliar) geovisualization tools and interactions in the other.

The position on the subject - researcher axis is uncorrelated with whether or not positive results that progress the creation of a geovisualization prototype are obtained. The geovisualization lecture and digital interactive prototyping with user testing are both heavily towards the 'researcher' side of the axis, but the former fails in its aims to communicate geovisualization to the subjects, whereas the user testing prototyping succeeds in eliciting exploratory activities and suggestions for improving the prototype.

One moment in the research sticks out as indicative of a subject changing the power balance in their favour. When I came to conduct the session on libraries' data and ways to examine it, L1 introduced me to two colleagues who L1 felt would be interested in learning about the subject matter – 'could they sit in?' These were L2 and L3 and they went on to be included in the subsequent SomVis free exploration session with L1. What at the time appeared to be L1 seeking to share an experience, in retrospect can be seen as a mechanism to tilt the power balance in L1's favour (it fact, it is both).

If future geovisualization researchers are to engage in the kind of close cooperation with co-discoverers/collaborators envisaged by Shneiderman and Plaisant (2006), then it would be advisable to avoid the HC approaches that are closest to the researcher on the power axis.

Where approaches have poor results (for example, the geovisualization lecture), then omitting them from the repertoire of HC approaches is not an issue. Where they deliver good results (for example, the user testing prototyping) then an alternative that is closer to the subjects in terms of power is preferable (in this case, free exploration is equally as successful as user testing).

Kelman (1972) offers suggestions for adjusting the power balance to be more in favour of the subject:

> *"When the research is carried out in a setting owned by the subject and takes the form of observing the natural flow of ongoing behaviour…the investigator's control is far less extensive."*
>
> *"the subject's…power could be enhanced by exploring models of research that would allow the subject more equal participation in the whole research process. Such models presuppose active efforts to share information with the subjects so that they would have the capacity to*

participate in meaningful ways….One major corrective approach…is the active development…of alternative research models…The models I have in mind can be characterized as participatory research*, in that they are designed to involve the subject as an active participant in a joint effort with the investigator…the subject, along with the investigator , would be interested personally in the process or the outcome of the research and involved actively in making it a success. This kind of model would go a long way toward removing the power discrepancies between investigator and subject."*

The second quotation from Kelman, resonates strongly with other strands in this chapter about regarding the 'subjects' as collaborators from the start.

A positive change might be to alter the some of the descriptions used to characterise roles. for example, in this thesis the phrase 'geovisualization expert' is used over 200 times. It would be better to put the emphasis on the help such a person can provide to 'collaborators' than emphasise their academic prowess.

It is possible that HC approaches that are more fun, playful and seem easier put users more in control. The use of 'game cards' and toy money in the knapsack session is one example, as is the use of (informal) paper in both wireframe and paper prototyping.

Finally, a number of contextual insights had their origin in conversations over tea or lunch with subjects once the audio recorder had been left behind, although these are unreported in this thesis for ethical reasons. These informal occasions are places where power is much more evenly balanced.

9.2.3 MAKING CHANGES AT THE WORKPLACE

A strand of comment in Chapter 6 from both sets of LCC users is that although they can see merit in working with a geovisualization prototype to explore their data, they are focused on day-to-day requirements of their jobs. Their time (and the number of staff employed) is related to other tasks that take priority - management reporting in both cases, and support for districts in their crime and disorder reduction issues (CDR subjects) and supporting LCC public libraries to market their services (libraries). There is evidence from CDR subjects in Chapter 7 that their day-to-day jobs place a premium on possible improvements to the CDR prototype that deliver those benefits. Neither set of subjects have a significant ability to change their working practices immediately to react to geovisualization exploration possibilities on offer.

The constraints on subject time and their conflicting priorities echoes the findings of Suchan (2002) who conducted work with Census analysts: "Analysts do not explicitly have time to participate in the…research. They need to make the task a priority among competing job responsibilities and they can justify doing so only when they are finding insights into their own data." (Suchan's comment also reinforces the case for using real domain data in working with subjects).

Recent thinking by Chabot (2009) on visual analytics resonates with this:

> "It seems indisputable that people adopt visual analytics primarily to see and understand hidden insights. How could I list this statement as a misperception? The answer lies in the definition of visual analytics itself…visual analytics is concerned with improving the process of analytical reasoning through interactive visual interfaces. In short, it's about the journey, not the destination. A visual analysis session might unearth a hidden gem. You find Bin Laden. Or discover corruption. Or uncover a million-dollar error. The problem with the belief that these "aha" moments are the crux of visual analytics, however, is that they aren't representative of the analysis process. Not for experts. Not for everyday people. Most of the time that people spend with data is in exploring it, cleaning it, gaining confidence in it, summarizing it, pursuing inconclusive paths, confirming facts, and presenting findings. None of these steps necessarily has anything to do with finding a hidden insight."

If these LCC subjects' situated context of their limited ability to alter their working practices to take advantage of geovisualization applications is typical of such roles within local government or indeed institutions in the wider private sector, then it begs the question as to how geovisualization can gain acceptance at this level. Certainly, a 'bottom up' from subjects such as these appears to be an unlikely route. But a 'top down' route seeking to engage senior managers who do not conduct data exploration themselves looks even more unlikely. This is problematic. Two possibilities come to mind. Firstly, Visual Analytics recognises the importance of implementation and might produce solutions given time:"The visualization of these processes will provide the means of communicating about them, instead of being left with the results…communicate assessment effectively for action"(Keim et al., 2008). Secondly, a process of diffusion of visualization possibilities and techniques might occur because of internet-scale developments such as Many Eyes and Swivel.

9.2.4 TRACTABLE REAL DATA

Another reason why data collection needs to happen early in the process of engagement with subjects is the time-consuming processing that must take place before most data can be rendered tractable, causing a delay to progressing activities with the subjects.

Fry (2004) offers a schematic to describe the 'Seven stages of visualizing data' (Figure 9.2). Here the visualization domain (InfoVis in this case) is bracketed together with HCI as the last in a chain of seven stages in visualizing data. "Part of the problem with the individual approaches of dealing with data is that the separation of the fields leads to each person solving an isolated part of the problem, and along the path towards a solution, something is lost at each transition" (Fry, 2004).

Figure 9.2: The Seven Stages of Visualizing Data from Fry (2004)

Fry suggests an approach to a solution of this acquisition to interaction chain:

> " In order to properly address the issue of complex data visualization, several fields need to be reconciled as parts of a single process…Computational Information Design…seeks to bridge the individual disciplines, placing the focus instead on the data and how it is to be considered—rather than from the viewpoint and tools of each individual field." (Fry, 2004)

Fry (2008) eschews tool libraries, promoting a data-centric approach using flexible software– in particular, his own programming language, Processing (Reas and Fry, 2003).

In this research, the parsing, filtering and mining stages of this chain took about a month for both the CDR and libraries data, starting from the moment a CD of data arrived in my hands. There is clearly a problem with a process that seeks to build accelerated trust and confidence with subjects to acquire data, only to disappear for a month or so. Slick and well-practiced tools, methods and skills for parsing and filtering are clearly highly desirable. Researchers would do well to have a prior notion of the data characteristics they should be seeking from domain experts. This should include as much metadata as possible, how, if at all, data has been filtered, aggregated, normalised or otherwise manipulated, the attributes of the data – dimensionality, continuous or discrete, nominal, ordinal, interval or real, univariate or bivariate, and so forth, as well as specific details relating to spatial data.

Clearly, other work on context can be going on in parallel while another team wrestles with the data. This parallel work stream could include transcribing interviews and using analysis techniques like keyword-in-context, undertaking desk research on the domain, summarising this material for colleagues (and to play back to the subjects) perhaps in the form of scenarios of subjects' context of use. However, this ameliorates rather than solves the problem.

9.2.5 GEOVISUALIZATION DESIGN SKILLS

It is clear that early exposure of initial designs to users works, and begins to close the knowledge gap between subjects and geovisualization possibilities. It builds trust, shows progress, finds gross errors and omissions, opens up channels of communication focused on subject data, subject tasks and design first thoughts.

I found it hard to synthesise elements for an initial design, and outline this experience in Chapter 5. The significance of this autoethnographic work is in highlighting this aspect of geovisualization design, which has hitherto been unremarked upon in the visualization literature.

My design experience is unlikely to be unique. In Chapter 5, I suggest that help is needed in design that could include:

- including design as a stronger strand of geovis teaching, perhaps with group learning and mutual criticism (Greenberg and Buxton, 2008); or
- improving visualizations through the use of graphic and/or visual design experts (Tory and Moller, 2005) and (Acevedo et al., 2008), but at as early a stage as possible in their development. That is, incorporate designers as collaborators.

Some tentative steps have been taken to share and critique designs in my own university department where a number of researchers *individually* tackled the IEEE VAST Challenge 2009 'Flitter' mini-challenge before pooling results and approaches.

9.2.6 A GEOVISUALIZATION REPOSITORY

Fry (2008) argues strongly for visualizations that "convey the unique properties of the data set it represents" and hence unique visualizations for each new problem. However, Amar and Stasko (2005) disagree: "Recently, a number of visualizations that address a specific domain or problem area have emerged… while they can be very effective, they raise the question of whether each new domain requires a new visualization."

At the current time, the provision of visualization 'toolkits' or 'workbenches' to bring together combined multiple tools is useful . The success of the library subjects in this research in using one of these (SomVis) is indicative that, with enough support, this approach can yield good results. Plaisant (2004) has cautioned that "potential adopters might be turned off if they perceive that the tool they are evaluating has not been designed specifically for their particular needs: biologists are looking for biology tools and petroleum engineers will be attracted to tools developed for petroleum engineering." The experience with the Library subjects with SomVis has not indicated this prejudice in any way.

If a tailored approach is appropriate – and geovisualizers should always entertain the contrary notion – then there might be a role for some kind of a catalogue or repository of code and tool snippets that holds the repertoire of possibilities for visualizing a range of different data types at different scales that could be used to create visual artefacts for prospective users of a final application.

Such a repository does not exist, but I refer in section 5.5 to the notion of a 'geovisualization probe' that could act as its predecessor, and how that might be 'scavenged' from existing applications of all kinds for elements that can produce help relevant visual representations of subject data quickly. I suggest that it could include:

- presentation software such as PowerPoint, Visio,
- dashboard software (Few, 2006)
- spreadsheets (like Excel), and useful Excel plug-ins (like Treemapper (Microsoft Research, 2006) and the Tufte-inspired sparklines (Rimlinger, 2009)), possibly connected to databases (like Access and MySQL) giving access to subject data,
- geographic information systems,
- internet-scale, static, visualization tools (such as Many Eyes (Viégas et al., 2007) and Swivel (Dimov and Mulloy, 2005)),
- single focus visualization and geovisualization tools created by practitioners and made freely available to academics (for example Mondrian (Theus, 2002), SomVis (Guo, 2005) and Estat (Robinson, 2005)),
- generic visualization and geovisualization toolkits created by practitioners and made freely available to academics (such as GeoVista Studio (Gahegan et al., 2000), Prefuse (Heer, Card and Landay, 2005), Improvise (Weaver, 2006b) and GAV (Jern et al., 2007))
- relevant benchmarked visualizations from the Information Visualization Benchmark Repository (Plaisant, Fekete and Grinstein, 2008).

The requirement for this assembly of 'odds and ends' is not yet clear. There are simply too few visualization researchers working with subjects using human-centered approaches. It can probably be pulled together in an *ad hoc* fashion as necessary. But there is merit in thinking about creating this once for the information visualization and geovisualization communities, and curating it to keep it up to date and relevant. To use the phrase that MacEachren et al (1994) used to refer to the uncoupled nature of visualizations to GIS at that time, it looks like "boot laces and sticky tape". Indeed, some techniques like paper prototyping will always be informal – it is their essential nature and their strength.

9.2.7 FAST AND FLEXIBLE TOOLS

This research has established the lack of success of standard and non-standard HC approaches in establishing viable requirements for a geovisualization application. Finding ways to get subjects to engage as soon as feasible with visual artefacts that include their own real data, which this research has shown elicits strong exploratory activity and generates myraid suggestions for improvement, is a logical next step for researchers to evaluate.

In order to do this, there will be a need for fast and flexible tools beyond the "boot laces and sticky tape" of the repository I refer to in section 9.2.6. Dykes (2005b) highlights the general approach of removing barriers to entry for those wishing to create geovisualization applications by means of "increasing efficiencies, sharing software components and reusing resources". More recently, Beringer et al (2008) debate the key aspects of End User Development "to allow users of software systems, who are non-professional software developers, to create, modify or extend software artefacts."

It is worth reiterating the point made by van Wijk (2006) that "novelty is relative" in visualization. What a visualization researcher considered "standard information visualization concepts… more or less straightforward" were to the domain experts "highly effective and the most effective tool for the purpose they knew." This implies that simple, known visualization tools is a good starting point with new subjects – and they may turn out to be an even better end point.

Approaches to developing prototypes rapidly in collaboration with prospective users through 'patchwork prototyping' has been mentioned before: "combining of open source software applications to rapidly create a rudimentary but fully functional prototype that can be used and hence evaluated in real life situations. The use of a working prototype enables the capture of more realistic and informed requirements than traditional methods that rely on users trying to imagine how they might use the envisaged system in their work, and even more problematic, how that system in use may change how they work" (Jones, Floyd and Twidale, 2007). This approach has been influential in recent work to geovisualize seasonal climate forecasts by Slingsby et al (2009).

Other approaches have promise to provide the speed and flexibility required. These include:

- mashups using application programming interfaces, such as in the work of Slingsby et al (2007) to link interactive tag maps and tag clouds for multiscale exploration of large spatio-temporal datasets,
- Using code libraries to streamline code production including event handling. One example is the javascript library environment, JQuery (Chaffer and Swedberg, 2007),
- employing advances in programming such as the Processing language (Reas and Fry, 2003) that has been mentioned earlier, to create code that can be assembled quickly for "making responsive images" and "sophisticated visual and responsive structures" for displaying subject data.

These approaches have their own challenges, not least how the degree of flexibility required to develop prototypes in a live or near live environment with prospective users can be achieved in practice.

9.2.8 INVOLVING HUMAN CENTERED EXPERTS

The multi-disciplinary natures of both human-centered and visualization domains makes designing applications taking account of expertise from both traditions difficult, as outlined in Chapter 5. There is a case for considering multi-disciplinary teams to approach HC-influenced visualization design.

HC experts would be able to contribute to approaches that required more creativity, for example, writing scenarios, or in providing specific skills like note taking and quickly coding of verbal information or think aloud narrative. HC experts with expertise in Contextual Inquiry or other ethnographic approaches who could be deployed in the early contact with subjects and with the context of use phase would be particularly useful.

There are examples in the literature of crossover activities between the HC and visualization domains and *vice versa*. Asahi, Turo and Shneiderman (1995) use treemaps to visualise the analytic hierarchy process. Goodell et al (2006) propose to tackle to problem of recording session histories with a visualization application that captures audio and text annotations, indexed to user actions and system state. Eccles et al (2008) provide an example where a 'story' is incorporated in the visualization to give it meaning, building on the HC approach of the 'scenario'. These crossover activities are more than mere curiosities. They might provide the catalyst to create a bridge between disciplines to help form collaborative teams of visualization and HC researchers.

A final aspect to bear in mind is that human-centered studies is an active field of research with new possibilities and methods emerging. A link with HC experts would tap into developments in that evolving domain.

9.3 AN 'ADVANCED' MODEL

In reviewing this work, the mass of results from different parts of the ISO13407 process would benefit from an over-arching model to express concisely the main findings. If there is a unifying theme to the findings it is that, in many cases, the complexities of geovisualization have led HC approaches from one part of the ISO13407 process to be advanced and pressed into service at an earlier stage. Some examples of this **'advanced model'** include:

- User testing, normally a 'late-stage' evaluation technique finds use in the Prototyping stage when combined with active intervention.
- Effective wireframe prototypes need to contain much more detail and real subject data, and thus 'pull forward' elements of paper prototyping.
- 'Undreamed of' possibilities cannot be realised in the form of subject requirements until subjects see tangible geovisualization artefacts. There is a need for subjects to see these as soon as possible, meaning that visual artefacts need to be created earlier in the process, bringing them forward from later stages in the ISO13407 process.
- Geovisualization artefacts that mean more to subjects that have to have real subject data. Therefore such data and its metadata has to be captured as early in the process as possible in the Context of Use stage
- Although the Volere template questions are not useful to establish geovisualization requirements, the questions themselves cover a good deal of ground comprehensively and might be a useful source for use with subjects in the Context of Use phase.

To this list, I would add the fact that although the AHP is workable, it is still time-consuming if it contains too many possibilities. In addition, development costs are difficult to establish given geovisualization's multiple routes for realization and interdependencies. It would be useful to 'advance' decision-making to make it a more immediate consequence of communicating geovisualization artifacts to subjects, using less formal, less rigorous approaches such as affinity diagramming with developers and subjects present, so ambiguities in possible improvements and multiple possibilities in development can be exposed and resolved.

9.4 GEOVISUALIZATION-SPECIFIC FINDINGS

This is geovisualization-motivated research and although there are strong links between information visualization and geovisualization, it is useful to highlight those findings that particularly relate specifically to geovisualization. These relate to:

- the development of criteria to select between numbers of groups to assess their potential to benefit from geovisualization. These use the extent of their involvement with spatial data as a specific criterion.
- card sorting permits the inclusion of tasks that include spatiality (that are important to geovisualization) to be set alongside other tasks. Card sorting also permits a geovisualization expert to perform the same card sort as subjects and thus permit comparisons between subjects' and a geovisualization expert's conceptual views of subject tasks.
- the results from consulting geovisualization experts with a scenario.
- the results from attempting to communicate geovisualization to CDR subjects with a geovisualization lecture.
- designing geovisualization wireframes.
- change of wireframe designs to create a 'geovisualization-modified' wireframe design.
- in prototyping, hypothesising can be hampered by lack of available spatial data.
- in prototyping, different subjects have different responses in a geovisualization situation as they hold different (tacit) spatial knowledge.
- in free exploration prototyping, geovisualization possibilities generate data exploration possibilities; and the effect of engaging with a spatial pattern is to focus the attention.
- subject behaviour in arguing from pattern to map in prototyping.
- the results from the geovisualization developer producing costs for possible improvements to a geovisualization prototype (inputs of ambiguity, vagueness and lack of specificity are manifest in the outputs of the geovisualization developer).

This is not a long list, and there are few findings that are unequivocally spatial in nature, because many of the tools of geovisualization derive from information visualization. I must offer a similar conclusion to that of Marsh (2007) and report that geovisualization context of use, requirement elicitation, design, prototyping and prioritising "may not differ in nature to that of [these]…in other domains, which are exploratory and visualization based, with ill-defined goals, such as information visualization."

9.5 LEGACY

It is appropriate to end this thesis with some mention of the legacy so far of this academic work. Parts of this research have been presented at three GISRUK conferences (Lloyd, Dykes and Radburn, 2007; Lloyd, Dykes and Radburn, 2008, 2009b). A summary of the whole thesis was presented at the Refactoring Visualization from Experience (ReViSe 2009) workshop at the IEEE Visualization 2009 Conference (Lloyd, Dykes and Radburn, 2009a).

One incidental outcome of this work is that R, the 'lead user' (von Hippel, 1986) for geovisualization within LCC pursued an opportunity to work for a year 50% of the time within my university department as part of Understanding population trends and processes (UPTAP) - a Secondary Data Analysis Initiative from the Economic and Social Research Council to transfer knowledge of geovisualization to public sector organisations. R's work focuses on further work within LCC public libraries via the vizLib project - Developing Capacity for Exploratory Analysis in Local Government - Visualization of Library Usage Data.

Another legacy of my work is the diffusion of visualization tools into LCC. In subsequent site visits I have noticed the use of tag clouds and treemaps in the work of the Research and Information team that were a result of being made aware of visualization possibilities through this research being conducted.

9.6 COMPARISON WITH INITIAL PROPOSAL

To end at the beginning. The original EPSRC proposal for funding for this research set out two broad objectives:

- to advance research into the use of innovative human-centred techniques for designing and evaluating software for the visualization of multivariate geographic information.
- to apply this research to specific information needs in the context of a requirement for evidence-based policymaking in Leicestershire County Council

Were these achieved? The central focus of this research has indeed been on human-centered approaches and applying them in a geovisualization context. Innovation has certainly been a running theme with many modifications and changes to standard HC approaches tried and results obtained. As regards the focus on 'designing and evaluating software', this was modified early on to reflect the disproportionate amount of visualization-related research into evaluation, and to substitute the under-researched context of use and establishing of requirements, with, I contend, positive research outcomes. The data used has certainly been multivariate and spatial in nature, although the libraries work showed that subject expectations of a significant spatial component to borrowing was misplaced. The sophistication of the tangible visual artefacts used was fairly modest, but this was appropriate to the subjects - "novelty is relative" (van Wijk, 2006). The subjects of the research were entirely LCC analysts and managers working in evidence-based fields, with the exception of the geovisualization experts who were consulted with the CDR scenario.

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APPENDIX

Explanatory Statement Information Sheet for the Research Project

Title of the project: Human Centered Geographical Interfaces for Evidence-Based Policy

Principal researcher: David Lloyd

Purpose of the study: Exploring local libraries customer borrowing patterns

Inclusion criteria: Library manager concerned with marketing to customers

Initial contact: This sheet will help you understand what the study is about and how will you be involved.

Benefits to you: Gives an insight into your customer data. It also advances the work of understanding how LCC might better market its library services to its potential customers and contributes towards the achievement of the researcher's PhD studies.

The Process: The session will be set up in a safe and comfortable environment. All or parts of the session may be recorded in audio or written form.
The session will involve exploring data on customer library borrowing and involve a number of numerical, graphical and visual tools. The researcher taking part in the process will be David Lloyd of City University London.

Consent: You will be explained the aim and purpose of the study. The researcher will go through the steps before commencing the study. You will have the opportunity to read this information sheet and the consent form, and clarify any points or worries. If you agree to participate in the study, you will be asked to sign the consent form.

Confidentiality: Any information you give during the interview will be treated as confidential and stored securely on a computer locked by password, in a secure office. Transcripts will also be stored securely in the secure office. Any data used in reporting the study findings, will be reported anonymously. Only **David Lloyd** and his supervisor, **Jason Dykes,** will have access to raw data collected.
All data will be stored in a safe location for up to 12 months after the completion of the study, and thereafter shredded and destroyed. All computer data, including the back-up files will be also then be deleted.

Time: The study will take place on 13 May 2008.

If you wish to discuss any part of this study further with the researcher, his contact details are:

David Lloyd
City University
A520
Department of Information Science
Northampton Square
London EC1V 0HB
Tel: 020 7040 0212
Email: at775@soi.city.ac.uk

Participation and Withdrawal: Your participation in this study is completely voluntary. You have the option to opt out during any part of the study. You have the right to refuse to answer any questions that you may feel are too personal or intrusive. All information will be kept completely confidential and will solely be used for the proposed research study.

Your access to the final data: You have the option of receiving a copy of any transcript of any part of the study of which you are involved. If you withdraw in the middle of the study you could still have access to the data related to yourself, and you will have an opportunity to discuss any worries will the researcher.

The University complaints clause: You can complain about the study if you don't like something about it. To complain about the study, you need to phone 020 7040 8010. You can then ask to speak to the Secretary of the Ethics Committee. You will need to tell them that the name of the project is: Human Centered Geographical Interfaces for Evidence-Based Policy; Name of the researcher is: David Lloyd.

You could also write to the Secretary. His address is:
Alex Sandbrook
Secretary to Senate Ethical Committee
Academic Registry
City University, Northampton Square
London EC1V 0HB
Email: a.e.sandbrook@city.ac.uk

Informed consent form for project participants

Project title: Human Centered Geographical Interfaces for Evidence-Based Policy

I agree to take part in the above City University research project. I have had the project explained to me, and I have read the Explanatory Statement (Information Sheet), which I may keep for my records. I understand that agreeing to take part means that I am willing:

- To be interviewed about my response to customer data and tools to analyse
- To allow the session to be audio recorded

Data Protection
This information will be held and processed for the following purposes:

- Understanding local library customers' borrowing patterns

I understand that any information I provide is confidential, and that no information that could lead to the identification of any individual will be disclosed in any reports on the project, or to any other party not present at the session. No identifiable personal data will be published. The identifiable data will not be shared with any other organisation. I understand that confidentiality cannot be guaranteed for information which I might disclose in the presence of others present.

I understand that I have the option to be given a transcript of data concerning me for my approval before it is included in the write up of the final report.

I understand that data will be anonymised to protect my identity from being made public. I understand that anonymised data will be used as part of a project to understand library customer patterns and will contribute to the PhD work of David Lloyd.

I agree to City University recording and processing this information about me. I understand that this information will be used only for the purpose(s) set out in this statement and my consent is conditional on the University complying with its duties and obligations under the Data Protection Act 1998.

Withdrawal from study
I understand that my participation is voluntary, that I can choose not to participate in part or all of the project, and that I can withdraw at any stage of the project without being penalised or disadvantaged in any way.

This consent form is seeking permission for the data to be used for the Human Centered Geographical Interfaces for Evidence-Based Policy project only.

Name: .... (please print)

Signature: ....Date: ....