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giCentre- School of Informatics

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Evaluation of Storytelling in Information Visualization

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A mini-thesis submitted to upgrade from MPhil to PhD

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Abstract

Story telling has been used throughout the ages as a means of communication between people and to convey and transmit knowledge from one person to another, and from one generation to the next. In various domains, formulating of messages, ideas, or findings into a story has proven its efficiency in making them understandable, comprehensible, memorable, interesting, and engaging. Information Visualization as an academic field has also utilised the power of storytelling to make visualizations more understandable and interesting for a variety of audiences, including experts. However, although storytelling has been a hot topic in information visualization for some time, little or no empirical evaluations exist to compare different approaches of storytelling through information visualization. There is also a need for work that addresses in depth some particular criteria and techniques of storytelling such as transitions types in visual stories in general and data-driven stories in particular.

A within subject experiment with 13 participants has been conducted to explore empirically how two different models of story delivery with information visualization influence narratives/stories constructed by audiences. Specifically, the first model involves direct narrative by a speaker using a visualization design to tell a story, while the second model involves constructing a story by interactively exploring visualization software. An open-ended questionnaire in controlled laboratory settings has been used in which the primary goal was to collect a number of stories derived from the two models. All the stories written by the participants were transcribed, analysed, and coded, using data-driven and preset themes. Themes included initial perception of the main story pattern/topic, insight types derived, narrative structures, and unexpected type of insights gained. This experiment was followed by a semi-structured interview where each participant answered two Likert-scale questions on each delivery model, and commented on the overall experiment. It is found that although most participants found telling a story easier with the first model (narrative) they did not perform better in other aspects. The second model (software) was advantageous in the variety of insight types gained and participants accepted the message and information more neutrally. In contrast, participants were more critical about the data in software model than in the narrative model. The role of time in structuring story events was more apparent in the software model. These findings have some significant practical implications on storytelling through information visualization. A statement of the work done and a work plan for the remaining period of the PhD is also included explaining the proposed enhancement to the experiment conducted and further research work planned to address the issue of transitions in storytelling visualization.

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1. Introduction

This transfer report presents my PhD research project, its area, progress, and planned future developments. It includes a short literature review around the subject of storytelling in general and in the context of information visualization, the initial experimental work done so far, and proposed area for investigation. As it is still a work in progress, some parts are subject to change, along with improvements, or refinement in order to achieve the best out of the whole PhD project.

This chapter provides some insights into the overall research context, its scope, and the research aim and objectives.

1.1 Research Context

For thousands of years, storytelling has been one of the most widespread and commonly used forms of communication. Many scholars have demonstrated the power of storytelling as a means of information transfer (Gershon and Page, 2001; Tergan et al., 2006). Over time, storytelling has evolved from its origins as an oral tradition from generation to generation, into new fields and new forms of communication such as novels, films, and computer games. Each of these storytelling forms has its own strategies, models, theories, and techniques. Recently, there has been a great interest in storytelling through information visualization, notably two workshops on telling stories with data at VisWeek conferences in 2010 and 2011. There have also been a number of papers on the topic (Hullman and Diakopolous, 2011; Segel and Heer, 2010). Although there are obvious differences in the details and ways stories are told through information visualization, when compared with films or written text and there are also differences in the nature and types of stories being told in each medium, there are certain concepts and characteristics of storytelling common to all fields.

Storytelling is a broad topic that can be addressed from many different angles, such as building a system that supports specific features/elements of storytelling, the role of the language and the body

language of the storyteller, the flow of story events and overall narrative structure, or the data type used in the story, etc. While there are different definitions of what constitutes a story, the definition considered in this research refers to any data-driven stories presented or told through the use of information visualization. This is very similar to the focus of data-driven journalism (The Data Journalism Handbook, 2012) where stories are told using some form of data; this particular form of storytelling has become more important and popular with the release and revolution of open data. Websites such as data.gov in the US and data.gov.uk in the UK provide a rich sources for data stories that are of interest to many agents ranging from local governments through to business stakeholders/organisations, to the general public. The latter is the focus of this research work. Thus, the story audiences targeted in this work are the educated general public.

In the first phase of this study, a controlled experiment was conducted, using two different models of story delivery with information visualization, to examine empirically how inexpert general users understand, construct, and tell stories. The first model involves watching a video where there is a presenter/speaker telling a story, using information visualization software, while the second model concerns letting the users explore an interactive visualization and construct stories by themselves. The second proposed phase of the project will be an exploration of the transition types that are used to tell stories through information visualization. New hypotheses and questions are expected to emerge from these two phases and will be addressed in the remaining period of the PhD.

1.2 Research Focus

To narrow down the focus of the research into something that is suitable and meaningful in a PhD, two specific areas or aspects of storytelling through information visualization have been chosen and an empirical experiment has been conducted to explore the effect of the two story delivery methods. The first area is the delivery model, where this research explores what advantages and disadvantages direct narrative has compared with the interactive exploration of the story in the information visualization, and

how these impact on the narratives constructed using each model. The second area is concerned with the transition types usually used to tell stories with information visualization, the patterns of using these types, and how they impact on the flow of narratives, comprehension, and understanding. Within this second area, the chosen case study data to explore transition types is the set of VAST challenge videos from 2008 to 2012 (Visual Analytics Community, 2012). VAST challenge is a series of tasks released annually as part of the world premier conference in information visualization, VisWeek, where a large dataset is provided and a number of tasks specified. There are typically two or three mini-challenges (or tasks) and a grand challenge. Every year a different dataset is released with different tasks types and a compulsory video submission is required to address these tasks. These videos provide a valuable and suitable dataset because the videos of any specific year are based on the same dataset and address the same tasks, and they each have the same length and format; thereby providing suitable data for valid comparison of the storytelling transition types.

1.3 Overall Research Aim and Individual Objectives

The overall aim of this research is to use existing theory and techniques from storytelling more generally and investigate their relevance to storytelling in the design of information visualization, and empirically examine the impact of different forms of storytelling visualization on story comprehension and understanding. Specifically:

1. To identify the characteristics of storytelling in general and as an emerging field within information visualization.
2. To investigate the effect of the story delivery model on narratives/stories constructed by audiences.
3. To explore and model the transition types used to tell stories through information visualization.
4. To investigate the effect of different transitions within data-driven stories on the resultant or perceived narratives/stories.

5. To provide guidelines and recommendations for the design of narrative visualizations based on the implications of the empirical research findings.

1.4 Value and contribution of the research

The value and contribution of the work completed to date combined with the intended work planned can be summarised in two main points. First, although useful studies have been conducted on storytelling in information visualization, the majority of these studies are designed as case studies or theoretical frameworks (Hullman and Diakopoulous, 2011; Segel and Heer, 2010). The main contribution of this work is that it takes the previous work in this area a step further by providing empirically-based results on the effect of the manner in which stories are delivered; in other words, whether they are delivered through the use of information visualization by a speaker, or whether they are constructed by users as a result of interactive exploration of information visualization. In addition, Lam et al. (2012) stated that evaluation studies on how visualization may support communication and knowledge transfer are less represented in the literature than other types of evaluation research such as usability studies.

Second, one of the reasons for conducting a user study was to test whether theories or results from different fields may or may not be applied to information visualization (Kosara et al., 2003). However, it can be argued that this last point is not limited to user studies, but can also be applied to other research types and strategies such as case studies and document-based research, which is the case in the intended future work on transitions types in data-driven stories. For this purpose, and as the storytelling in information visualization is still an emerging sub-field that has not been fully characterised and investigated, a number of techniques and theories on storytelling in filmmaking, journalism and comics have been discussed and connections between these techniques and information visualization have been made in the background section below in addition to the data analysis and implications sections of the first set of experiments conducted to date. Some of these models will also be used in the future work to

code the transition types used in VAST challenges videos, in particular, McCloud (1994, 2006) taxonomy of panel-to-panel transitions in comics stories.

1.5 Report Outline Structure

Chapter 1 Introduction

This chapter provides information on the context of the research in hand, together with the scope, aims and objectives of the research.

Chapter 2 Literature Review

This chapter provides a short literature review on some aspects of storytelling in general and, in particular, in the context of information visualization such as narrative structure, story delivery, transitions in storytelling, their benefits, taxonomies and the techniques used to facilitate these transitions. It also identifies the gaps and extensions needed to address this topic and the emergence of the research in hand from the previous work.

Chapter 3 Research Methods

This chapter provides some general information on the research strategies that have been chosen for the research in hand. It also provides details of data collection methods and the procedure followed when conducting the first empirical experiment/evaluation. It also briefly reviews information visualization evaluation literature in order to identify the most appropriate empirical methods from various alternatives to the objectives of the study in hand. The ethical considerations and limitations of the study are also summarised.

Chapter 4 Preliminary Findings and Discussions

This chapter reports and discusses the findings of the research to date.

Chapter 5 Implications of the Preliminary Findings of the First Experiment

This chapter provides some recommendations based on the implications of the preliminary findings of the first experiment.

Chapter 6 Work done and Future Work

This chapter briefly summarises the work completed and the activities and timeline of the future work toward the end of the PhD.

2. Literature Review

In this section, previous studies on storytelling in the field of information visualization are summarised and reviewed. Other literature on storytelling theories and techniques in filmmaking, journalism, and comics is also discussed with relevance, where appropriate, to information visualization. It is divided into 5 sub-sections each of which covers different aspects of storytelling, relating it to storytelling in information visualization. Sub-section 2.1 briefly touched on the previous work done explicitly on narrative visualization. Sub-section 2.2 discusses the role of narrative structure and provides some insights into a number of different methods used to tell a story in many domains and in information visualization. Sub-section 2.3 discusses the role of story delivery and how it impacts on the way audiences perceive and comprehend the story. Sub-section 2.4 provides an insight into the meaning of transitions in storytelling and briefly summarises a possible taxonomy of panel-to-panel transitions in comic stories and how it relates to storytelling through information visualization. Finally, sub-section 2.5, summarises the main points in the literature review, the required work in the area, and introduces the planned work in the research.

2.1 Storytelling in Information Visualization

Information visualization is considered to have two main purposes: exploration and analysis on the one hand, and presentation and communication of information to some target audiences on the other (Fulkerson et al., 2009; Keim, 2002). Storytelling or narrative visualization is usually listed under communicative or presentational visualization due to the fact that one of the main characteristics of any story is the message or the point that needs to be made. However, it can be argued that storytelling visualization, particularly with interactivity functions in dynamic visualization designs where users construct their own stories, has a combination of both exploratory and presentational visualizations, simply because it is not possible to construct and tell a story without first exploring the data using the available interactive features, or examining the static visualization.

Gershon and Page (2001) stated that using storytelling is an effective method of developing visualizations and to do so, it is necessary to adopt a number of storytelling techniques such as building the picture, animating the events, creating continuity, filling gaps, resolving conflict and ambiguity, etc. Given that there are various types of information that can be visualized, and that the information visualization methods and techniques used do not lend themselves to one-size-fits-all (Heer et al, 2005), storytelling through information visualization becomes a challenging task. A similar point has been made by Wojtkowski and Wojtkowski (2002), that what makes data visualization different from other types of visual storytelling is the complexity of the content that needs to be communicated.

In addition to choosing the best-fit solution or visualization technique to the data in hand, there are multiple formatting decisions in visual storytelling based on audience, topic, and objectives, vital to ensuring that the message or the point of the data-driven story has been effectively delivered and perceived by the target audiences. This requires deciding on the right data, amount of detail, the distance between the target audience and story context, and the balance between the interactive nature of information visualization and delivering an intended story or message. An interesting example that can be

used as a framework to classify the relationship between the audience and the story context has been provided by Quesenbery and Brooks (2010). Although they are focusing on storytelling in the context of engineering design, the model is still applicable to any domain that has different types of audiences and needs a medium such as information visualization. The example is designing an electronic medical records system, which is to create a story that helps explain the daily routine of hospital nurses as they check in patients and keep records of their medical conditions. Within this example, the framework comprises a three column table: Audience, Relationship, and Need. There are multiple types of relationships, for instance, nurses are an audience who are part of the story context, a patient is an audience who is related to the story context but has a different perspective than the central characters, while a database designer/developer who has been assigned to work on a healthcare system for the first time is an audience who knows the context from a technical perspective, etc. (Quesenbery and Brooks, 2010). It can be argued that such a classification and understanding of the intended audience is highly relevant to any visualization design. It is also essential in deciding on the amount of context and detail necessary to deliver a coherent story. Actually, a number of studies have been conducted in order to understand the manner in which different users approach information visualization. The importance of knowing the target audience is also highlighted in a number of sources (Grammel et al, 2010; Heer, 2010; Yau, 2011).

To help understand the design space of narrative visualization, Segel and Heer (2010) analysed approximately fifty information visualization case studies that have elements of narrative visualization, mostly from sources of journalism, and looked for recurring design techniques and strategies. They considered how users were led through visualizations and identified two approaches, author-driven and reader-driven. The author-driven approach to information visualization is based on a purposeful linear ordering of scenes in which the author's message and strategic audience guidance prescribes cognitive acquisition of key agenda items and learning objectives (Segel and Heer, 2010). Conversely, a reader-driven approach circumvents the rigid formatting of author-direction, allowing for free interactivity with

the presentation (Segel and Heer, 2010). This implies changes in the story path that each user or audience may follow and may also change the overall outcome of the story. There are inherent benefits to each approach based on the audience, the primary objectives of the presentation and the disseminated information, challenging the author/creator to consider the value of each technique before subscribing to one approach or the other. Furthermore, Segel and Heer (2010) identified seven genres used in storytelling visualization: magazine style, annotated chart, partitioned poster, flow chart, comic strip, slide show, and film/video/animation. They also provided three main narrative structures based on the author-driven and reader-driven approach. These structures will be discussed in sub-section 2.2 below.

A subsequent study by Hullman and Diakopoulos (2011) looked at the area of narrative visualization from different angles, focusing on some rhetoric elements when using information visualization to tell news stories. It also analysed a number of information visualizations that had storytelling elements, using concepts from other domains such as, literary studies, and tried to provide a theoretical framework of the rhetorical or persuasive techniques such as, information access, mapping, etc. used at four stages of visualization design, (data, visual representation, annotations, and interactivity), and how these techniques might influence interpretation.

However, although some useful studies have been conducted on narrative visualization, the majority of these studies have been designed as case studies or theoretical frameworks (Segel and Heer, 2010; Hullman and Diakopoulos, 2011). The lack of any empirical evaluation studies in this area was the main motivation of the work reported in this research. There are also other topics and aspects of narrative visualization that need to be explored and characterised; this research aims to address some of these topics and conducts some empirical evaluations, comparing different approaches of storytelling through information visualization.

2.2 Narrative Structure

Although elements of stories have variations across different domains, for example, film stories should have a character as a main component while in data visualization, or journalism the story normally consists of different kinds of data, common characteristics have been identified. All stories should have a structure that controls the progression and transition between events and builds a unitary coherent story (Block, 2001; Gershon and Page, 2001; Quesenbery and Brooks, 2010). Without this progression and structure, there is no story but just a series of facts.

According to Tobin (2007), whatever the format that is used, the structure of every story follows the same sequence; a beginning, middle, and end. However, Gershon and Page (2001) stated that in information visualization this format is hard to apply and that “*all stories should have beginning, middle, and end but not necessarily in the same order*”. As stated above, stories should contain change, or progression through a specific path(s). An obvious factor controlling this progression is change over time and this limitation to the scope of storytelling in information visualization is discussed below.

The reference literature offers different opinions regarding the role of time in storytelling and visualization of data (Kuchar et al., 2006). For example, time is used in facilitating understanding and comprehension of story events, and in the structuring or authoring of stories. Different aspects of time are used to convey such things as absolute and relative time, and story and discourse time (Alexander, 2011; Block, 2001; Kuchar et al., 2006). Some studies have proven that a chronological order of events in stories enhances comprehension, understanding, and makes it more memorable (Kuchar et al., 2006). Moreover, one of the main arguments for the role of time in structuring and holding a story together is that storytelling is based on *events*, and events are simply successive actions performed during a period of time. Hence, without time, no storytelling is possible. This argument suggests that only time-series data can be effectively used in storytelling, but this is clearly not the case in narrative visualization. Therefore, a discussion of some alternative solutions for initiating a progression in story events, using information visualization in order to provide a coherent unitary narrative without using time or chronology to order or

structure these events is essential. Heath and Heath (2007) also discussed the possibility of structuring a story as a myth and then chasing a clue, or an answer to a question. This may happen in films stories, such as the crime genre, as well as in information visualization. For example, a design study exploring the effect of the position and ethnicity of a candidate's name on the likelihood of being elected in the case of local elections in the UK (Wood et al., 2011) studied only one dataset in a specific year; with no change over time in the data. But it can be argued that the visualization told a story, as here there was a clue or an answer the designers were searching for as they investigated the problem in a series of steps, finally achieving a solution to the problem by the end of the story.

Furthermore, whatever the story time or story structure, stories can be told in many different ways in terms of the order of the events or narratives. In news stories for example, journalists often use an "inverted pyramid" structure in their reports (Grunwald, 2005) where story events are told in descending order, from the most important to least important. However, it can be argued that this structure aims mainly to attract the reader's attention without having to read the whole story. In this case, important considerations should be taken into account, such as the effect of the storyteller's subjectivity in judging the importance of events and the significance of not misleading the audience by using unrepresentative less important cases at the top of the pyramid. Another example of the discussion of time in storytelling is the common separation between actual time and story discourse time in films (Alexander, 2011; Block, 2001; Pramaggiore and Wallis, 2011). The actual story time is the chronology of story events in the real world, while the discourse time is the period during which the story events unfold when the story is told in films. This concept can be applied to storytelling presentations using information visualization such as those by Hans Rosling (Rosling, 2009) and VAST Challenges videos that provided and reported answers for specific tasks using information visualization (Visual Analytics Benchmark Repository, n.d).

Narrative structures in storytelling visualization have been looked at from a different perspective by Segel and Heer (2010). It presented three structures of narrative visualisation in an effort to reconcile the complex problem of data presentation strategies versus audience member impact/learning objectives.

These structures are used via an author or reader-driven approach. The unique stylisation of the story provides for variable experiences during the data navigation process, suggesting that in any presentation, there is one best-fit structure that could conceivably enhance the reader/viewer experience over the others. Firstly, the **martini glass** structure of a narrative visualisation involves a tight narrative path early in the presentation which evolves into an open informational vessel of free, place-marked exploration and informational review (Segel and Heer, 2010). Alternatively, an **interactive slideshow** structure involves user-driven content in which key, visually coded information is actively transitioned via forward and back buttons towards the primary objectives of the presentation, highlighting key points via amorphous charts, graphs, and visual effects (Segel and Heer, 2010). Finally, the **drill down story** structure involves the presentation of a general theme that is supplemented by individual (or grouped) details and backstories contained within the categorical distinction of the overarching theme and the study objectives (Segel and Heer, 2010).

The relevance of this discussion of narrative structure to storytelling in information visualization is how different strategies of storytelling with information visualization impact on the structure of the stories perceived by audiences and the insights they gained, as the main goal of visualization is to generate insight (Spence, 2007). There are other aspects of storytelling that can be studied along with narrative structure, one of which is the micro elements of the story structure or the transitions between smaller segments of the story. This is briefly discussed in sub-section 2.4 below.

2.3 Story Delivery

Information visualization can be defined as building a mental model of something (Spence, 2007). Therefore, some may argue that data stories are created and structured in peoples' minds, and not in the visualization design itself, as the latter only supports them to construct this mental model. A similar point has been raised by Kosara (2010) where he suggested that "*stories don't tell themselves*", and that

visualization only sets a background or context, but stories are told by people, including the users of the data.

Chen explains that different users may create different mental models, even when using the same system (Chen, 2006). Hullman et al. (2011) also explain that small changes in representing information visualization may provide different results or insights. In the same way, it can be argued that different storytelling strategies with information visualization may result in differences in the way people perceive, understand and construct narratives from them. There are various factors that can be examined, and one of them is the story delivery model that will be addressed in the experiment reported in section 3.2 below.

Before detailing the procedure and findings of the conducted experiment/user study, it is beneficial to review some story delivery techniques from other fields to enrich the scope of the study in hand and explain the relevance of these techniques and how each is expected to influence stories on the part of the recipients. A technique called “direct narration” or “voice-over narration” is sometimes used to tell stories in films and documentaries (Pramaggiore and Wallis, 2011). Voice-over narration means that there is a narrator, which may be a character in the film, who narrates and directs the viewers through the scenes in the film. The role the narrator has in the story they describe may be made explicit at the outset or “revealed” as part of the story telling process itself. The extent to which this technique is used varies from extensively narrated events to restricted narration, where the events in the story just unfold, without being directly narrated. An interesting critique of the voice-over narration technique is that it replicates what the visual narrative already shows (Henderson, 1983). Hence, it is suggested that this technique should be used to convey something different, and in some cases to highlight or emphasise some information (Henderson, 1983).

A similar delivery model to the voice-over narration technique in information visualization is employed when a speaker uses information visualization to tell a story. An example of this model of delivery is Rosling’s talks on various issues in global health and economics using an animated bubble chart (Rosling, 2009). However, it is difficult to avoid narrating what is shown in the visualization in

such talks, but the point is that it should provide something different. Another consideration with this story delivery technique is the effect of the personal and subjective interpretation provided by the narrator on the viewers' engagement in the story, and on their acceptance of its message (Pramaggiore and Wallis, 2011).

The lack of empirical evidence as to what effect an authored narration has on the interpretation of data-rich visualization was the motivation for the work carried out as part of this study. In the first set of experiments reported in sub-section 3.2 below, the effect of the story delivery and narration model on the narratives constructed by audiences will be explored.

2.4 Transitions in Data-Driven Stories

A transition simply means “*the process or a period of changing from one state or condition to another*” (Oxford English dictionary, 2012). This basic definition of transition can be applied to the use of this word in several contexts including storytelling and information visualization. As discussed in section 2.2 above all stories contain some kind of change in which the narrative structure adopted control these changes. Actually, there are micro level elements of the changes in each story. These can be called transitions. Transitions control the more detailed changes and progression in any story for example, scene transitions in films (Bordwell, 2008; Ganti, 2004), and panel-to-panel transitions in comics (McCloud, 1994, 2006). Some may argue that the meaning and use of transitions in information visualization is obvious, for instance, in a time-varying story that is based on change over time the transition occur from T1 (point of time) to T2 (another point of time). In stories that describe a process, the transition occurs between the steps of this process showing the cumulative outcome of these steps. However, as the communicative visualization and storytelling usually tend to make a specific point, and have a purpose whether it is to persuade or inform, the effective use of transitions to achieve the purpose, keep the flow

and continuity of the story, hold the audience attention, etc. extends beyond this obvious interpretation of the meaning and role of transitions.

Storytelling through information visualization, whether the story is delivered by a direct narrative or a speaker/presenter or explored interactively by users, consists of a chain of actions that trigger a transition from one event or scene to another. As a result, the story unfolds smoothly and gives a sense of continuity. This is similar to continuity editing in films where there are a number of techniques to ensure the smooth transitions between shots and scenes (Bordwell, 2008). It can be argued that the idea of continuity and smooth flow of the data-driven stories in information visualization has started from as early as Tufte's (2001) discussion of narratives of time and place. This gives a basis for possible elements to use to create this continuity, which are time and space. However, with the variety of data that can be visualized and used to tell coherent stories, it can be argued that time and place are not the only factors that can be used to tell a story through information visualization. This depends heavily on the main point of a story as with different messages or points; the designer may choose a different path and transitions to make his/her point. It also depends on the underlying purpose, focus, and the complexity of data and contents of the story. While there are some helpful studies and rules of the graphical representations suitable for different data types and patterns usually represented and communicated through the use of information visualization, such as, temporal patterns, network data, geographical patterns, etc., the choices of transitions the author/designer has to communicate a message or make a point and tell a story through information visualization are much more complex. It sometimes requires using several visualization techniques, a combination of conflicting views or facts, etc. The extent to which different types of transitions have been used to tell stories with data through information visualization is less represented in the literature. Hence, further studies to cover this aspect of narrative visualization are required. Looking at some characteristics and taxonomies of transitions across other more matured domains of visual storytelling, such as films and comics, could be highly beneficial to address the issue of transitions in storytelling visualization.

The characteristics and taxonomies of transitions in storytelling vary across domains. In comics, McCloud (1994, 2006) proposed taxonomy of transitions types from one panel to another. His taxonomy consists of six types of transitions: (1) *Moment-to-moment*: “a single action portrayed in a series of moments”. (2) *Action-to-action*: “a single subject (person, object, etc.) in a series of actions” (3) *Subject-to-subject*: “a series of changing subjects within a single scene” (4) *Scene-to-scene*: “transitions across significant distance of time and/or space” (5) *Aspect-to-aspect*: “transitions from one aspect of a place, idea, or mood to another” (6) *Non-sequitur*: “a series of seemingly nonsensical, unrelated images and/or words”.

This taxonomy of transitions has been considered an important theory in storytelling in comics for a number of reasons. It provides a detailed explanation and analysis of the process of constructing and telling a story in a visual medium through the use of a combination of pictures and words. It can be argued that communicating data stories through information visualization consists of that same elements/combination, the pictures (the visual representation) and words (such as, annotations and labels). However, information visualization has one more important component that impact on or influence the story development, it is highly an interactive medium. Despite this fact, it can be argued that McCloud’s (1994) taxonomy of transitions types is still valid to be applied to storytelling through information visualization as this interactivity still occurs in a sequential manner, with one action at a time to get to the next event or panel. This is agrees with McCloud’s (1994, 2006) definition of comics stories as a sequential art.

Actually, before adopting McCloud’s (1994, 2006) taxonomy and applying it to information visualization case studies, this model should be refined and each type of transition should be defined in the context of information visualization. As the research in hand is still in progress, this task is not fully completed but an initial important step has been taken towards this refinement. A Glossary of equivalent terms could be developed as follows:

Table1: Terms used in McCloud (1993, 2000) taxonomy of transitions and possible equivalent terms in information visualization

McCloud Taxonomy of Transitions	Equivalent Terms in Information Visualization
Panels	Views
Subjects	Data variables or dimensions
Action	Change (on one variable)
Scene	Key facts or direct comparison without detailing how a single object in the comparison exactly changes. Conflict or comparison of space and time. For example, in 1990s and in 2012, or now and ten years ago.
Moment	Point of time or timestep. Such as in some small multiples.
Aspect	Viewpoints, different angle of views. Similar to camera movements in films. Connecting two different ideas/datasets and establishing comparisons. Time mostly stand still, but can also change in some occasions.

Moreover, there are good and valuable user studies on transitions in information visualization. Heer and Robertson (2007) provided a taxonomy of animated transitions in statistical data graphics and conducted a user study on different aspects of using animated transitions between different statistical charts using

object tracking tasks. This study has been followed by Dragicevic et al (2011) who also conducted a user study on animated transitions, particularly on temporal-distortion or pacing of animation. Although these are useful and valuable user studies, they are limited to animated transitions and used object tracking tasks to look for time and error metrics. Further work is still needed to address the issue of transitions in narrative visualization.

There are a number of factors that may aid understanding, controlling, and going through the transitions in any data-driven story delivered or told through information visualization, particularly when stories are interactively explored and constructed. One factor is the use of annotations (Hullman and Diakopoulos, 2011). It can be argued that annotations are essential not just as legends or axis-labels, but also in leading the users through the story path to its main message or point in both static and dynamic or interactive visualizations. This contributes to the process of narrative construction and forming a mental model by users and audiences. Kosara (2003) discussed the issue of context and focus and how the transitions occurred between them. An example of this could be an interactive step such as distortion or zooming in a specific area on a map which entails a transition. However, the discussion of these techniques is beyond the scope of this research at this stage.

2.5 Emerging issues and need for empirical research

The literature review reveals that storytelling in information visualization has been a hot topic in recent years and although some useful studies have been conducted on the topic of storytelling visualization, the majority of these studies were designed as case studies and theoretical frameworks on specific aspects of the storytelling. As a result, there is a need for some empirical evaluation studies which compares different approaches of storytelling with information visualization. The lack of these studies was the motivation for conducting an empirical experiment comparing two different models of story delivery, the

first is a direct narrative by a speaker using an information visualization design, and the second is by interactively exploring a dataset using an information visualization software. The experiment conducted, its factors and procedure are detailed in the next chapter.

Furthermore, the literature review reveals that much of the work on transitions in information visualization has focussed more on technical or graphical techniques used than on the placement of these transitions within a story, their impact on the meaning and comprehension, and their role in narrative construction. This research is concerned with the use of transitions, changes, or shifts within data-driven stories. It also focuses on comprehension and understanding rather than usability and metrics such as error and time. The proposed work to be done in this area is to qualitatively code a dataset of storytelling visualizations that use different transitions to tell a story based on the McCloud (1994, 2006) taxonomy of transition types with some refinement and adjustment of the model. Then, subsequently to explore the use of the patterns of these transitions within this dataset. A dataset of VAST challenges videos (Visual Analytics Benchmark Repository, n.d) has been chosen for this work/task for a number of reasons. The timeline for completing this and the justification of the dataset chosen is detailed in the future work plan chapter below.

3. Research Methods

The literature review chapter above has touched on some aspects of storytelling and the previous work completed on this sub-field in information visualization. The literature review has shown that little or no empirical evaluation exists to compare different approaches of storytelling visualization. This chapter is mainly related to objective 2 mentioned previously in the introductory chapter. It also provides brief explanation and justification of the research strategy that will be used in the future intended work, and to accomplish objective 3 of this research. It is divided into two main subsections. Sub-section 3.1 discusses concisely the research strategies to be adopted in both the work achieved so far and the proposed work.

Sub-section 3.2 details the experimental design and procedure of the first set of experiments conducted. More specifically, the experimental factors, the experimental design decisions, and questionnaire tasks for each delivery model, the participants and their selection criteria and academic backgrounds, and the detailed experiment procedure. An outline/description of how some ethical issues have been addressed in the first experiment is also included.

3.1 Research Strategy

The primary aim of this research is to gain insight into the area of storytelling visualization, understand and characterise some of its aspects, and to conduct some empirical practical work to fill in the gaps and expand the previous work in this area. It starts with a general question as to how different models of information visualization delivery differ and impact on comprehension and narrative construction and development (objective 2). It will expand into the area of transitions used in story telling through information visualization as the next step in this research which relates to objective 3.

Saunders et al. (2002: 92) concluded that it is important to choose the appropriate research strategy for the research question. Hence, for objectives 2 and 3 of this research, different research strategies have been chosen. For objective 2, the work completed so far, *an empirical experimental evaluation* research strategy has been adopted. The justification of methods, the details of conducting this part of the research, and the sample chosen are discussed in the sub-section 3.1 below where appropriate. For objective 3, the future work planned, *a case study* research strategy will be adopted.

The second area chosen for this PhD research is the transition types in storytelling through information visualization. As stated in objective 3 in the introductory chapter above, this research is aimed at exploring and modelling the transition types used in telling stories with information visualization. Therefore, a dataset of a number of data-driven stories is needed to address this objective, and to explore and analyse the transitions in the stories. This dataset should be suitable for comparison and modelling of

transition types. To accomplish this, a case study research strategy has been chosen to study VAST challenges videos (Visual Analytics Benchmark Repository, n.d.) Therefore, for each video, the types of transitions used, the time and order of these transitions, and the graphical representation used will be investigated. The next step after investigating and coding the videos is looking at the whole dataset generated, analyse it, and aggregate or group it by different factors, for example, by author(s), years, winners, etc.

Documenting and analysing these transitions through the use of the VAST challenges videos will provide the framework for studying how very similar stories are told and allow exploration of what is going on at specific points in time during the story discourse time (the period in which the story is being told), which transition types are common to start with and which transition types to close with. This will also enable identifying the graphical representations or techniques of these transitions. This work will provide the context for the remaining stages of the research in hand, the transition types used, pattern of usage, and how these impact on story development/construction, understanding, and comprehension. Accordingly, based on the findings at this stage, appropriate experimental design should to further explore the topic.

For the work done and the proposed work, the mixed methods approach in dealing with and analysing the data will be used. Both quantitative and qualitative results provide opportunity for an in-depth analysis of the user response. Thomas (2003) and Creswell (2009) argue that in a complex, modernised sociological environment, a mixed-method of research provides academics with a best-fit model for capture of multiple, inter-related streams of data.

3.2 Experiment #1: Story Delivery Models

3.2.1 Experimental Factors and overall Experiment Design

The aim of this study is to explore and compare the effects of two different story delivery models that use information visualization on how people construct narratives, comprehend and tell stories about the data. The information visualization software used to explore this is Gapminder (Gapminder, 2012). This is an

animated bubble chart where the x and y axes allow user selected variables to be compared, and the bubbles represent countries. These bubbles are coloured by continent, and an animation and/or timeline slider can be used to show how the bubbles move over time. Within this context two delivery models of storytelling have been examined:

1. Direct narratives by a speaker who is using information visualization to deliver a story to the audience.

For this model, a video of Hans Rosling talking in TED (Rosling, 2009) has been chosen. Rosling's model of storytelling with information visualization is one of the most famous in the field. He used Gapminder's animated bubble chart to give talks on several topics. The chosen video concerns the HIV epidemic where the x-axis is income per person in USD, and y-axis is the percentage of adults infected by HIV.

2. Let the users/audiences explore the data at their own pace using interactive visualization software similar to that represented by the speaker in the first model.

For this model, Gapminder World software (Gapminder, 2012) has been used and the participants were allowed explore a dataset on child mortality (y-axis) and fertility rate (x-axis) for the same timing of Rosling's video.

A number of experimental design decisions have been made to control factors that may affect the experiment results:

First, a within-subject experimental design has been used so that there is less variance due to participant disposition. This means that any results or differences will be due to difference among

conditions rather than behavioural differences between participants. In addition, a within subject experiment was also beneficial in getting a sufficiently large sample for the purpose of the study.

A position paper by Robertson recommended getting a sample of between 12 and 20 in controlled experiments and fewer than this for qualitative or insight-based experiments (Robertson, 2008). As the study in hand combines elements of both types, a sample of 13 participants should be adequate. This takes into account the amount of qualitative data that needs to be analysed and the difficulty of recruiting volunteer subjects.

Hans Rosling's video on HIV has been chosen for the first delivery model for a number of reasons. First, the number of views this video has received on multiple websites such as YouTube and TED is fewer than other videos by Rosling. This makes it less likely that potential participants will have seen the video. The second reason for choosing this video is to control the overall time for each experiment session. This video is only about 10 minutes and focused on a specific topic.

However, for Gapminder, a different dataset has been chosen to avoid participants' answers being influenced by the first model they had experienced. The dataset chosen for the Gapminder interactive model were also from a very similar domain to minimise the effect of participants' backgrounds.

A counterbalancing technique has been used to assign participants to two groups. Each group experienced the two delivery models in a different order to account for any learning effect.

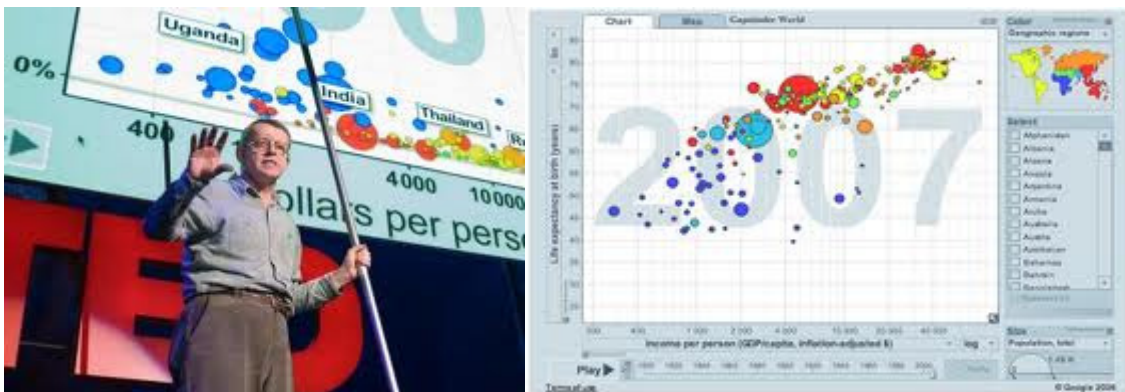


Fig. 1 From left to right: Hans Rosling presenting facts on the HIV epidemic (Story Delivery Model #1) and the Gapminder World interactive information visualization platform (Story Delivery Model #2)

3.2.2 Questionnaire

The experiment consisted of two phases followed by four Likert-scale subjective feedback questions. In the first two phases, participants were required to answer five questions after watching the video and five similar questions after exploring data on Gapminder. For each question, an estimation of the time required to answer the question was given. This helped to control the overall experiment time and assisted participants in estimating the amount of emphasis and focus needed for each question.

As the aim of this experiment is not to measure the usability of delivery models, measures such as time and accuracy would not be appropriate; instead, the experiments aims to understand and explore how each model affected users in constructing narratives and telling stories in addition to individual insight. Hence, open-ended questions are important. Moreover, open-ended questions where participants tell stories in writing help them to formulate their mental models about the story and to produce unitary narratives (North et al., 2011). This is in contrast to think-aloud techniques used in insight-based evaluation which generates a series of insights gained in the order they were discovered (North, 2006; North et al., 2011). An open-ended question was asked to trigger the re-telling of a story to find out how participants sequence story events gained from each delivery. This is a task that is widely used in education to assess comprehension (Fulkerson et al., 2009). Part 1 of the questionnaire on Rosling's video consisted of the following five questions:

1. What was the video mostly about? (Approx. 1-2 min)
2. Re-tell the story you gained from the video in as much detail as you can. Try to write a story that makes sense to someone who is not familiar with the story/topic. (Approx. 6-8 min)
3. What did you learn that you did not already know? In other words, describe new information/knowledge you gained from the video. (Approx. 2-3 min)

4. Did you learn something that contradicts what you already know about the topic? What is it?
(Approx. 2-3 min)
5. What do you think the speaker's purpose was in producing this video? (Approx. 2-3 min)

Part 2 of the questionnaire had exactly the same layout and approximate time needed for each question as Part 1. The only difference being the precise wording of the questions. This was changed slightly to refer to the second delivery model with Gapminder rather than Hans Rosling's video. At the end of the experiment, participants were asked to answer two five-point Likert-scale questions on each model. The two questions on Hans Rosling's video were as follows:

1. How easy or difficult did you find telling a story after watching the video?
2. How curious were you about the data/story in the video?

The answers ranged from "easy" to "difficult" for the first question and from "not at all" to "very curious" for the second. Two similar questions were asked about the data/story they explored in Gapminder.

A copy of the full questionnaire as used in the experiment/study is attached in Appendix A.

3.2.3 Participants and Procedure

13 students (9 Females and 4 Males) were recruited from a local university. The age of the participants ranged between 23 and 48. Three main selection criteria were identified: participants should not have taken a Data Visualization course/module, they do not have advanced knowledge in information visualization, and they are not professional data analysts. In other words, this study aimed for educated but non-expert users of information visualization. This is also a difference between this study and an insight-based evaluation approach which requires expert users (North et al., 2011). In the sample used, participants came from varied academic backgrounds where eight of them had elected, but not yet started

to study a Data Visualization module, five of them came from an HCI course where data visualization was not covered at all in their studies.

As it is difficult to recruit subjects from the general public, students who are likely to be motivated about the scope of the study but also do not have advanced knowledge about the topic have been chosen. Students who chose a Data Visualization module from a number of options are expected to have an interest in visual data representation and communication while students with a HCI background are expected to be interested in the interactivity aspects of the visualization systems.

The entire experiment was carried out in a single session for each participant. Total time for a single participant was about an hour.

Initially, each participant was briefed on the purpose of the experiment and the experimental procedure and asked to sign the consent form which was sent to them by email in advance.

Next, participants were randomly assigned to one of the two groups. Each group was shown the two models of story delivery with information visualization in a different order.

Participants were allowed to take notes while watching the video or exploring Gapminder if they wished and they were given a note sheet for this purpose. These notes could be used as a reminder of important events in the story and to serve as an outline to tell the whole story. However, usage of this option by participants was very limited.

Group A watched the ten-minute video of Hans Rosling presenting data on the global HIV epidemic using an animated bubble chart (Rosling, 2009). Then, they answered Part 1 of the questionnaire. In the next stage, they were briefed about Gapminder and were given a simplified version of the Gapminder user guide to provide instructions about the available interactivity functions when exploring the data (Gapminder, 2012). They were asked not to change the indicators (X and Y axes) in order to control the number of indicators participants had to work with in both delivery models. Then, they answered Part 2 of the questionnaire. Finally, they were asked to answer the four Likert-scale subjective feedback questions, and to comment on the overall experience and to clarify their choices.

3.2.4 Framework for Data Analysis

In this sub-section, the process of analysing and coding the data is described while in the next chapter the findings after following the analysis procedure detailed in this section are reported.

After transcribing all participants' answers, the analysis and coding process for each question were as follows:

3.2.4.1 Q1. Main Theme of the Video/Software

A completely data-driven coding approach was followed as there were no previous expectations about the answers of this question. It was originally set to introduce the story and to gradually direct the participants to the more important and longer question that follows. The emerging theme here was how participants initially perceived the topic and the main factors for comparison in the story. Responses were coded according to the main themes mentioned in answer to this question. Answers to this question were coded into a total of four categories:

- **Geographical:** if the participant only reported spatial change. An example of this perception of the story is “*HIV epidemic in different countries*”.
- **Temporal:** if the participant only reported change over time as the main topic of the story. An example of this perception is “*how child mortality changed over time*”.
- **Geographical and Temporal:** if the participant reported both patterns in his/her answer to this question.
- The fourth category/code was **Neither**. This code was assigned to answers that could not be described as Geographical, Temporal, or both. For, example, “*number of children in respect to child mortality*”.

The total number of answers that fill into each of these four categories for each story delivery model is described in sub-section 4.1 and shown in Fig. 2.

3.2.4.2 Q2. Retelling the Story

Q2 was considered to be the question which would make the most significant contribution to the research, and as a result, was the question that participants were encouraged to spend the longest amount of time in answering. In the analysis of answers to this question, the first thing was to start identifying some possible themes for coding participants' stories such as, sequencing story events, and the role of unexpected information and outliers.

Other themes and detailed codes under some themes have emerged from the data. Participants' stories have gone through a number of coding cycles. First, the stories have been prepared for analysis by grouping stories generated from each delivery model separately. Each story has been formatted into a four-column table. The first column contained the stories separating each sentence for analysis. The second column contained space for preliminary description and code notes which represented the first coding cycle. These notes helped to provide a transitional link between the raw data and codes in the following coding cycles. The third column contained codes under the first emerging theme, *Insight Types*; this column represented the second coding cycle where we employed an approach similar to the insight-based evaluation approach. The fourth and last column was assigned to the *Narrative Structure* theme which was identified as part of the third coding cycle. The classification was reiterated several times using a code book of definitions and themes to ensure consistency amongst all participants and delivery models.

I- Insight Types Theme

The main goal of visualization is to generate insight (Spence, 2007). While the definition and characteristics of insight are discussed in a number of studies (North, 2006; Saraiya et al., 2005; Yi et al.,

2008) there are still some ambiguities, as well as contradictions between the definition of insight and the way it is evaluated in information visualization. While North defined the insight as complex, deep and qualitative (North, 2006), studies on insight-based evaluation suggested counting the accumulation of smaller insight occurrences (Saraiya et al., 2005; Yi et al., 2008). However, although this study agrees and identifies types of insight in the experiment, it did not count occurrences of insight, the arguments for this approach in the data analysis are discussed below.

In insight-based evaluation, each occurrence of *insight* is registered. This in turn gives a total number of insights gained. Then, for each occurrence the insight type is identified and can be categorised into simple or complex insights (North, 2005, 2006; North et al., 2011). However, although this method looks like the most appropriate evaluation method for the data and objectives of this study, despite the fact that we aimed for general users, it is still challenging to categorise the insights into simple and complex varieties since the authors do not accept the claim that a number of simple insights accumulate to form a more complex one.

In contrast, North has classified insights like finding a minimum or maximum value as simple insights while a combination of minimum and maximum values, called a *Tradeoff* insight, was classified as a complex insight (North, 2005). This also makes it difficult to count insight occurrences, particularly in written format stories as minimum and maximum values might be counted as two simple insights or one complex insight. As a result, in the analysis of data based on the insight types theme, only insight types gained by each participant have been identified but their number or significance has not been quantified. In the end, the number of participants who gained each insight type has been calculated.

The insight types that emerged and which were used in coding the data based on the *Insight Type* theme were:

- **General Pattern:** the general trend or pattern of most countries. For example, the general rise or decline in an aspect, or a general relationship between two factors.

- **Detailed Pattern:** description of details on specific points of time or instances in general patterns. For example, the general pattern is a decline in child mortality while the detailed pattern is the average mortality rate in different periods of time to show how this happened.
- **Outlier:** maximum, minimum, or anything outside of the general pattern; in other words, an exception.
- **Tradeoff:** a combination of minimum and maximum or making comparisons between most and least in terms of one or more specific factors.
- **Grouping:** to group different things in one category based on one or more specific criteria. In other words, define a subset or category of data. For example, Western and Eastern countries have different figures, or oil-rich and Western countries have lower child mortality.
- **Anomalies:** the ability to identify data errors if there are any. For example, missing countries at specific periods of time.

II- Narrative Structure Theme

The second theme used to analyse Q2 answers was *narrative structure*. The structure is simply how the story is progressed, the order of sentences or information blocks in the story. It is important to distinguish here between the narrative visualization structures as identified and discussed by Segel and Heer (2010) and written narrative structure. The narrative structure here refers to the written narrative structure. In other words, narratives and stories constructed and written by participants using the two delivery models; not how information is structured in the visualization design.

A range of educational literature on assessing learning progress and comprehension through re-telling has been consulted as well as literature on written news stories (Fulkerson, 2009; Grunwald, 2005; Spiegel, 1981) in order to identify common narrative structures and develop appropriate codes for them. In addition, some further narrative structures became obvious when reading through the participants' stories.

In the analysis of participants' stories, up to two structures have been recorded for each story. All stories were assigned a *main narrative structure* that is the most appropriate one to explain the flow of narrative in the story. Some additionally had a *sub-structure* which is the structure used within the main story theme. For example, the main structure might be a *chronological* one but within this chronology it may demonstrate a *cause and effect* over a specific period of time. Some of the stories written by the participants had a clear sub-structure while others had only a main structure. Each of these main and sub-structures were assigned one of the following five types:

- ***Problem-Solution***: emphasising the problem and suggesting solutions whether from external information used by the narrator in the first delivery model or from personal knowledge about the topic either in the first or second model.
- ***General to Specific***: starting from the general trend to more specific instances, details, outliers, maximum, minimum, and more specific insights and relationships.
- ***Specific to General***: starting from outliers, maximum, minimum, etc. to more general trends or the bigger picture.
- ***Chronological***: starting from past to present; in other words, describe relationships, patterns, outliers, and any other insights in a chronological order.
- ***Cause and Effect***: describe a figure, pattern, or insight and provide the cause(s) for this insight.

When data was coded based on the *narrative structure* theme, the following points were taken into account:

- In both the *general to specific* and *specific to general* structures, participants may have written a statement to conclude the overall message for delivering this kind of information. This does not change the main narrative structure in the story.

- In the *chronological* structure, participants may start with a general statement describing the aim of the visualization or the general pattern in the story as an introduction. However, the remaining details are told chronologically.

3.2.4.3 Q3 and Q4. Participant Learning

A content analysis for these two questions in terms of what insight types were reported by participants as new or contradictory information has been performed and recurring codes identified. The insight types categories in sub-section 3.2.4.2 above for this purpose. Some participants' answers to these two questions contained additional different types of information to the insight types. However, this additional information did not show any pattern in the results, as it depends heavily on the individual background about the topic. The second thing taken into account when analysing answers to these two questions was whether they represented part of the participants' stories in Q2.

3.2.4.4 Q5. Narrative Purpose

Although no specific themes have been used in this question the difference between participants' answers to this question in the two delivery models were apparent and discussed in Section 5 of this paper.

3.2.4.5 Subjective Feedback Questions

The subjective feedback answers were treated as ordinal data and simple frequencies have been calculated. We compared the two delivery models in terms of difficulty in telling stories and curiosity as well as the relationship between curiosity about the data and difficulty of telling stories within each delivery model.

3.2.5 Ethical Considerations

Ethical approval was obtained from the school Ethics Committee before conducting the first set of experiments. As previously stated, all participants have been informed in writing (by e-mail) prior to the

experiment and verbally before starting the each experiment session about the study purpose, procedure, duration, and that participation is a voluntary basis. A copy of the consent form used has been sent to them in advance and written consent to participate has been obtained from the participants. They were aware that they may withdraw from the study at any time. Raw data in the form of questionnaires is stored securely for the period of the PhD research and then will be completely destroyed.

The preliminary results reported in chapter 4 below have been presented to the Data Visualization module students including those who took part in the study in the last Data Vis lecture in Term2 in 2011/2012.

Participants will also be informed about any publications based on the study they took part in.

A copy of the Explanatory Statement and Consent Form for Participants is attached in Appendix B.

3.2.6 Limitations and Enhancement to the Work Done

One limitation is that the coding is not consistent yet. A plan to overcome this limitation is by providing a sample of the participants' answers to one or two of the giCentre members along with the CodeBook used to qualitatively coding these answers and ask them to code them again if possible. The generated codes will be compared with the one created by the researcher. Appropriate techniques to assess any differences that might arise in coding will be used. One possible quantitative technique that is commonly used in such situations is Fleiss-Kappa scoring which gives a measure of how similar several codings are. Using such technique to assess and ensure consistency of coding will enhance the reliability of the study.

Further enhancement to the experiment reported above is planned. This is to conduct a complementary similar user study controlling for the possible effect of dataset on narrative construction. Specifically, to conduct a within-subjects experiment with two Hans Rosling videos (one for each data set) and then counterbalance data sets between participants (half see video A, half see video B).

So far, the sample size is small and further experiments should be conducted to provide more generalizable results that may provide firmer evidence for some observations. This will also allow for further quantitative analysis and variance depiction.

4. Preliminary Findings and Discussions

In this section the preliminary results of data analysis are reported. In the next section some of the implications for storytelling visualization are discussed.

4.1 Questionnaire

4.1.1 Initial Perception of Geographical and Temporal Patterns (Q1)

The results point to an interesting difference between the two story delivery models in terms of how the participants perceived the main pattern or factor of comparison in each story (see Figure 2). This is despite the fact that in both models, the same visualization design has been used and the characteristics of the datasets were exactly the same.

It is found that after watching Rosling's video, 11 participants (85%) emphasised only the *Geographical* pattern, only one participant (8%) emphasised both *Geographical and Temporal* patterns, and one participant (8%) did not emphasise either. This seems to result from the way in which Rosling told the story. At the beginning of his talk, he played an animation to show how the HIV infection rate has changed over time in the world. However, he spent most of the talk stressing trends and causes in different countries.

In contrast, after exploring the data on Gapminder, only one participant (8%) emphasised the *Geographical* pattern, four participants (31%) emphasised only the *Temporal* pattern, five participants (39%) emphasised both *Geographical and Temporal* patterns, and three participants (23%) did not identify clearly the main comparison factor or pattern in the story in their answers to Q1 in the questionnaire.

This shows the important role of time in stories and that when users have the ability to freely explore time-series data they perceive the chronology and temporal pattern in the first place. This tendency was countered when their attention was strongly directed throughout the sequence of narratives as in Rosling's video.

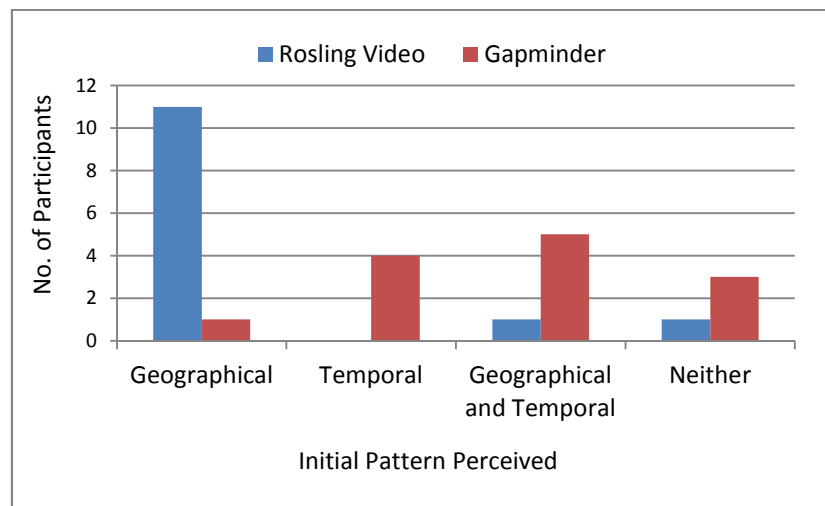


Fig 2 Initial perception of Geographical and Temporal patterns in the story in the two delivery models

4.1.2 Insight Types Gained (Q2)

In terms of the insight types gained by participants from each delivery model, the results clearly indicate that a difference in the story delivery model affected users' ability to gain specific insight types (see Figure 3). Generally, the participants' stories that were written after exploring the data on Gapminder contained a slightly greater variety of insight types per story than the stories written after watching Rosling's video. Duplicate insight types were eliminated so that each insight type is distinct within a story. In other words, with the Gapminder model, more participants gained a greater range of insight types than from Rosling's video. However, there were two interesting exceptions in the results. The first is that the *general pattern* insight type was gained by more participants from Rosling's video than from Gapminder. The second exception was that the *anomalies* insight was only gained from Gapminder.

Perhaps this is due to the fact that participants' attention was directed by Hans Rosling when watching the video so they are less likely to spot deficiencies in data unless the speaker clearly point to it.

In some cases, participants just described how to use visualization to gain knowledge or the story. This happened in both delivery models. Therefore, in these cases we were not able to identify specific insights from the data, although a clear understanding of interactive design and the video was apparent in their stories.

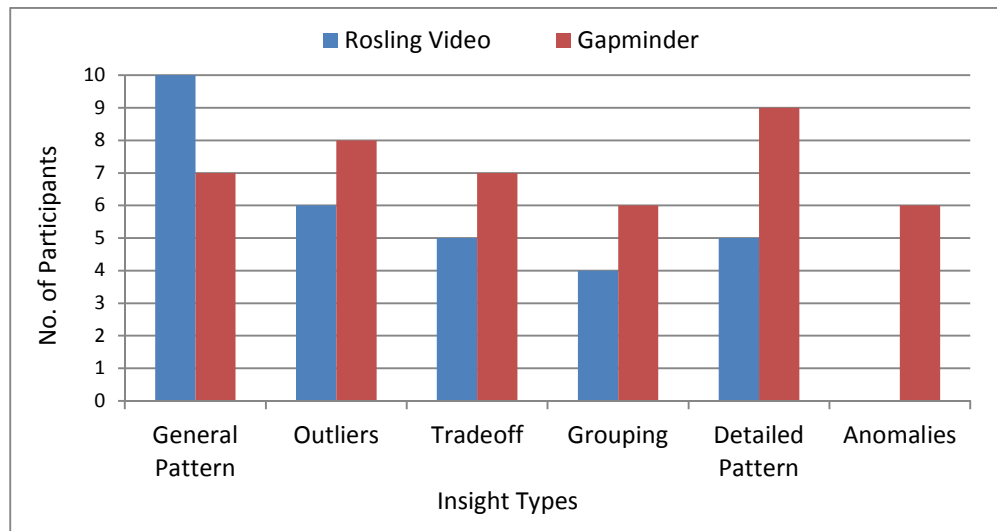


Figure 3 The number of participants (out of 13) who reported each insight type in their stories for each story delivery model

4.1.3 Narrative Structure- Sequencing Story Events (Q2)

Generally, the most common narrative structure in the participants' stories in both delivery models was the *general to specific* structure (see Figure 4). Nine participants used it with Rosling's video and eight participants used it with the Gapminder model. In Rosling's model, seven out of the nine participants who used a *general to specific* structure as the main structure also used a *cause and effect* structure as a sub-structure which means that they followed the narrative structure used by Rosling. In addition, two participants used a *specific to general* structure and one of them used a *cause and effect* structure as a sub-

structure. This might also result from the emphasis Rosling has given to specific countries in the video. Only one participant used a *problem-solution* structure with Hans Rosling’s model. From this participant’s comments at the end of the experiment, it seems that this is due to background knowledge in the topic so the participant was able to provide details on the problem and discuss solutions rather than following the speaker’s narrative structure.

An interesting finding was that the *Chronological* structure has not been used at all with Rosling’s model while two participants used it with the Gapminder model. Although change over time is an important part of the story in Rosling’s video, the speaker emphasised the context and reasons for patterns within specific countries. In contrast, when participants explore time-series data independently, the role of time becomes apparent for structuring and initiating progression in story events.

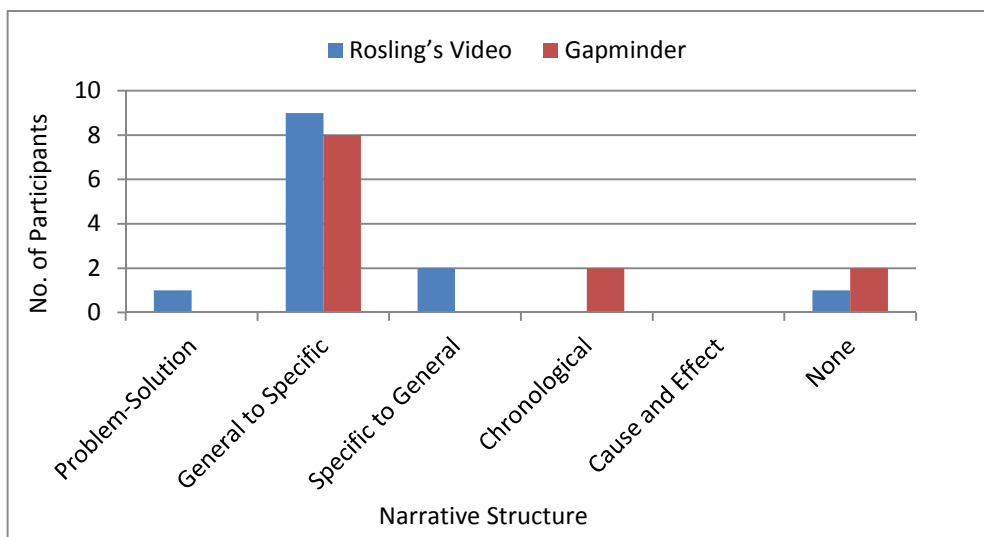


Figure 4 The number of participants (out of 13) who used each narrative structure as a main structure of their stories for each story delivery model

4.1.4 Unexpected Insights Gained (Q3 and Q4)

In Rosling’s model, twelve participants answered Q3 on the new information they had learned, seven of them reported at least one outlier as part of the answer. Ten participants answered Q4 that asked them if

they learned something that contradicts what they already know. Five of them also reported at least one outlier as part of their answers.

In the Gapminder model, ten participants answered Q3, four of them reported at least one outlier in their answers. Six participants answered Q4 but none of them reported outliers in their answers. However, some participants interpreted the two questions in the same way and referred to Q3 in their answers to Q4.

For Q2 stories in both models, participants tended to use their answers about unexpected information gained or part of them, whether this was new or something contradictory, outliers or other insights.

Specifically, they usually reported more examples and details in their answers to Q3 and Q4 while using one of these details to express an idea or findings in their stories in Q2.

4.1.5 Expected Purpose in Delivering Stories in Each Delivery Model (Q5)

For both models, most answers ranged from raising awareness about the topic, urgency in solving the problem or providing the data in a more compelling way that is easier to understand than a tabular format. In other words, the purposes identified were mostly relevant to the data and the visual representations. However, an interesting result occurred in the answers provided by two participants on the speaker's purpose in producing the video in Rosling's model.

They thought that there was a personal purpose behind the story. For example, one of them said that the purpose was "*political posturing, perhaps to seek funding*". The apparent objectivity offered by the Gapminder software did not prompt such questioning.

4.2 Participants subjective Feedback

Although most participants found telling a story after watching Rosling's video easier, they did not perform exceptionally better in other aspects such as the variety of insight types they gained as shown in section 5.2. We could not say that the more the participants were curious about the data/story the easier they found telling a story in both models, although this has happened in some cases.

However, some participants who were more curious about the video than Gapminder commented “*there is nothing wrong with the tool (Gapminder), it is about the data*” while participants who were more curious about Gapminder provided comments such as “*if I had more time I would spend it exploring more data and playing with the tool rather than watching the same video again*”. One participant who followed a *chronological* structure for their story for Q2 commented that with a specific question or goal in mind it would be easier to tell a story using Gapminder. An interesting point here is whether the participant would have used a different structure if they had a specific point or message to support. As this was not the case, *time* was the most obvious parameter she could use to structure her story.

The results we found from the subjective feedback questions are summarised in Figures 5 to 8.

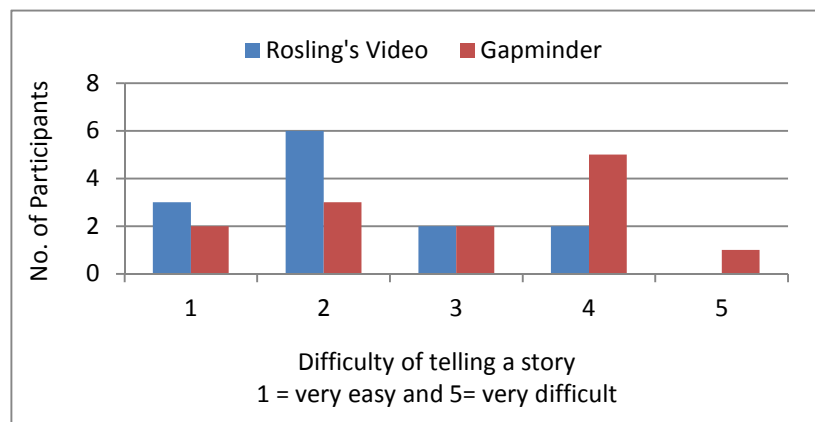


Figure 5 Participants’ subjective feedback on the level of difficulty of telling a story for each story delivery model

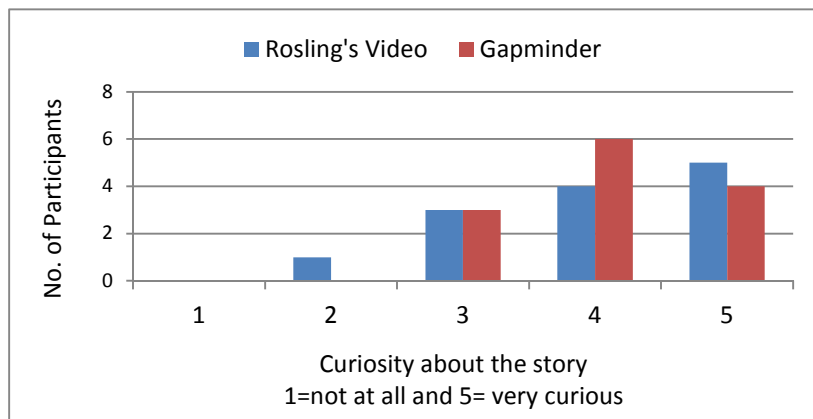


Figure 6 Participants’ subjective feedback on the level of curiosity about the data/story for each story delivery model

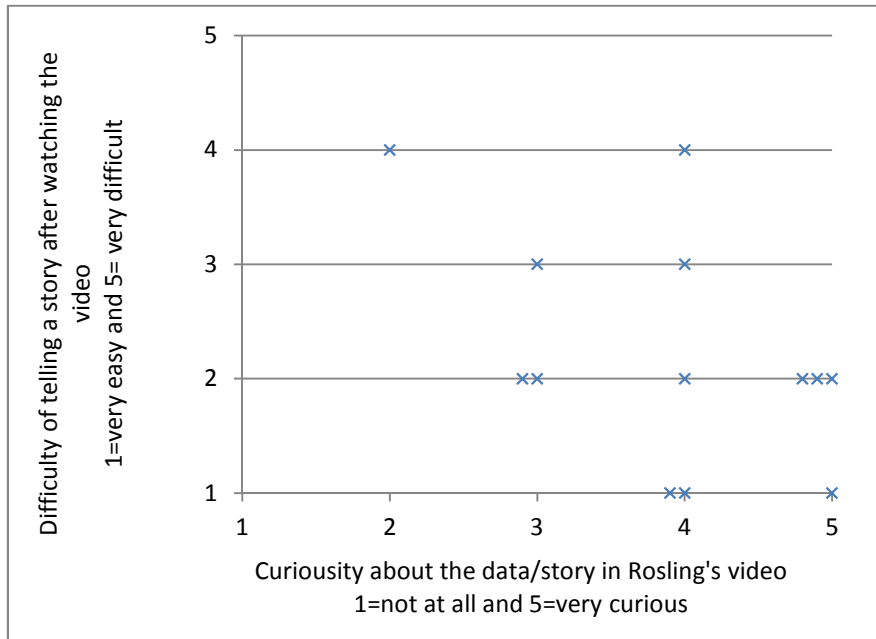


Figure 7 The relationship between curiosity about the data/story and difficulty of telling a story for Hans Rosling's model of story delivery

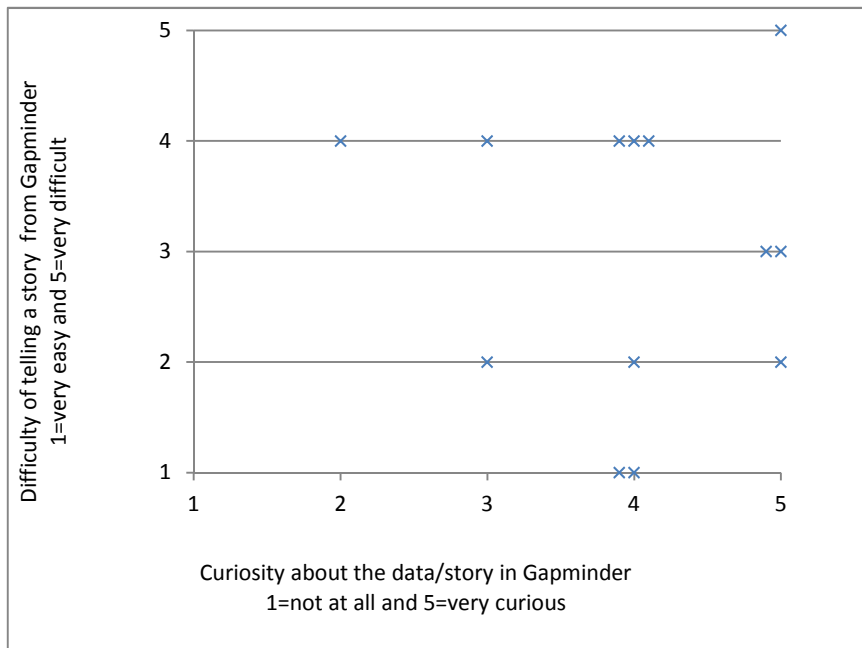


Figure 8 The relationship between curiosity about the data/story and difficulty of telling a story for the Gapminder story delivery model.

5. Implications of the Preliminary Findings of the First Experiment

The first experiment in this PhD project reported above has several implications for storytelling through information visualization, based on the two story delivery models investigated. Most of the differences between these two models seem to relate to the extent to which they direct and control audience attention. The following recommendations are based on the implications of this study, and particularly on the findings described in the previous section:

I- Pay more attention to data errors if there is no presenter or narrator to control and direct audience attention

Participants were less critical about the data in the narrated Rosling delivery and did not spot any data errors. In contrast, with regards to the Gapminder software, they were more critical about data and more able to spot data errors. This might have resulted from the way in which participant attention was strongly directed throughout the story in Rosling's delivery, limiting ability to spot data errors. It suggests that more attention should be paid to data errors in information visualization stories that are delivered and constructed through users' interactive exploration. If there are any errors that are apparent to a designer before a tool or design is released, avoiding these errors or, alternatively, providing some notes or explanations, can help to minimise their negative impact on audience engagement and avoid distracting the users from the overall flow of the narrative they are exploring.

II- Consider providing other views and interpretations, in order to minimise the effect of a single point of view on audience acceptance of the message.

Participants' answers about the expected purpose of producing or providing the data/story in Rosling's video and in the Gapminder software highlight an important point. The "direct narration" or "voice-over narration" techniques used in films entail interpreting or explaining story events from the narrator's point

of view (Pramaggiore and Wallis, 2011). In information visualization, the narrator's background knowledge and understanding of the topic play an important role in his or her interpretation of story events. In some cases, this might affect audience acceptance of the message or purpose of the story. The results of our study show that two participants thought that there was a political or personal purpose behind Rosling's presentation, while none stated this in relation to the Gapminder software. A reasonable approach for tackling this issue when delivering a data story is to consider ways in which alternative perspectives can be demonstrated in the delivery of a message. This may be in conflict with the deliberate subjectivity that can enhance the narrative. A trade-off is needed between the narrative coherence of a single point of view and the confidence in the data implied by multiple or more objective perspectives.

III- Use outliers and contradictory information to capture and direct audience attention without misleading the audience.

It can be argued that in storytelling in any medium, the primary goal is to capture audience attention, after which, one can direct this attention to story events. Outliers were described by participants in this study as unexpected findings or knowledge gained from both story delivery models. The fact that outliers catch audience attention might be important, particularly in the absence of a narrator who directs audience attention and emphasises the desired events in the story. This may also apply to known contradictory information in a story during the design phase, but in our analysis of the contradictory information reported by participants, we could not generalise on insight or knowledge types other than outliers, as these depend heavily on individual background with regard to a topic. The danger in this approach is that outliers, by definition, are not representative of the data as a whole, so care is needed to lead users from the attention-grabbing outliers to the core messages implied by the data.

Work to Date and Future Work toward the Completion of the PhD Thesis

This section provides a summary of the work done so far. In addition, this section describes the approach I will follow to address the remaining research objectives.

Before summarising the work done and future work plan, it is important to list the objectives of the PhD research project to best describe how they are going to be addressed:

The overall aim of this research is to use existing theory and techniques from storytelling more generally and investigate their relevance to storytelling in the design of information visualization, and empirically examine the impact of different forms of storytelling visualization on story comprehension and understanding. Specifically:

1. To identify the characteristics of storytelling in general and as an emerging field within information visualization.
2. To investigate the effect of story delivery model on narratives/stories constructed by audiences.
3. To explore and model the transition types used to tell stories through information visualization.
4. To investigate the effect of different transitions within data-driven stories on resulted or perceived narratives/stories.
5. To provide guidelines and recommendations for design of narrative visualizations based on the implications of the empirical research findings.

Work Done

This sub-section summarises the work completed so far. For each task carried out, the research objective it contributes to is provided.

Literature review (objective# 1)

The relevant literature to storytelling in the area of information visualization has been carried out. Additionally, some related similar theories and principles from other domains such as, comics,

filmmaking, and journalism, have been considered and reviewed, linked and positioned within the scope of the PhD research. The gaps in the knowledge and remaining areas to be investigated have been identified as well as different approaches and methodologies in tackling the topic of storytelling in information visualization. Further reading will be undertaken to remain updated about developments of this area and to help shaping, or enrich and improve the future work. The literature review chapter in this report touched on some areas covered in the literature review, this chapter will be expanded, detailed, and perhaps re-structured in the final PhD thesis.

The first set of experiments (Story Delivery model)- (objective# 2)

The first set of experiments has been designed and carried out, data has been analysed and preliminary results have been reported. Additionally, a review of the research methods used in this type of experimental evaluation research in the information visualization domain has been carried out and the relevance of these methods to the research question in hand has been discussed and identified in order to choose an appropriate approach to the research question addressed in the first set of experiments. An enhancement to this experiment is also planned and described in the future work plan below. A poster based on the work done was submitted and accepted in VisWeek2012 conference.

Future Work

To best explain my work plan I have divided the tasks into 10 categories:

1. Literature review

While part of the literature review done was included in this upgrade report, additional materials, sections, and details have been covered and need to be included in the final PhD thesis. Further reading will also be undertaken to keep updated about the development of the research in the area. Hence, this task will be ongoing as shown in the Gantt chart below.

2. Data Coding (VAST Challenges Videos)

This is including working on the McCloud (1993) taxonomy of panel-to-pane transitions in comics stories to develop and explain a model that can be clearly applicable to storytelling through information visualization. Part of this work has been done by developing a preliminary/initial glossary of terms that relate the meaning of the transitions types in comics to the possible meaning of these transitions in information visualization. Then, by qualitatively coding the VAST Challenges videos based on this model to explore the transition types used. Furthermore, to ensure consistency of codes a copy of the codebook used for coding the data of the first set of experiments and for coding the VAST challenges videos along with sample data will be given to some PhD students to code the data if possible. VAST challenges videos from 2008 to 2012 will be considered. Each year there are between 50 to 70 videos which means that the dataset will be big enough to explore patterns and create visualizations.

3. Data Analysis (qualitatively coded data or data from experiments)

This task includes any qualitative analysis or coding of data obtained by experiments i.e. open-ended questionnaire data of the first set of experiments and any other data generated by further experiments. Again, to ensure consistency of codes a copy of the codebook used for coding the data of the first set of experiments along with sample data will be given to some giCentre members to code the data if possible. Furthermore, this task also includes any quantitative analysis of the coded data, whether data from experiments or data generated from qualitatively coding VAST challenges videos based on the transitions types used.

4. Create visualization of results

This task entails doing some grouping and aggregation of the codes generated in task 2 above.

This is to look for similarities and differences within and across datasets, tasks, years, authors, etc. then, to create appropriate visualizations to represent the patterns and findings.

5. Formulate new questions and/or hypothesis based on the findings

After analysing and visualizing the findings, new hypothesis and/or questions for further work are expected to emerge. Depending on these questions, appropriate research questions should be addressed and appropriate experimental design should be completed.

6. Experimental Design

Based on the hypothesis/questions formulated from the findings, an appropriate experiment framework will be designed.

7. Conducting Experiments

This task includes running experiments in the lab, for both the first and second set of experiments.

This task will take place in Autumn and Spring Terms as a good number of responses are expected. It is not expected to take place during Summer, Christmas or New Year vacations.

More participants are going to be recruited for the first experiment (on Story Delivery Models) to enhance the generalizability of the results and enable further quantitative analysis of the data. A further complementary user study to the first experiment is also planned; this will differ from the presented experiment in this report in that the first delivery model will be a video or presentation of the visualizations used by Rosling without him present. The findings of the two sets of experiments will then be compared. This task will be tackled simultaneously with coding and analysing data.

8. Writing papers/posters for publications

This task depends on the achieved progress and the work produced. As the targeted and most relevant venue to the research is the VisWeek conference which usually takes place in October, the likely papers and posters submission deadline has been used to allocate time for this task (March and June).

9. Attending or presenting work in academic conferences

As said above the most relevant venue to the research work is the VisWeek conference. So, attending this venue would be a valuable experience. Additional venues might also be attended as appropriate.

10. Write-up

Although this is an ongoing task, 12- 18 weeks have been allocated for the write-up at the end of the research work.

Research Activities and Timeline for the remaining period toward the completion of the PhD

	2012				2013												2014				
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Literature Review	Primary Task												Secondary Task								
Data coding (VAST challenge videos)	Primary Task																				
Data analysis (from experiments or quantitative analysis of coded data)						Primary Task										Primary Task					
Create visualization of results					Primary Task																
Formulate new questions based on the findings								Primary Task													
Experimental design									Primary Task												
Conducting Experiments		Primary Task											Primary Task								
Writing papers/posters for publication										Primary Task											
Attending or presenting work in academic conferences		Secondary Task												Secondary Task							
Write up	Primary Task																Secondary Task				
Primary Task																					
Secondary Task																					

Conferences Attended and Planned Publications

There are two publications based on the MSc dissertation which have a relevance to this PhD work. These two papers are:

Wood, J. & Badawood, D. & Dykes, J. and Slingsby, A. (2011). BallotMaps: Detecting name bias in alphabetically ordered ballot papers. *IEEE Transactions on Visualization and Computer Graphics*, 17(12), pp. 2384-2391

Badawood, D. and Wood, J. (2011) Effects of candidate position on ballot papers: Exploratory visualization of voter choice in the London local council elections 2010, *Proceedings of the GIS Research UK 19th Annual Conference*

A poster based on the work done so far has been accepted for presentation at VisWeek2012 conference:

Badawood, D. and Wood, J. (2012). The Effect of Information Visualization Delivery on Narrative Construction and Development. Poster presented at *IEEE VisWeek2012, Seattle WA, US, October 2012*.

It is also planned to write and submit a paper or poster for publication to an international conference based on the 2nd year work and implementation of the second set of experiments in the PhD research project.

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Appendices

Appendix A Questionnaire used in the first set of experiments (for GroupA)

Part I

(HIV Epidemic Video)

Age: _____
Gender: M F

1. What was the video mostly about? (Approx. 1-2 min)

.....
.....

2. Re-tell the story you gained from the video in as much detail as you can. Try to write a story that makes sense to someone who is not familiar with the story/topic. (Approx. 6-8 min)

.....

.....

If you need more space please use the back of this page

3. What did you learn that you did not already know? In other words, describe the new information/knowledge you gained from the video? (Approx. 2-3 min)

.....

.....

.....


**4. Did you learn something that contradicts what you already know about the topic?
What is it? (Approx. 2-3 min)**

.....

.....

.....

5. What do you think the speaker's purpose was in producing this video? (Approx. 2-3 min)



Part II

(Graphical Representation of Child Mortality)

1. What was the data you explored in Gapminder mostly about? (Approx. 1-2 min)

2. Re-tell the story you gained from Gapminder in as much detail as you can. Try to write a story that makes sense to someone who is not familiar with the story. (Approx. 6-8 min)

.....

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3. What did you learn that you did not already know? In other words, describe the new information/knowledge you gained from Gapminder? (Approx. 2-3 min)

.....

.....

.....

4. Did you learn something that contradicts what you already know about the topic? What is it? (Approx. 2-3 min)

.....

.....

.....

5. What do you think the purpose was in providing this data in Gapminder? (Approx. 2-3 min)

Appendix B The Explanatory Statement and Consent Form Used in the First Set of Experiments

Explanatory Statement and Consent Form for Participants

Project Title: A Research Experiment on User Interpretation of Graphical Data Representation

Explanatory Statement

Purpose of the Study:

The aim of this study is to examine how the general users (non-expert users) interpret different forms of data visualization (graphical data representation), construct meaning and make sense of them.

Suitable Participants:

A suitable participant for this experiment should satisfy the following criteria:

- _ Participant has not previously taken any Data Visualization module (IN2393).
- _ Participant does not have advanced knowledge in data visualization
- _ Participant is not a professional data analyst

Benefits of the experiment in general and for participants:

This study helps understanding how people interpret and comprehend data represented graphically/visually. The outcomes of this experiment contributes to the body of the knowledge by providing information on how different forms of data visualization affect the way in which people interpret and make sense of it and therefore, provide useful design guidelines of data visualization.

As the participants who have been asked to take part in this study are students in the School of Informatics who have the Data Visualization module as an option for elective modules in the next semester, this experiment is a good opportunity for them to get a flavour of what is involved in data visualization.

Experiment Procedure:

Overall, the experiment will take approximately 1 hour distributed as follows:

11 min: watching a video.

15-18 min: answering a questionnaire (Part I).

11-15 min: exploring an interactive graphical data representation.

15-18 min: answering a questionnaire (Part II)

2-3 min: chatting/interview

However, the order of this procedure will be followed for one group of the participants and reversed for the second group to account for learning and ordering effect in the results of the study. At the end, there might be a 2-3 minutes interview to get a general feedback on the experiment.

What will happen to the results of the study:

This experiment represents part of the PhD project of the researcher (see below for contact details). The results will be reported in the PhD thesis and/or any published material based on it (e.g. a journal article or conference paper). Participants will be informed about the results of the

study once it is completed by e-mail.

For any inquiries about the research contact:

Donia Badawood (the researcher) PhD Student giCentre School of Informatics- City University London E-mail: Donia.Badawood.1@city.ac.uk	Dr. Jo Wood (the supervisor) Reader in GI Science giCentre School of Informatics- City University London E-mail: jwo@soi.city.ac.uk
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If you need to complain

If you would like to complain about any aspect of the study, City University London has established a complaints procedure via the Secretary to Senate Research Ethics Committee. To complain about the study, you need to phone 020 7040 3040. You can then ask to speak to the Secretary to Senate Research Ethics Committee and inform them that the name of the project is: *A Research Experiment on User Interpretation of Graphical Data Representation*

You could also write to the Secretary at:

Anna Ramberg
Secretary to Senate Research Ethics Committee
Research Office, E214
City University London
Northampton Square
London
EC1V 0HB
Email: Anna.Ramberg.1@city.ac.uk

Consent Form

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, which I may keep for my records. I understand that agreeing to take part means that I am willing to:

- Use a computer to watch a video
- Use a computer to explore some graphical data representation
- Complete questionnaires on both the video and the interactive graphical data representation

_ Be interviewed by the researcher if needed and allow the interview to be audiotaped

Data Protection

This information will be held and processed for the following purpose:

To explore/examine how users/audience interpret and construct meaning from different forms of graphical data representation.

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. No identifiable personal data will be collected nor published.

Withdrawal from study

I understand that my participation is voluntary, and that I can withdraw at any stage of the project without being penalised or disadvantaged in any way.

Name:(please print)

Signature:Date: