Building bridges between methodological approaches: a meta-framework linking experiments and applied studies in 3D geovisualization research

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1. Introduction

We propose a meta-framework that relates studies using a range of research methodologies as we investigate the use of abstract graphical representations of numeric data in 3D desktop based virtual environments. Selected approaches varying along a continuum from perceptual experiments to studies in applied settings provide the supports for the methodological bridge that we build by relating the design and findings of each. Doing so enables us to benefit from the advantages and overcome the limitations associated with studies conducted at any one stage. For example, we can evaluate the focused results of a controlled experiment in a more applied setting and thus address a key shortcoming of controlled experiments by taking into account contextual information.

2. The 'land'

At either end of the continuum we bridge are contrasting established approaches - the 'in vitro', quantitative and controlled environments used in psychophysical response studies and the 'in vivo', qualitative, case study research that evaluates applications ‘in the wild’ (Figure 1).

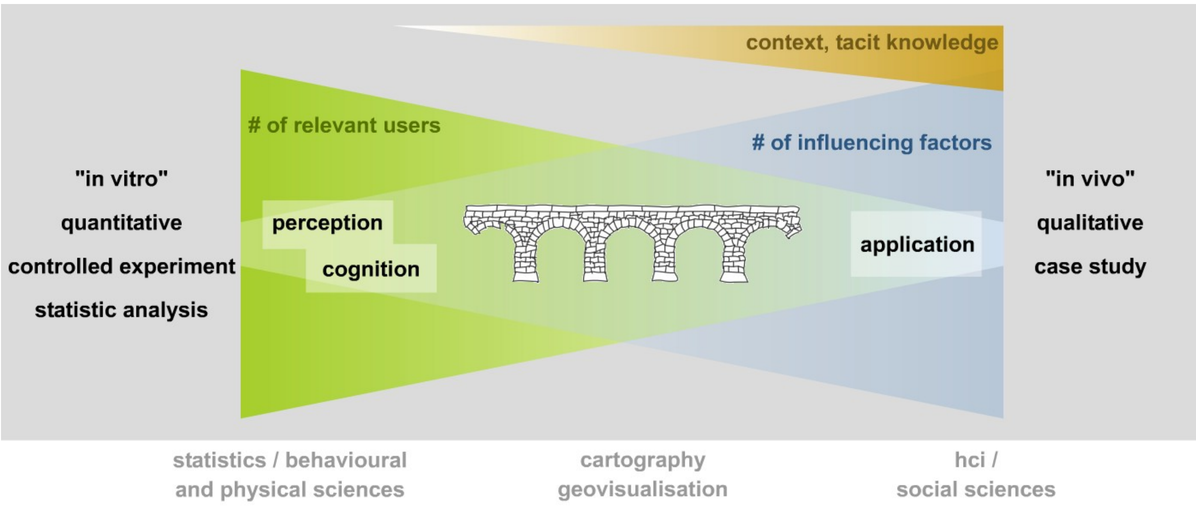


Figure 1. The meta-framework bridge between the two sides of 'in vitro' and 'in vivo' research

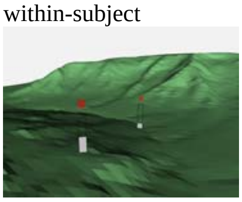
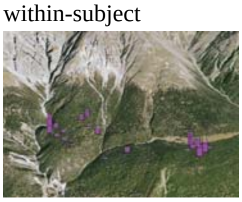
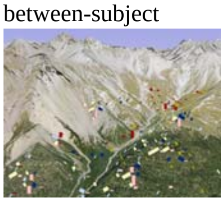
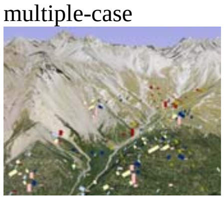
Activities on the experimental end are typical for the behavioural and physical sciences including cartography (Montello 2002). They usually involve large numbers of users, with little contextual information and thus no (or few controllable) influencing factors. On the applied side very few users are typically involved and qualitative approaches are employed. Much contextual and tacit knowledge influences and enriches these studies and many influencing factors exist that we cannot or do not want to control (Yin 2003). Research in geovisualization is done mostly towards the experimental side of the bridge (e.g. Bair and House 2007; Fabrikant, Montello et al. 2006). Case studies or applied settings are often used regarding implementation or usability issues (e.g. Brooks and Whalley 2008; Koua, MacEachren et al. 2006) and rarely evaluate the effectiveness of a visualization. Research along the bridge, for example, using experimental settings for the evaluation of different visualization types for easing understanding of and gaining insight into a dataset (Rester, Pohl et al. 2007) is rare.

3. The bridge

In the case of geovisualization we typically have a small number of experts who work with large amounts of data in an applied setting. They employ complex visual tasks to better understand and gain insight into the data. The complexity of such a setting with its many influencing factors, such as the tacit knowledge of the user, may be best researched 'in vivo'. However, certain more generic aspects of a geovisualization application can additionally be researched in a more controlled environment with a larger number of informed participants and thus underpin the 'in vivo' evaluations.

The four stages of our bridge are different methodical frameworks. We briefly describe those used in our evaluation of the graphical representation of numeric data through abstract symbols in 3D desktop virtual environments. Table 1 gives an overview of the specific or common characteristics of the different stages used when we employ this approach. The images in the table show how each visualisation might look like in the context of our particular research activity.

Table 1. Characteristics of each stage along the bridge

	stage I	**stage II**	**stage III**	**stage IV**
data type	synthetic/random	deer data SNP[1]	deer data SNP[1]	case data
variables	two values	# of visits per location	# of visits per time and location	many
symbol	single bars	single bars	bar charts	bar charts
setting	synthetic landscape	realistic landscape	realistic/real landscape	real landscape
# of tasks	two, pre-defined	seven, pre-defined	some, open, insight	open
task complexity	low	medium	medium/high	high
main sampling method	questionnaire (quantitative)	questionnaire (qualitative)	insight reports	observation, interview
participants	many (GI students)	many (GI students and staff)	some (GI students and staff)	few (data-experts)
study design	within-subject	within-subject	between-subject	multiple-case
example visualisation				

3.1 Stage I

Stage I consists of a controlled experimental framework that compares two different symbol types (bars with and without frames) in two different display settings (2D and 3D). The experiment participants complete two simple tasks: defining the higher of the two bars and judging the size of the smaller bar in comparison to the taller bar. The details of the framework and the results of this study, which enabled us to establish that task performance is no less effective but a little less efficient in the 3D setting, can be found in Bleisch et al. (2008). We hypothesise that the participants taking longer in 3D are also engaged in other processes such as assimilating and understanding the landscape. In the

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experimental setting of stage I these cause a longer task completion time only. The usefulness of such processes can only be explored in more context-rich settings where, for example, comprehension of the landscape is important for the analysis of the data displayed – this may be where geovisualizationis most useful.

3.2 Stage II

Stage II sets up an experimental framework using a within-subject design. The data consist of aggregations of deer sightings and thus have some context. As in the first experiment the data are displayed as single bars. But, given the knowledge that low-level tasks can be achieved in the 3D setting, participants undertake more complex tasks that require more cognitive processes than in stage I - such as finding and relating patterns of deer sightings with regard to location and altitude.

Initial results show that the times needed to perform the tasks have a high variance but in contrast to the experimental results of stage I efficiency is not significantly different between the interactive 2D and 3D settings. More differences are apparent between task completion times of the seven tasks, which are not equally complex (Figure 2). The user's confidence ratings, too, vary more between tasks than between 2D and 3D.

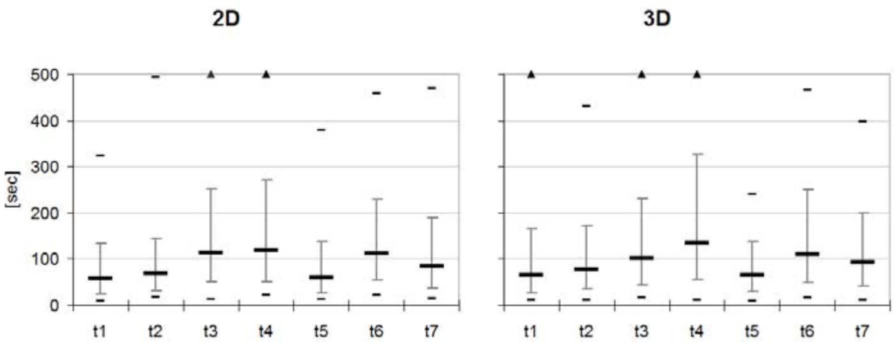

Figure 2. Mean, standard deviation and min/max values in seconds for the log-normally distributed task times for each of the seven tasks in 2D and 3D (▲ = max value outside displayed range)

3.3 Stage III

Stage III moves another step closer to the applied side of the bridge. Having determined that more complex tasks are feasible in 3D and that performance is as good as in the 2D case, data and task complexity is increased by considering a temporal component. The data consist of aggregations of deer sightings for different times of the day. Adding this 'data dimension' requires that an additional information carrying dimension be employed and so the data displays are no longer single bars but rather bar charts accounting for the multi-dimensionality of the data. They are displayed in the virtual equivalent of the environment the data was collected in adding important context. In addition to pre-defined tasks, the participants are asked to work with the visualisation and report the insights into the data gathered (North 2006). We will be interested in seeing whether and when the findings derived through experiments I and II hold.

3.4 Stage IV

Stage IV approaches the research aims in applied settings with data experts as typical in geovisualization. Case studies are valuable for studying single or few cases in depth (Gerring 2004) and learning about the real world applications of the findings of the previous stages. A multiple case design with a selection of diverse cases (Seawright and Gerring 2008) combined with cross case analysis enhances the representativeness of this method and allow us to compare less controlled 'in vivo' experiments involving expert users with those conducted 'in vitro' across our methodological bridge.

4. Conclusions

The selection of the stages as the bridge supports and their related research methodologies is driven by the increasing amounts of context, data and task complexity. We could select other criteria and then the stages might be positioned and methodologically defined differently. But, while exploring a dataset the user's effectiveness and efficiency is influenced by data and task complexity and the application context and that is the combination of aspects we want to analyse and gain insight to.

The meta-framework presented in this paper experimentally explores the visualization of numeric data in 3D desktop based virtual environments by relating methodologically different research stages. The findings from each stage inform those that follow and results from later stages are related back to validate or question earlier ones and thus generating deeper understanding as we develop a ‘bridge’ of knowledge between 'in vitro' and 'in vivo' research. The results from the first two stages of the bridge sustain our position that this is a valuable research strategy which might also be applicable to other research topics in geovisualization.

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Biography

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Stephan Nebiker is professor for geoinformatics, photogrammetry and remote sensing at the University of Applied Sciences Northwestern Switzerland FHNW in Muttenz, Switzerland. Among his research interests are virtual globe technologies, 3D geovisualization, mobile geosensors and augmented reality.