COMPARISON OF THE EXTRINSIC AND INTRINSIC VISUALIZATION METHODS: EXPLORATIVE EYE-TRACKING ANALYSIS

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Abstract
The aim of the study is to identify the differences between the cognitive processes underlying different map-reading tasks. An eye-tracking study was designed based on our previous research. We hypothesized that significant differences may occur when utilizing two different methods of presenting two phenomena in one map (i.e. bivariate scales). Specifically, the extrinsic and intrinsic methods will be compared using two different types of tasks: The participants will be presented with maps that provide information on soil moisture and soil depth, and will be asked to identify the areas that meet the required conditions (e.g. area with the highest soil moisture and low soil depth). The research sample will consist of university students of humanities and social sciences, for it is our intention to focus on the people with no significant cartographic experience. In order to explore the collected eye-tracking data, an explorative analysis will be used. The main objective of the analysis will be to find out whether either of the bivariate scales requires more saccades to accomplish the task, requires more direct transitions between the legend and the map, and whether the different visualization types induce different cognitive processing methods. Our results will shed some light on the topic of computational (non)equivalence of the extrinsic and intrinsic visualization methods. The presented study will provide a basis for the upcoming cross-cultural research. The paper presents the suggested experimental design of the research and the means of analysis.

1 INTRODUCTION

Empirical investigation of visual stimuli plays an important role among cartographical research methods (Juřík et al., 2020, Herman et al., 2018; Juřík et al., 2017, Kubiček et al, 2014, Kubiček et al, 2017, Svatotýnová and Kolejka, 2017). The aim of this paper is to present the design of an experiment comparing the impact of extrinsic and intrinsic
visualization using bivariate maps (Elmer, 2013, Nelson, 1999, Nelson, 2000, Nelson, 2002), and to suggest suitable methods of analysis. In order to meet the requirement for objectivity, we suggest using the eye-tracking technology which can provide a deep insight into the cognitive processes and strategies employed by the participants when performing map-related tasks (Alaçam et al., 2009, Çöltekin et al., 2009, Herman et al., 2017, Opach et al, 2017, Popelka and Brychtová, 2013). The presented experimental study is a direct follow-up to the work by Kunz (Kunz, 2011,Kunz and Hurni, 2011), who created bivariate maps quantifying the avalanche risk (along with the degree of uncertainty of the risk). The methods employed by Kunz were empirically tested by Šašinka et al. (2019), whose results indicated, inter alia, that the familiarity of the map content to the participants plays such an important role that its impact may override the effect of the phenomena under investigation (Alexander et al., 1994). Therefore, relatively simple and widely understandable topics were selected for our study: soil moisture and soil depth. The presented study will employ a broader design that will allow us to examine not only the participants’ individual cognitive style, but also the role of cross-cultural differences in perception. We consider bivariate maps to be highly suitable for the above type of experiment (Šašinková et al., 2020).

We suggest using the technology of eye-tracking for our study because it provides a unique possibility to investigate the differences in the participants’ cognitive processing; thanks to eye-tracking, we can study the very process of task-solving in addition to the results of the participants’ cognitive activity. The oculomotor data can be used to reveal if the same or different cognitive styles are used for the different types of visualizations (of identical data).

2 STIMULI AND EXPERIMENTAL DESIGN

The stimuli and the types of tasks will be the same for all the groups of participants. The instructions will be displayed in the upper part of the screen; the map legend will be shown on the right side, the map field on the left and the button bar with 4 buttons (used to indicate the correct answer) will be shown in the bottom part of the screen (see Fig. 1 and 2). The identical design of the stimuli will provide for full control of the experimental environment. The participants will be familiarized with the type of the visual stimuli prior to the experiment in order to ensure that any differences in the participants' performance are visualization- or type of task-related.

![Figure 1 Example of an intrinsic visualization, subtest 1 (analysing wider areas consisting of 4 units), one variable is in question here.](image-url)
The study will include two subtests, each consisting of 15 items. The participants will be presented with bivariate maps divided into small square units. For each item, four areas are marked either with a single square (in the subtest No. 2) or with 4 squares (in the subtest No. 1). The participants will be asked to choose the area that fits the criteria defined in the instructions (e.g. “Select the area with low soil moisture AND high soil depth”). Some items will require only one condition to be considered (e.g. “Select the area with low soil depth”), others will require two conditions to be met (such as the above-mentioned example).

It needs to be stressed that the study was designed in such a way that the impact of practice and the type of task could be controlled and assessed. We consider it necessary to use a between-subject design in order to be able to compare the data related to the two types of visualizations. If a within-subject design were used (that is, the participants would be presented both extrinsic and intrinsic visualizations), the users’ experience with the first task would significantly affect their performance in the subsequent tasks. A disadvantage of the between-subject design consists in that a larger sample of participants needs to be used. Because the test contains several different types of tasks (a single-square vs. multiple-square area, one variable vs. two variables), the participants will be divided into four groups (Counterbalanced Measures Design). To the third and the fourth groups the tasks will be presented in a reverse order (single-unit areas are presented before the four-unit areas). In this way we will be able to counterbalance the effect of experience (resulting e.g. in shorter response times).

*Figure 2 Example of an extrinsic visualization, subtest 1 (analysing only isolated units), two variables are in question here*
Figure 3 Experimental design: comparing intrinsic and extrinsic visualizations in two subtests, presenting two types of items (considering one or two variables at a time).

2.1 Apparatus

Data collection will be done in the HUME Lab using an SMI RED-m eye-tracking device. The eye-tracker will be connected to an external screen on which the tests will be presented to the participants. The experiment will be administered via the Hypothesis software (Šašinka et al., 2017) and the eye-tracking data will be recorded using the Experiment Center 3.7 software, with the frequency set at 250 Hz. Ogama software (Voßkühler et al., 2008) will be used for data analysis and the data will be transferred to Ogama via the HypoGama application (Popelka et al, 2016).

2.2 Participants

The participants will be university students of humanities and social sciences. It is essential that the participants have no expertise in maps because previous knowledge would likely distort the data. Participation will be rewarded financially. Due to the expected high discard rate, the number of participants needs to be overestimated.

3 Data Analysis

The analysis of the collected data will be a two-level one, the first level consisting of the analysis of the oculomotor data and the second level of the analysis of the behavioral phenomena. The behavioral data include response time and correctness. Because of the complexity of the experimental design, several complex statistical models will need to be used to investigate the behavioral phenomena. Even the basic version of the design involves several factors (culture x visualization x type of task; see Tab. 1); therefore, a mixed-factor ANOVA will be considered, which makes it possible to investigate the interactions between the factors involved. Another factor can consist in whether the user looks for a single variable or both variables at a time.

Table 1 Main factors in the research design

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<th>Culture</th>
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The main goal of the explorative analysis of the collected oculomotor data will be to identify the possible differences in visual scanning of the map during task-solving. The analysis will employ two types of eye-tracking metrics: 1) transitions (saccades between AOIs) and 2) AOI dwell time.

Several Areas of Interest (AOI) will be created: the area of instructions, the legend, the visualization field (i.e. the map itself) and the buttons (Figs. 4 and 5). We will be interested in the total duration of the fixations on the selected AOIs (point No. 2; see Fig. 5). The information about the total dwell time will make it possible to determine the amount of attention allocated to the various parts of the task at hand. The AOIs representing the visualized areas (possible responses) will be used to establish which distractors were considered by the users to be the most probable before they made the final decision.

The transitions metrics (point No. 1; Fig. 5) provides more detailed information about the dynamics of the task-solving process. The main question is: How many direct saccades out of the defined AOIs were made and in what direction? The following two attention-shift directions are particularly important: the “map-legend” shift and the “legend-map” shift. A high number of map-legend transitions indicates that the user needs to repeatedly check the correctness of their choice.

Figure 4 AOI dwell time assessment
4 Discussion

Based on the pilot testing as well as on our previous studies, the intrinsic map legend is considered less intuitive, and thus is expected to take more time to decode than the extrinsic legend. However, it remains to be answered how the efficiency of the users' task-solving is affected by practice, and also if the intrinsic legend can induce better results with some tasks than the extrinsic legend. Other topics to be investigated include the impact of the users' cultural background and of their individual preferences for one or the other type of visualization.

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REFERENCES


