Can experts interpret a map's content more efficiently?

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ABSTRACT

This paper describes the statistical comparison of the results from an experiment with a 'between user'-design. The first group of participants consists out of novices whereas the second group consists out of experts which have experience in map use and have had training in cartography. The same stimuli (twenty screen maps) are presented in a random order to the participants who have to locate a number of labels on the map image. The participants are asked to indicate when they located a name by a button action, resulting in a time measurement. Furthermore, the participant's eye movements are registered during the whole test. The combined information reveals a same trend in the time intervals needed to locate the subsequent labels in both user groups. However, the experts are significantly faster in locating the names on the map ($P \leq 0.010$). The recorded eye movements further confirm and explain this finding: the expert's fixations are significantly shorter ($P \leq 0.001$) and can consequently have more fixations per second ($P \leq 0.001$). This means that an expert can interpret the map content more efficiently and can thus search a larger part of the map in the same amount of time.

BACKGROUND AND OBJECTIVES

The main goal of this research is to improve the quality of maps with a focus on how the information should be presented to the user to allow an efficient interpretation of its content.

Therefore, insights are needed in how users perceive the information presented to them, which is in turn related to how map readers store this information internally and thus to their cognitive map (Downs and Stea, 1977; MacEachren, 2004; Montello, 2002; Slocum et al., 2001). Harrower (2007) stated that the current bottleneck for creating acceptable animated maps is no longer caused by the hardware, software or data, but by the limited visual and cognitive processing capabilities of the map user. In his article, Harrower (2007) also describes the Cognitive Load Theory (CLT) in relation to information processing and learning, which involves the long-term memory and working memory. These terms are crucial to understand how persons, including map users, process and store the information presented to them. The effectiveness or quality of a map can be enhanced by reducing the complexity of the map and remove unnecessary distractions from it. This results in a reduction of the user's cognitive load (both the intrinsic and extraneous cognitive load), creating extra room for the third type of cognitive load which is associated with learning: the germane cognitive load.

Furthermore, 'map users' cannot be considered as one homogeneous group: different categories of users and individual user differences have to be taken into account. These differences in gender, age, background knowledge, experiences, etc. may have an influence on how they interpret, process and store the spatial information. (Aykin, 1989) One important and interesting difference between users is the background knowledge and the level of experience they have with the topic under investigation, maps in this case (MacEachren, 2004; Nielsen, 1989). As a consequence, designers of user studies often have to make a difference between experts – the user group which has a high level of experience – and the novices – the user group with a low level of experience (Duchowski, 2007; Nielsen, 1993; Rubin and Chisnell, 2008).

In this paper two sets of experiments are described, which test whether experts (a group of persons with cartographic training and experience in interpreting maps) can interpret a map's content more efficiently. Since the same stimuli – screen maps in this case – will be presented to two different user groups – experts and novices –, the study has a 'between user'-design (Duchowski, 2007; Nielsen, 1993). The contents and structure of this study will be described in more detail in the next sections.

APPROACH & METHODS

Participants

The expert group selected for these tests consists out of participants who have obtained a Master degree in Geography or Geomatics and who are currently working in de Department of Geography at Ghent University. A group of Bachelor students, linked with the Faculty of Psychology and Educational Sciences are selected to constitute the non-expert group. The same stimuli and assignment is presented to both groups of participants, resulting in a 'between-user' experimental design. The expert group counts 16 participants, whereas the novice group has 15 participants.

Task & Stimuli

During each trial a screen map consisting, out of a simple background with points and their associated labels, is presented to the participant. On the right side of the screen the participant can see a list with five names which he has to locate on the map image. Each time the participant finds a name, he is asked to push a button (resulting in a time measurement). After 50 seconds, a horizontal pan operation is simulated and the list with five names changes simultaneously. Two names were already present in the initial list, but on a different location. After this simulated user interaction, the participant again has to locate these five names on the map image, indicating that he found one by a button action. In total, the participant has to complete twenty trials and thus perform a visual search on twenty different demo-maps. Each of these maps has the same background and a comparable number of labels on it, but their distribution may differ. The locations and names on the map originate from existing areas in order to create realistic point and label distributions on the maps. However, the regions are chosen as such that the participants are not likely to be familiar with it (e.g. in Africa) in order to avoid biases. An example of a screen map used in one of the trials is depicted in Figure 1.

This assignment corresponds to an operation which is actually executed rather often by users on dynamic and interactive maps: the user is trying to locate the position of an area of interest from which he knows the name. To be able to do this, the user first has to orientate the map and subsequently scan its content to discover the position of a certain symbol, such as a label.

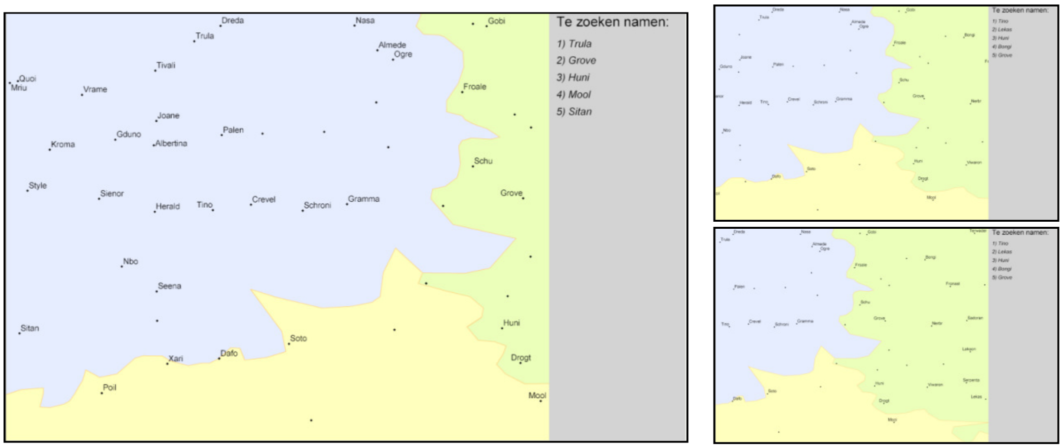


Figure 1: Example of a demo map with on the left the initial view, top right a view during the pan-operation and bottom right the final view

Data & Apparatus

Besides the time measurements from the button actions, the participant's eye movements are registered during the entire test. This latter data consists out of a long list of screen coordinates (x,y) where a user was looking on the map, at a certain timestamp (t). Fixations are moments when the (x,y) position of the eye movements is stable for a certain amount of time and the user is thus interpreting the map content at that location. The duration and number of these fixations are closely linked with the level of difficulty for interpreting the content of the map. Poole and Ball (2006) and Jacob and Karn (2003) present a more detailed description of these eye movement metrics and their link with the user's cognitive processes. For example, longer fixations are typically associated with a complex content (which is more difficult to interpret). The time measurements indicate how fast the participant finds a name, but it is essential that these measurements are linked with the eye movements to discover which name was found (and if it was a correct one).

The equipment used to conduct these test consists out of an Eye Link 1000 device from SR Research (Mississauga, Ontario, Canada) which registers a person's POR (Point of Regard) at a rate of 1,000 Hz (or once every ms). This device, along with the other necessary equipment, is located in the Eye Tracking laboratory of the Department of Experimental Psychology, Ghent University. Each test start with a calibration phase using a grid of nine points, which does not takes more than a few minutes.

RESULTS

A detailed statistical analysis of the response times from the novice users show a trend in the time intervals needed to find subsequent labels, both before and after the interaction. The median values in Table 1a and the error bars in Figure 2a indicate that a longer time interval is associated with locating the first label, which corresponds to an orientation phase. The shortest time interval is linked with the second label, followed by increasing time intervals for the subsequent labels. The time interval is also always shorter before the interaction than after for corresponding labels. The statistical analysis for the novice groups are described in more detail in (Ooms et al., 2009). Table1b and Figure 2b show the results for the same metrics, but for the expert group. A comparison of both results (experts vs. novices) suggests a similar underlying trend: highest value for the first label, smallest for the second label, increasing values for the next labels (both before and after the interaction) and shorter corresponding time intervals before the interaction. However, the mean and median values are always smaller for the expert group than for the novice group, suggesting that the experts can find the labels more quickly (and thus efficiently) than then novices.

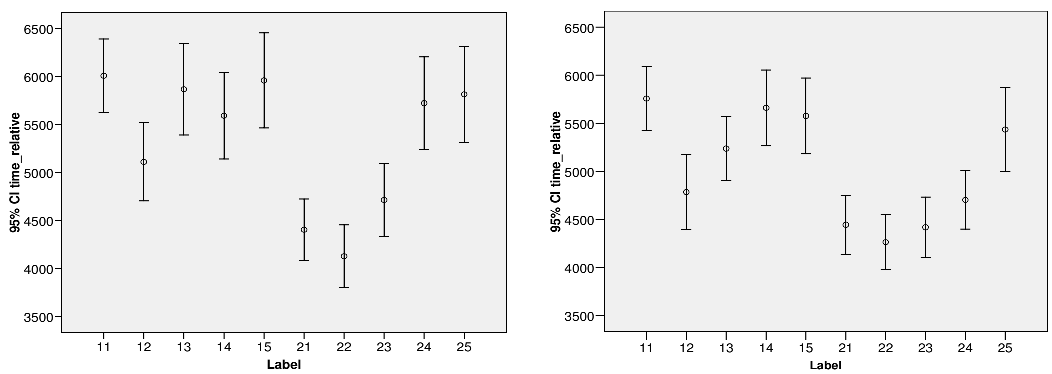
Table 1: Median values for the time intervals (ms) for locating subsequent labels

Label	Before (1*)	After(2*)
***1**	5324,0	3775,5
***2**	4368,5	3427,0
***3**	4933,0	3875,0
***4**	4551,0	4477,0
***5**	4897,0	4595,0

a. novices

Label	Before (1*)	After(2*)
***1**	4945,5	4009,0
***2**	3873,5	3626,0
***3**	4540,5	3636,5
***4**	4647,5	4162,5
***5**	4693,0	4171,0

b. experts



a. novices *b. experts*

Figure 2: Error bars with a 95% confidence interval for the time intervals (ms) for locating subsequent labels

A statistical comparison between both groups shows that a significant difference can be noticed in how experts interpret a map's contents in comparison to non-experts. The expert group is significantly faster at locating the ten names (*Mann Whitney test, Z=-2.570, P ≤ 0.010*). This is further explained by the metrics derived from the recorded eye movements. The average duration of an expert's fixation is significantly shorter (*t-test, t= 3.845, df=1069, P ≤ 0.001*). Furthermore, the number of fixations per second is significantly higher (*t-test, t= -5.845, df=873, P ≤ 0.001*) in the group with experts. This means that an expert needs less time to interpret the content of the map (shorter fixations) which allows them to have more fixations per second.

CONCLUSION AND FUTURE WORK

This study with a 'between user'-design shows a same trend in how maps are interpreted by the two user groups: novices and experts. Both before and after the simulated interaction the first label is found after a relatively long time interval. This can be explained by the time needed to orientate the map before the user is able to start looking for a label. This orientation time is also included in this first interval. The shortest interval is linked with the second label. In this case, the orientation phase is finished and a mental image of the map is present in the working memory allowing fast retrieval of the label's location. With each subsequent label, more information is stored mentally (such as the former labels and their locations), increasing the cognitive load in the working memory. This results in longer time intervals for locating the subsequent labels. The shorter time intervals after the interaction can be explained by the learning effect. A part of the map remains visible with which the participant is consequently more familiar and which may thus have been stored in the participant's long term memory. This reduces the overall cognitive load in the working memory after the interaction.

Besides this same trend, an important difference is noticed: the experts are faster at locating the names on the map. The reason for these shorter time intervals can be found in the eye movement metrics, which give insights in the user's cognitive processes. Since the fixations of experts are significantly shorter, it can be concluded that they can interpret the map's content more efficiently (Jacob and Karn, 2003; Poole and Ball, 2006). The significantly higher number of fixations per second in the expert group is closely link with the shorter fixations. This means that experts can 'scan' or interpret a larger part of the map in the same time interval, compared to the non-experts. This results in the fact that the experts are faster at finding the names on the map.

In a next step, the eye movements of the expert group will be analyzed qualitatively. This visual analytical technique has already been applied to the eye movement data of the group with novices, revealing some interesting patterns in how users interpret the map's content (Ooms et al., 2010). A comparison between the eye movement patterns from both groups (novices vs. experts) might indicate if the experts also have a different technique in orientating and searching on the map which may reveal some new elements regarding the efficiently with which experts interpret the map's content.

REFERENCES

Aykin N. M. (1989). Individual differences in human-computer interaction. *Computers & Industrial Engineering 14*(1-4), 614-619.

Downs R. M. & Stea D. (1977). Maps in Minds. Reflection on cognitive mapping. New York, Harper & Row. pp.284.

Duchowski A. T. (2007). Eye tracking methodology - Theory and practice, Springer. pp.328.

Harrower M. (2007). The cognitive limits of animated maps. *Cartographica 42*(4), 349-357.

Jacob R. & Karn K. (2003). Eye tracking in human-computer interaction and usability research: Ready to deliver the promises. In: *The Mind's Eye: Cognitive and Applied Aspects of Eye Movement Research*. R. Radach, J. Hyona and H. Deubel. Amsterdan, Elsevier, 573-605.

MacEachren A. M. (2004). How maps work : representation, visualization, and design. New York, Guilford Press. pp.xiii, 513 p.

Montello D. R. (2002). Cognitive map-design research in the twentieth century: theoretical and empirical approaches. *Cartography and Geographic Information Science 29*(3), 283-304.

Nielsen J. (1989). The Matters That Really Matter for Hypertext Usability. *Hypertext 89 Proceedings*, 239-248.

Nielsen J. (1993). Usability Engineering. San Francisco, Morgan Kaufmann.

Ooms K., De Maeyer P. & Fack V. (2010). Analysing eye movement patterns to improve map design. *AutoCarto*, Orlando, Fl., USA.

Ooms K., Kellens W. & Fack V. (2009). Dynamic map labelling for users. *24th International Cartographic Conference*, Santiago, Chile.

Poole A. & Ball L. J. (2006). Eye tracking in human computer interaction and usability research: current status and future prospects. In: *Encyclopedia of Human Computer Interaction*. C. Ghaoui, Idea Group, 211-219.

Rubin J. & Chisnell D. (2008). Handbook of Usability Testing. How to Plan, Design and Conduct Effective Tests. Indianapolis, Wiley Publishing. pp.347.

Slocum T. A., Blok C., Jiang B., Koussoulakou A., Montello D. R., Fuhrman S. & Hedley N. R. (2001). Cognitive and usability issues in geovisualisation. *Cartography and Geographic Information Science 28*(1), 61-75.