Cartographic Design Matters – A Comparison of Thematic Polygon Design with Eye-tracking Analysis

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ABSTRACT

In this study we compared four cartographic designs of thematic polygons: only boundaries, transparencies, hatches and icons (Figure 1). The aim of the comparison is to investigate whether the designs are good for identifying the extent of the polygons and if the design disturbs the reading of the background map. The comparison is based on an eye-tracking study, where 24 participants performed polygon identification tasks as well as background search tasks.

The study revealed that hatches were more efficient than the other designs for polygon identification. Hatches had significantly shorter total fixation times as well as scanpath lengths, possibly since the participants were able to identify the extent of the polygon solely based on the interior (i.e. the hatches), while for the other designs the participants were extensively reliant on the boundaries.

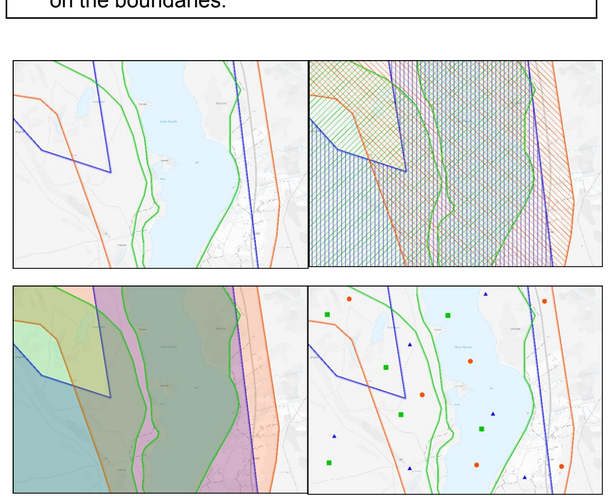

Figure 1: Thematic polygon designs: boundaries (top left), hatches (top right), transparencies (bottom left) and icons (bottom right).

INTRODUCTION

A common use of view services is to have thematic polygons on top of a background map. An advantage with (standardized) view services is that a user can combine several services at one time. The challenge is that the view services do not, in general, provide styling options that enable cartographically good maps if they are combined. The design of the thematic polygons that are to be added on top of the background map should support:

1) Identification of the extent of the thematic polygons. That is, the design should support a good figure–ground contrast. This is below denoted the extent property.

2) As little disturbance as possible of the searching and reading of information from background map. This is below denoted the obscuring property.

THE AIM

The comparison is based on user tests of the efficiency (response speed) and the effectiveness (accuracy of response) of the designs, as well as the search strategies enabled by the design. Since we are especially interested in how the map reader uses the interior and boundary of the thematic polygons, as part of the search strategies, it is not enough to only measure the time and correctness of map tasks for the different designs. We also need information on how the map user solves the tasks.

The reason for selecting an eye-tracking approach is that this method records the map reading process unobtrusively with a high temporal resolution, and without adding an additional task for the participants.

RESEARCH QUESTIONS

The specific research questions are:
1.Which design is the most efficient in terms of extent and obscuring properties?

2. Are there any differences in search strategies enabled by the designs? The main question here is whether the difference in the interior of the polygons enables different types of searches.

3. Are there any differences between the designs in terms of effectiveness?

METHODS

To evaluate the efficiency of the polygon designs, two different tasks were performed by the participants while their eye movements and responses were recorded. In the first task, called the polygon identification task, participants were asked to identify which of the polygons that enclosed a location marked with a house (see Figure 2). In the second task, referred to as the background search task, the participants were instead asked to find a group of houses or a lake located within a region specified by the intersection of three polygons. The step-by-step structure of the experiment is displayed in Figure 3.

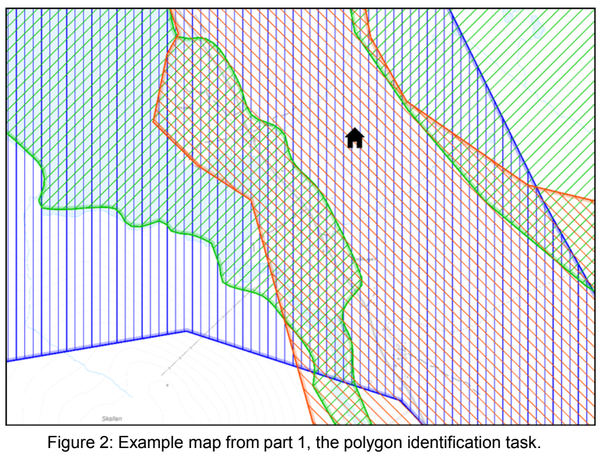

Figure 2: Example map from part 1, the polygon identification task.

Participants

Thirty-two participants with knowledge of cartography/geography/GIS took part in the experiment. As the study was targeting guidelines for view services (which are mainly used by professionals), only participants with good or moderate experience in map reading were selected.

Maps and design

Stimuli were static maps, consisting of a background map overlaid with a thematic polygon. The background maps were generated from the topographic web map service with faded colours from Lantmäteriet, and the thematic polygons are restriction areas (polygons) from Länsstyrelsen (2014).

Procedure and tasks

The experiment was carried out individually for each participant. To confirm that the participants understood the designs and the test procedure, they were initially given an oral description of the tasks, and examples were provided for each of the map designs,

Analysis

Four dependent variables were considered in the analysis: total fixation duration, average fixation duration, scanpath length and total dwell time.

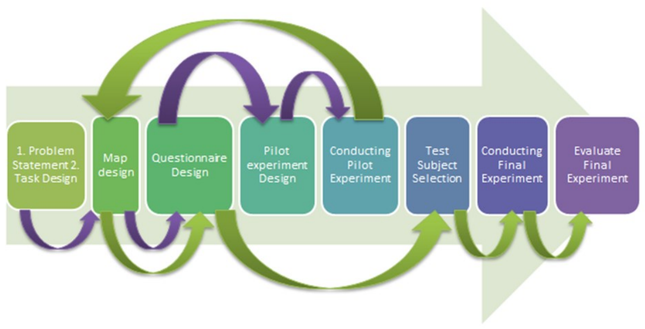

Figure 3. Experimental design workflow.

RESULTS

Examples of scanpaths for one of the background maps combined with each of the four different polygon designs are shown in Figure 4. Lines represent saccades and circles represent fixations, where the diameter of a circle is proportional to the duration of a fixation. Each participant's scanpath is represented with a unique colour. The example shows that there are large differences in how the maps are visually inspected depending on the selected polygon design. Hatches, in particular, seem to take the participants straight to the target without excessive visual search.

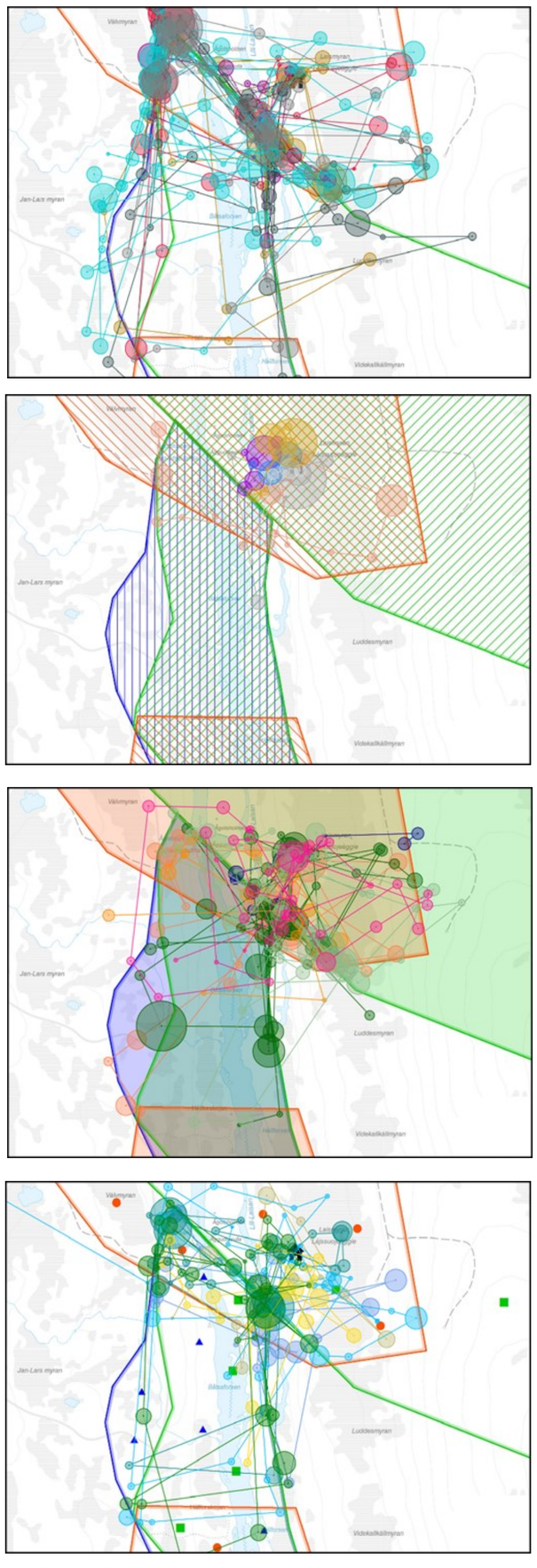

Figure 4. Scanpaths recorded during the polygon identification task.

Total fixation duration

As illustrated in Figure 5, hatches generated the lowest total fixation duration and boundary lines the highest. Post-hoc tests for the polygon identification task revealed that hatches led to a significantly lower total fixation duration compared to all other designs ($p < 0.05$), which were not significantly different from each other. During background search, the total fixation duration for boundary lines was significantly higher compared to the other designs ($p < 0.05$).

Scanpath length

Figure 6 shows how the scanpath length differs across the polygon designs. Pairwise comparisons for the polygon identification task showed that the scanpath length was significantly shorter for hatches compared to other designs ($p < 0.05$), For the background search task, all pairwise comparisons, besides that between transparency and icons, were significant at the 5% level.

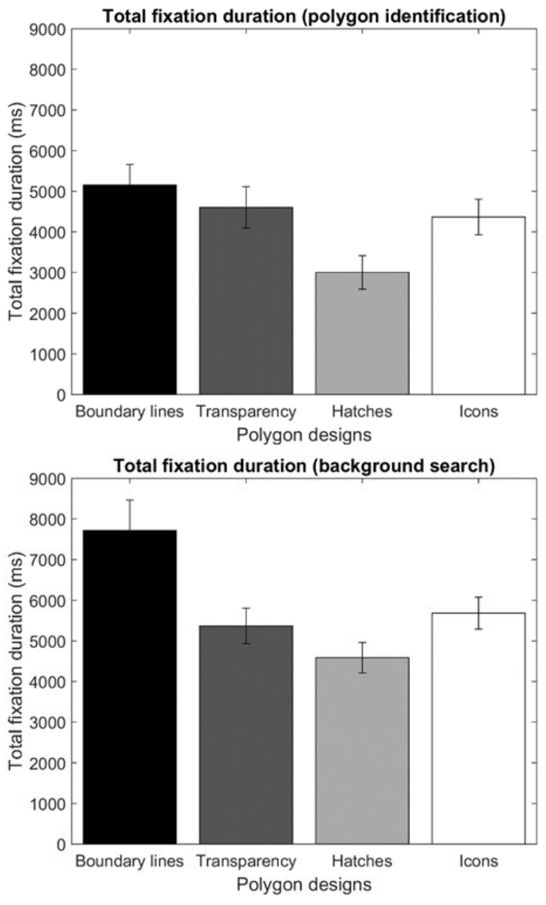

Figure 5. Total fixation duration.

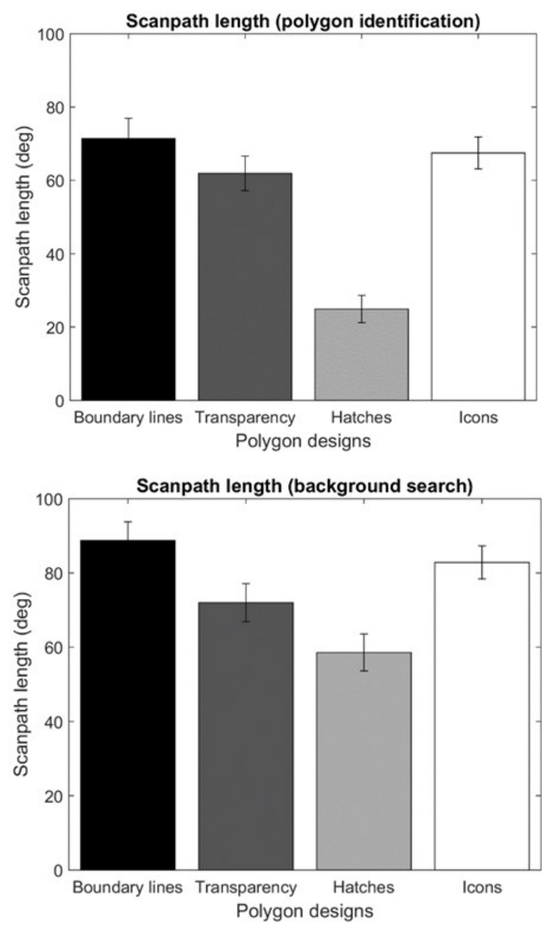

Figure 6. Scanpath length.

Total dwell time

To investigate whether people used the borders when performing the tasks, the total dwell time on polygon borders was computed and compared (Figure 7). All designs in the polygon identification task yielded significantly different viewing times ($p < 0.05$), In the background search task two significant differences were found, indicating that the boundary lines design produced higher total dwell times on the borders compared to both hatches and icons (Figure 7).

Average fixation duration

As a final eye movement metric, the average fixation duration was compared across polygon designs, as depicted in Figure 8. In both tasks, the average fixation duration was significantly higher when using hatches ($p < 0.05$), whereas the other designs did not differ significantly.

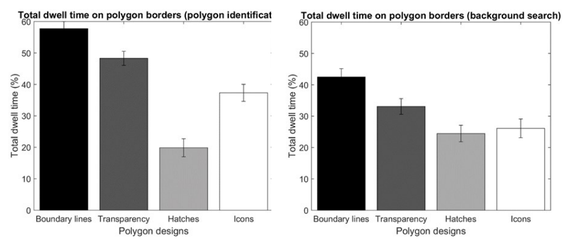

Figure 7. Percent of the total dwell time spent on polygon borders.

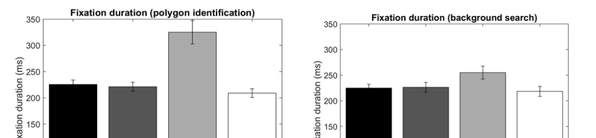

Figure 8. Average fixation duration.

DISCUSSION

Efficiency

The efficiency can be estimated by the total fixation duration, which reflects how much time the participants needed to complete the task, as well as the scanpath length, which measures the total distance travelled by the eyes. Based on Figures 5 and 6, and related statistics, hatches are the most efficient design. The difference between hatches and the other designs is especially large for the extent property.

Strategies

The second research question concerned the search strategies enabled by the design. It seems that the hatches enable the identification of polygons by only studying the interior of the polygon, while the other designs required more searches on the boundaries. On the other hand, it seems that the map reader has spent a longer time on the target for the hatches than for the other design (at least for the polygon identification part).

Effectiveness

The third and final research question concerned the effectiveness of the design. The proportion of correct answers was high for all designs and we cannot, based on this study, conclude that a certain design provides more correct answers. Possibly, the results indicate that using only a boundary tends to provide somewhat worse results than the other designs.

According to the subjective measures, the most likeable design was transparency, with twice as many votes as the hatches. Several participants felt that the hatches were the most efficient design, but pointed out that they still did not like it. One reason could be tradition; we tend to prefer what we normally use. A second drawback with the hatches is that they introduce additional clutter in the background map, making it harder to resolve relevant map symbols. This could at least partly be solved by using hatches with a longer distance between the lines (Figure 9).

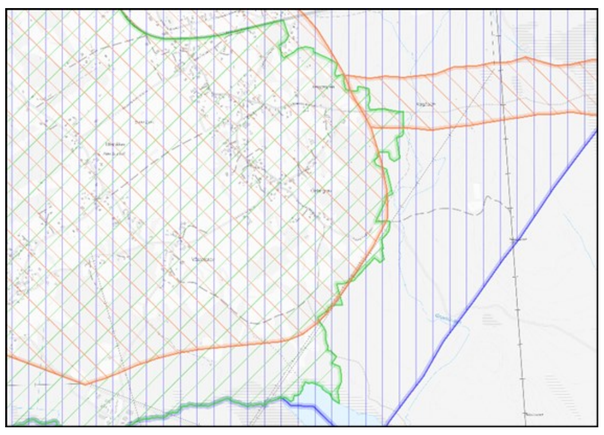

Figure 9. A proposal of another design of hatches to improve reading of the background map.

CONCLUSIONS

This study was triggered by the need to define cartographic guidelines for producers of view services; today these services are technically possible to combine but quite often the combination will result in maps with bad cartographic quality. Our main conclusion is that cartographic design matters; the four tested polygon designs affected how quickly the maps were read as well as the participants' visual search behaviour. Hatches, in particular, seemed to quickly guide the reader to task-relevant regions in the map. Also, map providers should support more than one design for thematic polygons.

We also conclude that eye-tracking is a valuable method in cartographic design, and provides insights into the map reading process. Eye-tracker data offer additional empirical evidence, and support the traditional measures of efficiency and effectiveness.

FUTURE WORK

This research could be extended with further studies:
- Special design for hatches – gap distance, color and line width
- More maps and complicated tasks
- Gradually add more map elements and increase the task difficulty
- Other eye-movement measures
- Get more general results - less controlled study

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Full study for references available: