Georeferencing Eye Tracking Data on Interactive Cartographic Products

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Abstract. A user study was conducted in which participants had to execute four tasks in GoogleMaps (only by means of a panning operation). Two of these tasks consisted of following a route in Belgium; in the two other tasks the participants had to locate Belgium on a less detailed map (scale level 7). Furthermore, an alternation between the map and satellite view was implemented. The recorded mouse actions revealed strong task-related interactive behaviour. The recorded eye movements also indicated differences in the participants' attentive behaviour on the two scale levels, which are associated with different tasks. Furthermore, the attentive behaviour is also influence by the type of view (map or satellite) and whether it occurs during a panning operation. Moreover, the georeferenced eye movements were imported in a GIS for spatial analyses such as buffers. Based on these spatial queries, we discovered that the duration of the fixations is also associated by its' location on the map.

Keywords: interactive cartography, user research, eye tracking

1. Introduction

Over the last years, thousands of interactive cartographic products have been made accessible on the World Wide Web, without prior evaluation and even without considering the users' needs (van Elzakker & Wealands 2007). Almost no user feedback regarding their usability or effectiveness has been purposely gathered and verified after their release either. As a consequence, still very little is known on how the end users actually read, interpret and process screen maps, while interaction tools themselves have been found to have a serious impact on the map users' cognitive processes and thus on the usability of the systems (MacEachren & Kraak 2001; Fabrikant & Lobben 2009; Montello 2009). Montello (2009) pointed out that some research considering the map users' cognitive issues has already been undertaken (e.g.Fabrikant et al. 2008a), but this specific research issue still needs more attention. The visualisation issues of neocartographic products, for example, were considered to be a new research challenge on the agenda of the International Cartographic Association (Virrantaus et al. 2009; Cartwright 2012). According to van Elzakker and Griffin (2013) there are nowadays still a lot of (design) issues related to dynamic and interactive maps that are actually not yet well-understood.

1.1. Eye Tracking on Interactive Stimuli

Current state-of-the-art eye tracking systems have limited automated solutions to deal with the analysis of interactive stimuli (Ooms et al. 2015). Users' gaze locations, are typically recorded in screen coordinates (e.g. pixel locations in a display) and not in geographic coordinates, which induces a spatial data analysis challenge when evaluating interactive cartographic products. Nevertheless, the viewed geographic locations might be particularly relevant for a specific spatial decision making task.

Interactive maps in user studies are often approximated by pre-computed animations or by automatically loading a number of subsequent static images (e.g. Fabrikant et al. 2008b; Ooms et al. 2012). In doing so, the experimenter introduces a high level of experimental control to facilitate empirical data analysis with dynamic displays. To increase ecological validity, however, participants should be able to execute a task on interactive maps as they would normally do (which is: without restricting their inference making behaviour or the interactivity levels of the tested map display). Other solutions - e.g. segmenting screen recordings based on user action, Dynamic Areas of Interest, Semantic Gaze Mapping, etc. – typically demand a high amount of time consuming manual work, which decreases their attractiveness in interactive cartographic user studies.

To evaluate interactive cartographic products, it is essential that human-map interactions are tracked as well. In User Centred Design (UCD), user-system interaction logging (e.g. mouse movements, key-stroke analyses, etc.) is often utilized to gather quantitative data from users who execute a task with a product (e.g. Nielsen 1993), and this has also been linked with eye tracking on interactive applications. For geographic analyses, this collected data should ideally be represented by means of map or geographic coordinates. By combining the gathered data (initial settings of the interactive map, eye movements and user actions in pixel coordinates), all recorded eye movements can be georeferenced and thus placed on their corresponding geographic location. This methodology is described in detail in Ooms et al. (2015) and will be applied in a user study to investigate the influence of the panning behaviour on map users' cognitive processes.

2. Study Design

2.1. Participants

In total, 24 employees at the Department of Geography, Ghent university took part in the user study, with an average age of 28 years. During their training they received several courses in cartography and work currently with maps on a regular basis. Nevertheless, due to some errors in the recordings, not all data could be used for the analyses.

2.2. Tasks and Stimuli

We integrated a globally well-known interactive mapping application in the user study to serve as stimuli: Google Maps. Both the available map and satellite view are included in the user study. It was decided to include two scale levels in the test: level 7 and level 13. These correspond roughly to a scale of 1 : 9 000 000 (overview, continental level) and 1 : 150 000 (detail, regional level). During the test, participants could only use the panning operation to complete their assignment (and could thus not change the scale level).

Because of the difference in detail and consequently the objects that are visible at these two scale levels, different tasks are designed for each. On scale level 13, the participants have to navigate along two different prescribed routes, using only panning: (1) from Spa tot the coast; (2) from Spa to Aarlon. The initial views (map or satellite) that were shown on screen to the participants at the beginning of the tasks are depicted on the right in Figure 1. While they were following the route they had to count the number of crossings with other mayor roads (type E-, A-, Nx or Nxx-roads). Across the participants, we alternated between the map and satellite view for the two tasks.

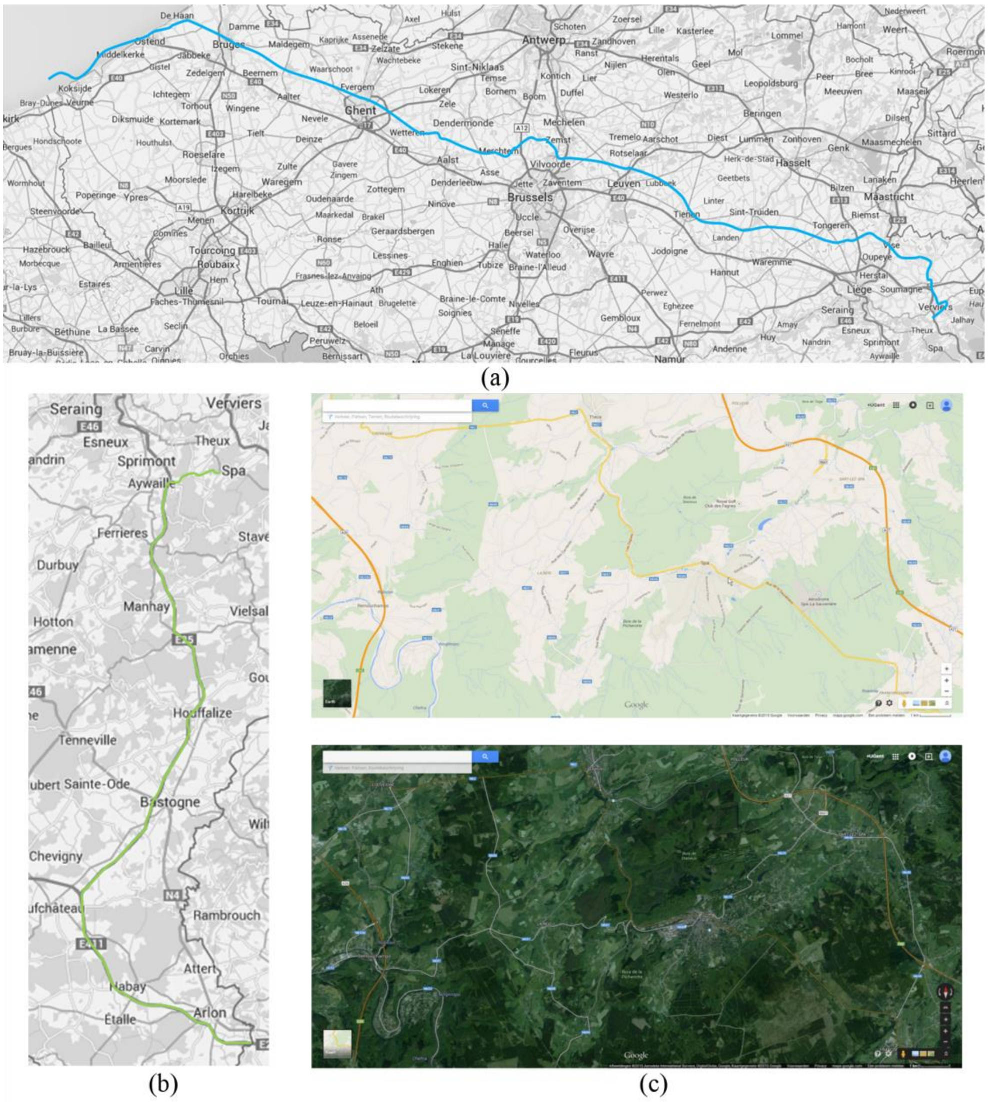


Figure 1. Overview of stimuli during task 1 and task 2

During Tasks 3 and 4, participants were asked to locate Belgium (using only a panning operation), starting from an unknown location. The locations where the participants were 'dropped' are marked in red in the top image of Figure 2(Fiji in Task 4 and north of Canada in Task 5). The four images below present the start screens that were shown to the participants at the beginning of their test (depending on the task and type of view).

Figure 2. Overview of stimuli during task 3 and task 4

During the test, the participants were asked to talk out loud and there eye movements were recorded. In order to get the participants familiar with these instructions (thinking aloud, using only panning) and the stimuli (Google Maps, map and satellite view) they had to complete a pilot test first. After the pilot tests, participants had to fill out a short questionnaire on personal characteristics (age, study, etc.). Next, the eye tracker was calibrated and the user logging tool activated.

2.3. Apparatus

All experiments took place at the eye tracking laboratory of the Department of Geography, Ghent University. Because of the mixed methods approach, variety of tools and devices are used in combination with each other. The participants' eye movements were recorded with an SMI RED 250 eye tracker device, using a sampling rate of 120 Hz. The stimuli were depicted on a 22 inch screen with a resolution of 1680 x 1050 pixels. In accordance to what was suggested in Ooms et al. (2015) we used the PyHook-based logging tool to register all user actions on a detailed level (mouse and keyboard input).

3. Results and Discussion

3.1. Panning behaviour

The participants' mouse actions were logged during the experiment. This gives us information regarding where (screen coordinates, in pixels) the mouse down and mouse up action occurred and the panning distance. Figure 3 visualises the locations where participants interacted during the four tasks (mouse key down action in green, key up action in blue). This reveals the main panning direction, which is in correspondence with the task they had to execute.

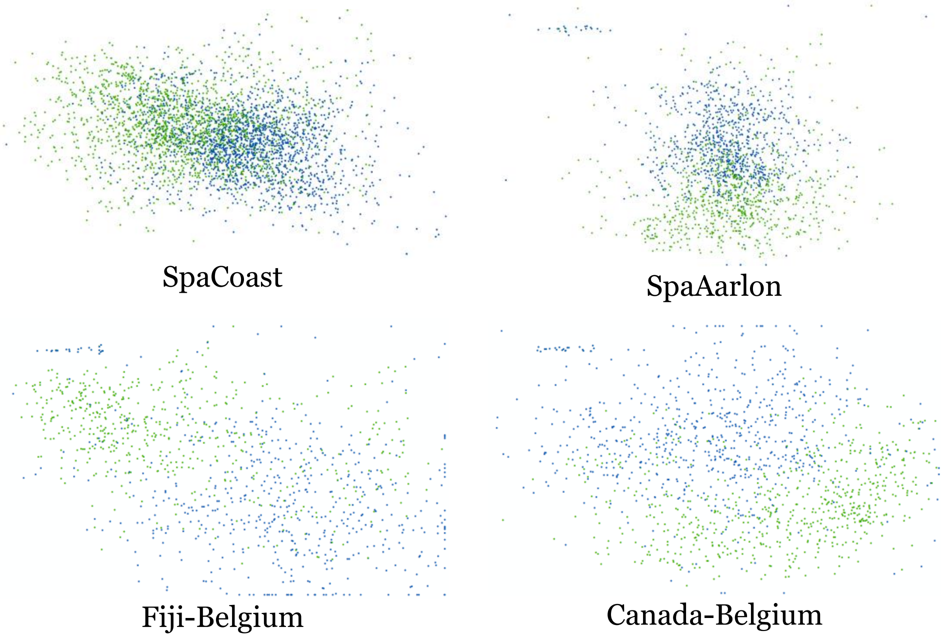


Figure 3. Locations of the mouse key down (greend) and mouse key up (blue) actions during the different tasks

When looking at the panning distances, we find significant (ANOVA, $P < .05$) lower values for Tasks 1 (M = 361.2 px; SD = 158.2 px) and Task 2 (M = 328.7 px; SD = 169.6 px), compared to Tasks 3 (M = 685.8 px; SD = 254.2 px) and Task 4 (M = 686.6 px; SD = 186.7 px). However, no significant difference in the panning distance between the map and satellite view was discovered (M = 554.5 px; SD = 287.1 px and M = 528.6 px; SD = 277.2 px respectively).

3.2. Attentive behaviour

From the recorded eye movements we calculated the mean fixation durations, mean saccade length (distance between two fixations) and number of saccades per second. The results are presented in Figure 4. The combination of these metrics can give insights in the participants attentive behaviour and search strategies. The number of saccades, for example, can give an indication regarding the intensity of the search behaviour (Abrams et al. 1989; Goldberg & Kotval 1999; Duchowski 2007).

The most pronounced difference in these metrics can found between the two scale levels. However, previous research has indicated that the task is also a significant influencing factor on eye movement metrics (Duchowski 2007; Peters & Itti 2007; Betz et al. 2010; Borji & Itti 2014).

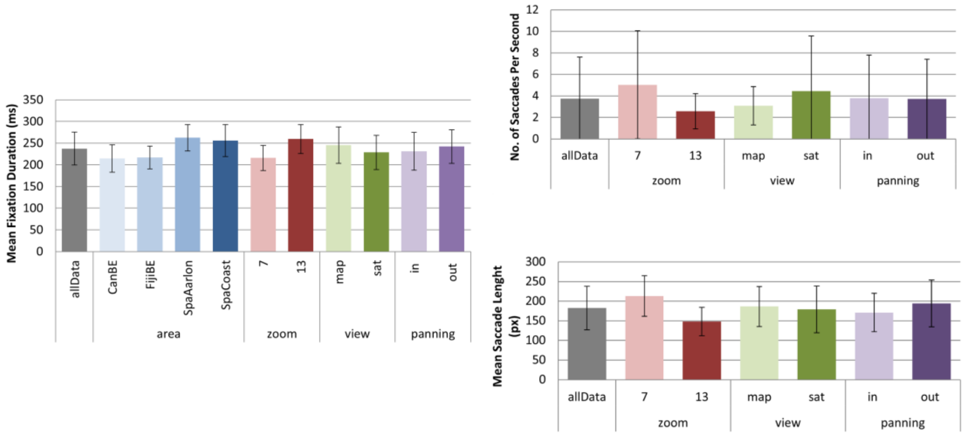


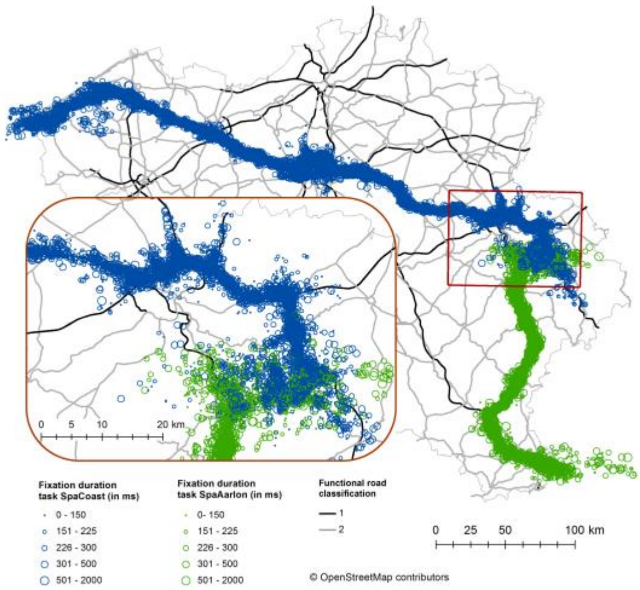
Figure 4. Graphs presenting an overview of the participants‘ fixations and saccades during the test

The durations of the fixations on the satellite view are significantly shorter (ANOVA, $P< 0.05$). From the participants recorded verbal expressions, it can be concluded that this indicates a more chaotic searching patterns. The analyses on the participants' saccades confirm this finding: significantly more saccades on the satellite view. Nevertheless, the length of the participants saccades does not seem to be influenced by the difference in map view type.

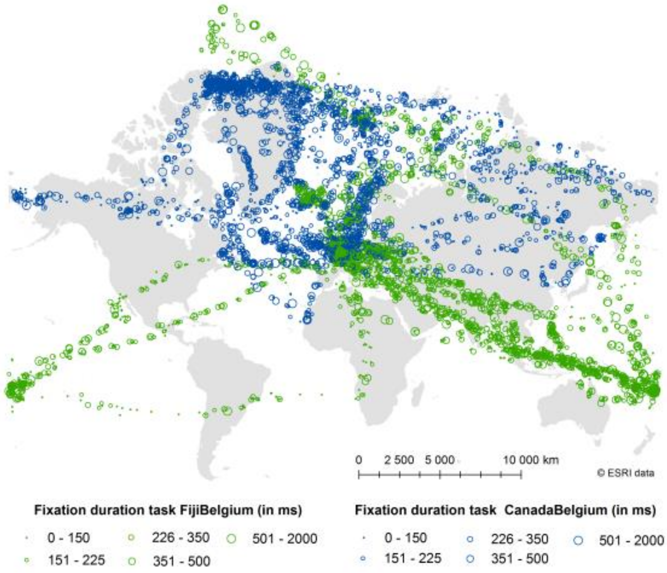
Besides focussing on the characteristics of the stimuli, we also considered the influence of the map users' interactions (panning in this case) on their attentive behaviour. Although the number of saccades is nearly equal, the length of the saccades is significantly shorter during the panning operations. This could be explained by the dynamic aspect of the stimulus when panning; the map extent changes, causing objects to 'move' across the screen.

3.3. Georeferenced Attentive behaviour

Based on the methodology described by Ooms et al. (2015), we were able to georeference the recorded eye movements and visualise them in a GIS (see Figure 5). By applying a number of standard GIS functions (calculating intersections, buffers, clip-operations, etc.) we were able to filter out all fixations – related to Task 1 and Task 2 – whose position was close to the intersections with other main roads, and subsequently compare these with the other fixations (further away from the intersections). The statistical tests clearly show that the participants fixated the map objects longer ($P < 0.01$) when they were located close to these junction ($M = 275$ ms near the junctions and $M = 247.6$ ms outside the buffer). This corresponds to the task they had to complete: the participants needed to study these junctions and decide whether the road that crossed their main trajectory had to be counted. This decision was based on the road's colour (symbology) and its name label.



(a)



(b)

Figure 5. Georeferenced fixation locations for tasks 1 & 2 (a) and tasks 4 & 5 (b)

4. Conclusion and Future Work

The user study described in this paper uses a mixed methods approach which gives insights in: (1) how the participants' interact with the interactive map (logging mouse actions); (2) the attentive behaviour of the participants (recording eye movements); (3) what these measurements mean (thinking aloud). Furthermore, by georeferencing the recorded eye movement data, we were able to link the participants' attentive behaviour to locations and objects on the map. Furthermore, the application of available GIS-tools, such as buffer operations, facilitated the analyses significantly.

In this phase of the research, the zooming operation has not yet been included. Only this way, we could examine the actual influence of the panning operation on the map user can be investigated. In a next phase, the zooming operation will be investigated and finally, all will be integrated in a concluding experiment.

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