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Comparison of spatial orientation using topographic map and orthophotomap in a virtual environment representing urban space.

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Abstract:
Virtual environments are computer-generated immersive spaces that can stimulate both real and imaginary worlds. Their purpose is to immerse the user in a realistic virtual environment (Stanney and Cohn, 2009). A particularly interesting aspect is their effect on spatial orientation, which is defined as the ability to remain oriented in a spatial environment when viewing objects in that environment from different positions (Kozhevnikov and Hegarty, 2001). It is one of the main components of spatial abilities (Carbonell-Carrera & Saorin, 2017). Spatial abilities are involved in everyday activities, such as finding one's way in an environment (Hegarty et al. 2002). People acquire spatial information through direct experience when moving through an environment or looking at a map (Richardson et al., 1999).

As part of the project "Comparison of spatial orientation using topographic map and orthophotomap in a virtual environment representing urban space" - ADVANCEDBestStudentGrant a group of 60 people were given the task of reaching a destination on a map without knowing their location in real time in a created virtual environment. The time needed to reach the given destination was measured and the eye-tracking method was used to analyse users' strategies. Participants were then asked to rate their spatial orientation skills using a questionnaire (Santa Barbara Sense of Direction Scale; Hegarty et al., 2002), and data was collected on the use of navigation applications and the frequency of playing computer games with virtual spaces.

A person's ability to orient themselves in their spatial environment is a complex phenomenon that involves a large number of cognitive functions (e.g., attention, perception, memory, mental imagery) and enables individuals to effectively learn, plan, execute, and update movements from a starting point to a destination (Yu et al., 2021). The study compares two mapping products to show differences in spatial orientation while using them in a virtual environment that simulates a selected section of urban space. The study also includes testing the cognitive load (pupil diameter) for each map. Based on the findings of Kiefer et al. (2014) that participants performed better in orientation tasks when they switched more frequently between viewing the space (especially the landmarks) and the map, the number of revisits to the map and their effect on the time parameters achieved as well as the success rate was tested.

The study involved 60 respondents (46.67% female and 53.33% male) with an average age of 21.6 years (SD = 3.34). The Santa Barbara Sense of Direction Scale was used to assess respondents' subjective sense of spatial skills, with participants scoring an average of 4.95 (SD = 0.997). 78.33% of respondents correctly completed the task of reaching the designated target in an average time of 345.78 s (SD = 196.53 s). In relation to the maps analysed, those who used an orthophotomap (mean = 17.47) were more likely to turn it on than those who used a topographic map for orientation (mean = 17.17). The cognitive load was tested by measuring the mean pupil diameter of the eyeballs. The results

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showed that the subjects who used the orthophotomap were more cognitively loaded ($p < 0.05$), which may suggest that it is more difficult to obtain spatial information. This could be due to the lack of use of cartographic generalisation. This may also be influenced by the different colours of the two maps.

The size of the pupil diameter ($r = -0.2798$) and the time to reach the target ($r = -0.3841$) correlated negatively with the Santa Barbara Sense of Direction Scale score ($p < 0.05$), which can confirm a lower cognitive load in people with a better assessment of their spatial abilities and consequently be reflected in a faster reaching of the target, regardless of the map used. The length of the first map entry correlated negatively with scanning speed ($r = -0.2988$) and positively with the number ($r = 0.2729$) and mean time of fixation on the map ($r = 0.2790$, $p < 0.05$), which may indicate that the first map entry already provides insight into spatial ability and that individuals who look at the map for longer on first viewing orientate their visual strategy towards scanning slowly and making more and longer fixations. Those who successfully reached the target looked at the map more often on average (those who reached it = 0.06 map openings/completion time; those who did not = 0.04 map openings/completion time) and their average opening time of the map was shorter (those who reached it = 4.56 s; those who did not = 6.87 s). This could indicate that people with better spatial skills are more likely to turn to the map but look at it for a shorter time, which is also supported by the negative correlation between the score achieved in the SBSOD and the average number of map turns ($r = -0.2588$, $p < 0.05$).

The present study allowed us to demonstrate the differences between the analysed maps (topographic map and orthophotomap) during spatial navigation in a virtual environment. The eye-tracking data obtained made it possible to observe differences in cognitive load between maps and visual strategy between successful and unsuccessful participants. In addition to the central consideration of the analysed maps in the study, the authors also found interesting correlations for the scores on the Santa Barbara Sense of Direction Scale. However, it is worth noting that the proposed analysis is extended to include, among others, the length of the first map opening as well as the average number of map openings during the way and the average map opening time, which break down the process of spatial orientation in the virtual environment more thoroughly.

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