Evaluation of user preferences during reading of 2D and 3D cartographic visualizations

Currently, thanks to advances in computer and Internet technology, the production of digital cartographic products is massive. Map makers, cartographers or graphic designers perceive maps differently than the target audience. The considerable degree of subjectivity is put into during the map making. In many cases, the specialist cannot imagine how the map will be used. For these reasons, it is necessary to make research of user perception and cognition of maps.

In modern cartography, it is very popular to depict the spatial information using 3D visualization techniques, perspective views and pseudo - 3D techniques like hillshade, hill or hatch hypsometry methods. The research question is to find out the real value of 3D cartographic methods for the perception and use of maps.

3D maps are generally considered as a way how to better show the vertical spatial relations, while classical 2D representations (orthogonal maps) are regarded as more suitable for distance and area perception. Both mentioned visualization methods has pros and cons, and it is necessary to objectively specify, which one is suitable for solving different spatial tasks.

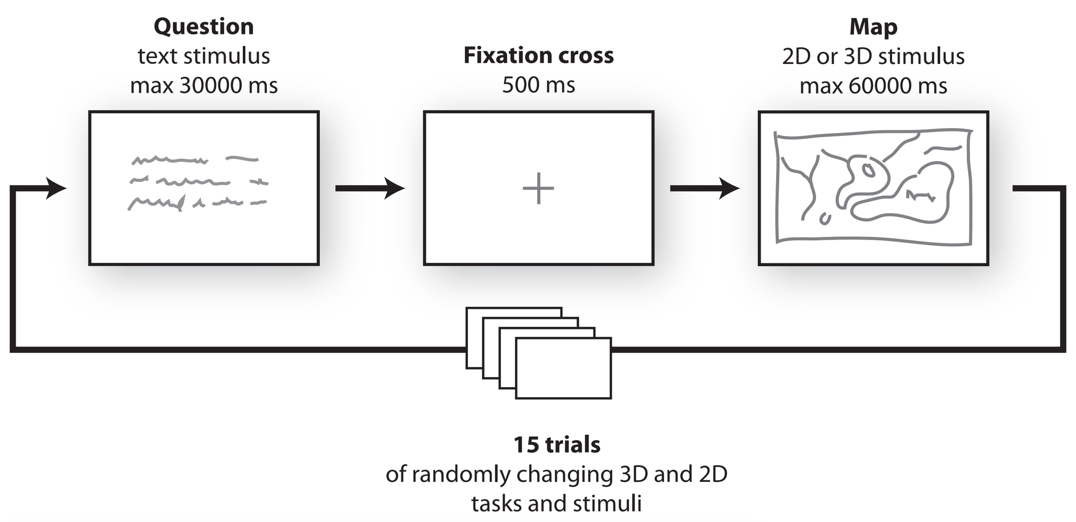
Eye-tracking technology was not fully utilized in the cartography or geosciences yet. It is clear that it will have great importance in optimization of car tographic products and visualization of geographic data in the future.

Experiment Design

Two kinds of experiment were designed and executed in order to find out map user behavior when reading 2D and 3D cartographic visualization and map user preferences. Respondents of experiments were 20 students of Cartography and Geoinformatics.

1. Single map experiment

The first experiment was designed as a set of stimuli containing single maps. Half of them was using 3D visualization, whereas the second half was in 2D. Purpose of this experiment was to evaluate users behaviour during answering the spatial query (e.g. Find the highest peak, Find the furthest point, etc.).



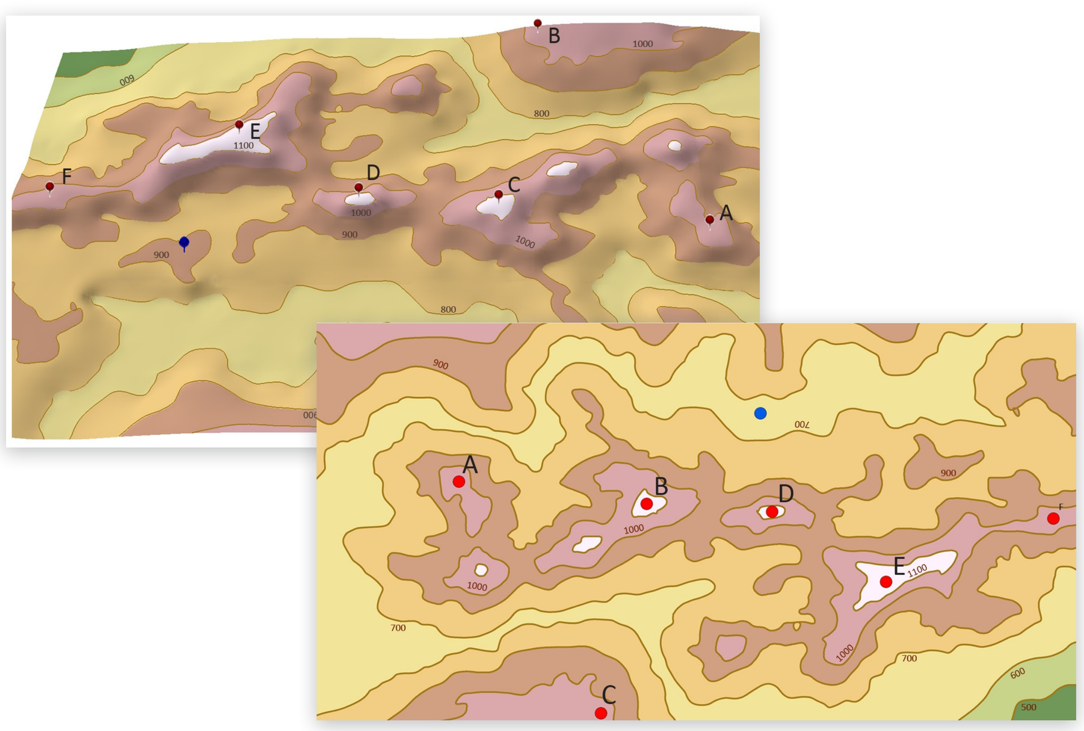


Fig. 2: Example of single map stimuli - (a) 3D stimulus (b) 2D stimulus. Both stimuli have the same task on the user: „Mark the red points, from which the blue point can be seen."

2. Double map experiment

The second experiment was focused on finding out the user preferences between both visualization methods. Stimuli was represented as a pair of maps in 2D and 3D side by side. The aim was to reveal, which kind of visualization will be preffered when searching for answer on spatial querry.

To avoid the influence of the location of maps within the stimulus (left, right), two groups of users were tested. Stimuli for both groups were the same, but the position of 2D and 3D maps within the stimulus was changed.

After the eye-tracking experiment, each respondent was asked to fill an online questionaire. Questions were focused on user subjective attitudes to both visualization methods.

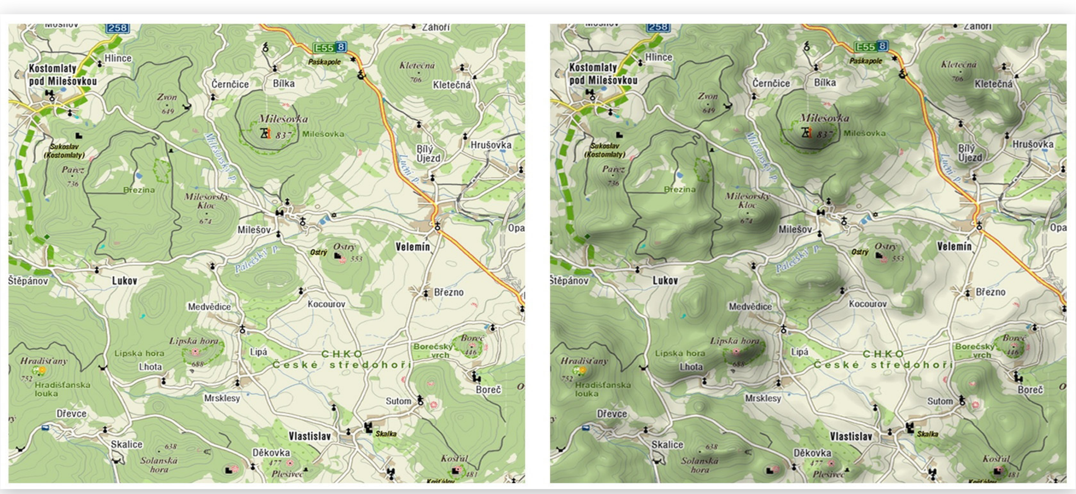
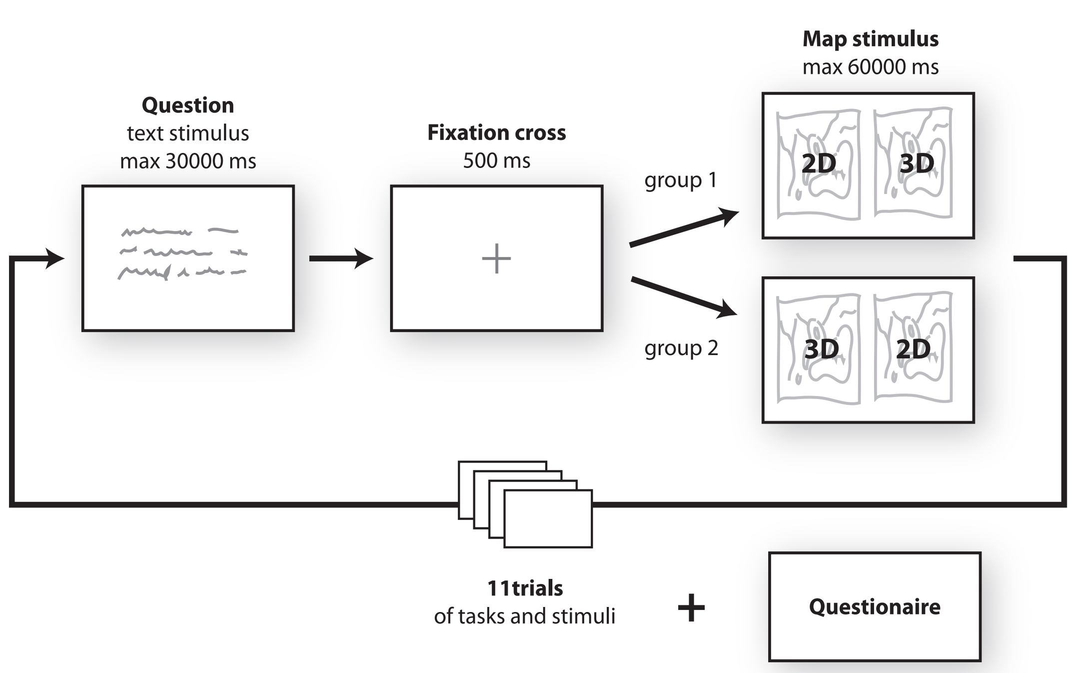


Fig. 3: Example of double map stimuli. Task on the user was to mark the Milešovka peak.



Research Task

The aim of the contribution is to present results of eye-tracking experiments on evaluation of user preferences during reading 2D and 3D cartographic visualizations. The overall goal of the research is to describe differences of map perception of cartographers and non-cartographers and to create a theoretical framework for investigating effectiveness and preferences of 3D and 2D cartographic visualizations.

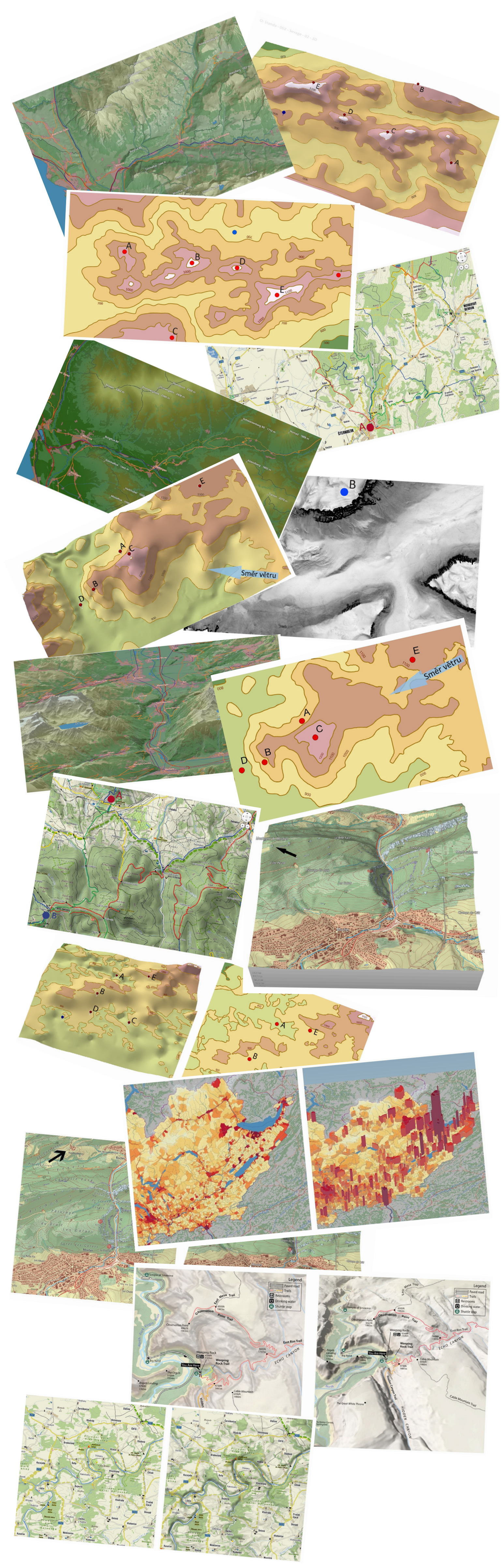
Lab Setup

SMI RED 250 eye-tracker with 120 Hz sampling rate
SMI Experiment Center - design of experiment
SMI BeGaze, OGAMA, R software - data analyses

SMI
SensoMotoric Instruments

Fig. 1: Eye-tracking laboratory setup at Department of Geoinformatics, Palacký University in Olomouc.

Stimuli



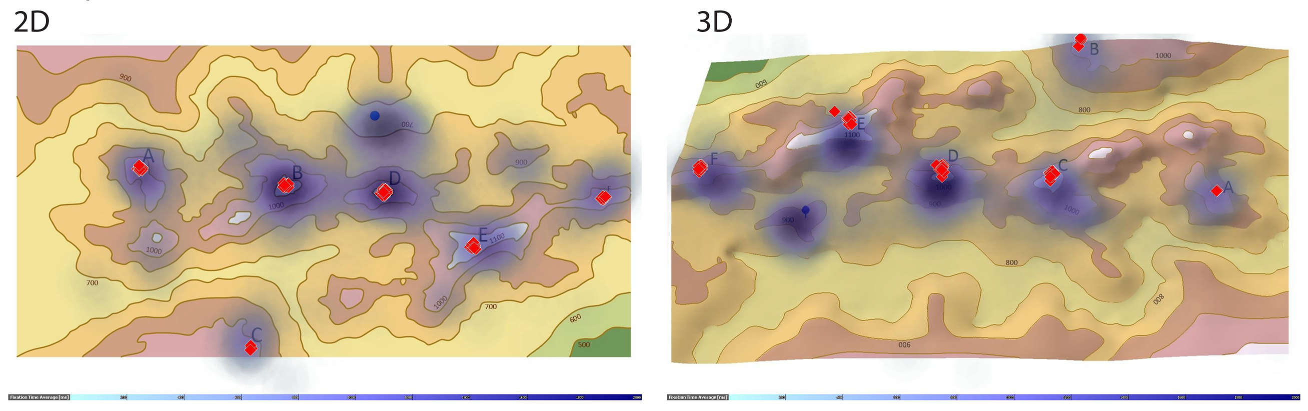
Preliminary Results

Currently (May 2012) presented experiment is not finished yet. In the respect of this fact we can show only preliminary results, which are based on investigation of gaze data visualisation and statistical analyses of various eye-tracking metrics.
In the future more relevant and statistically backed up arguments will be published.

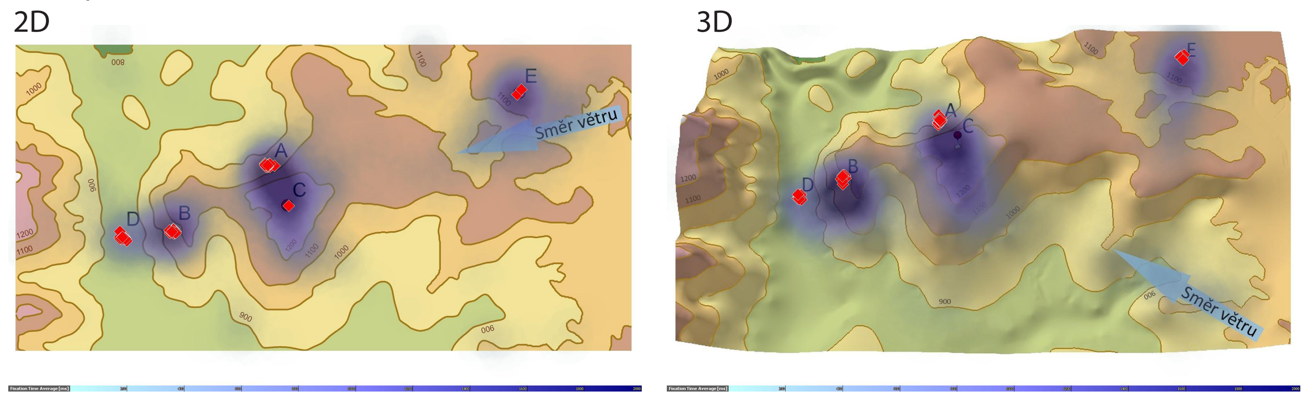
Diferences of users perception of 2D and 3D maps

The aim of experiment was to prove differences of user perception of 2D and 3D maps. Dependent variables were represented by following metrics derived from the analysis of eye-tracking data: Average fixation duration, Saccade velocity average, Fixation count, Saccade count, Saccade/fixation ratio, Sacade amplitude and Time to correct answer. All of these dependent variables are important indicators of a particular behaviour of map users in searching for answers.
Prior to the statistical analysis the data were tested for normality. Results of Two-Sample t-test are shown in the table 1. No significant differences between measured metrics on 2D and 3D maps were proven according to computed p-values on the significance level α = 0.05.

Example 1
2D 3D



Example 2
2D 3D



Example 3
2D 3D

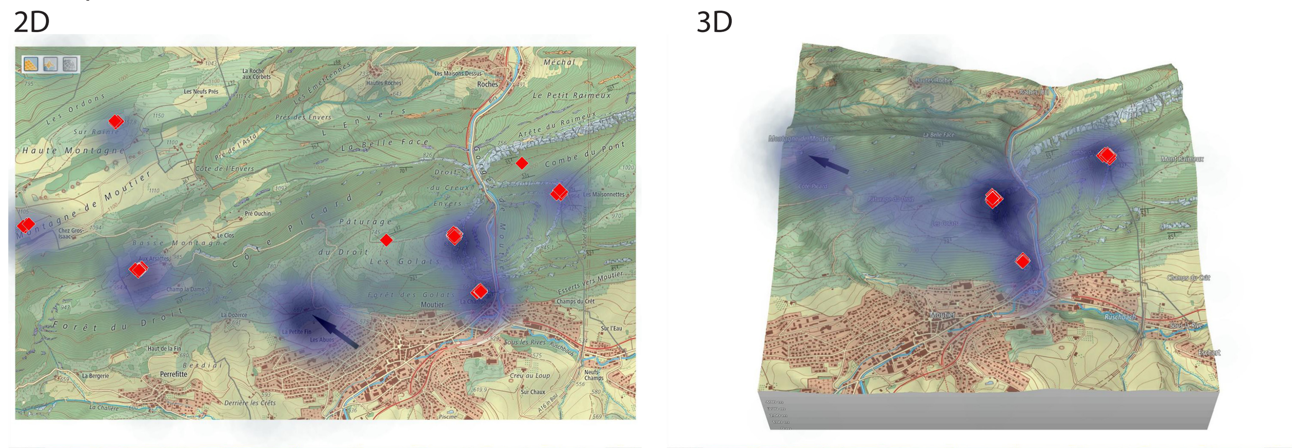
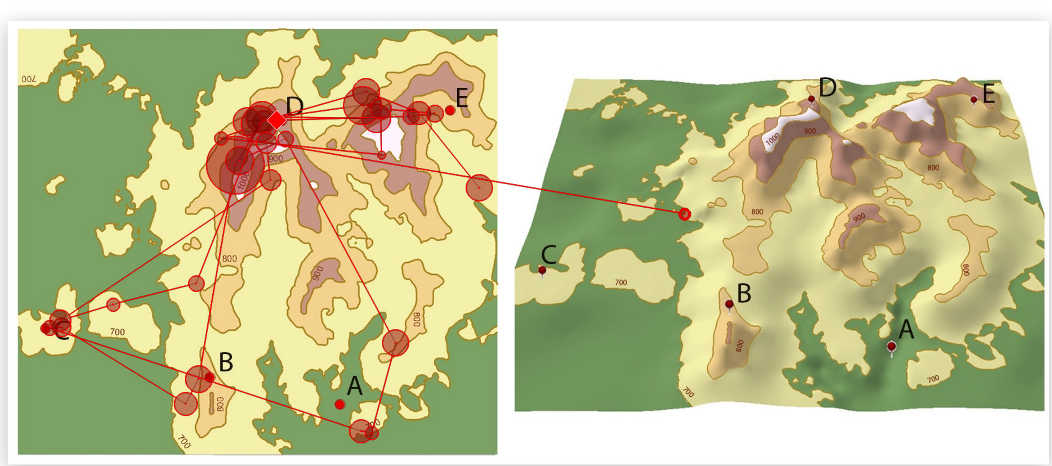


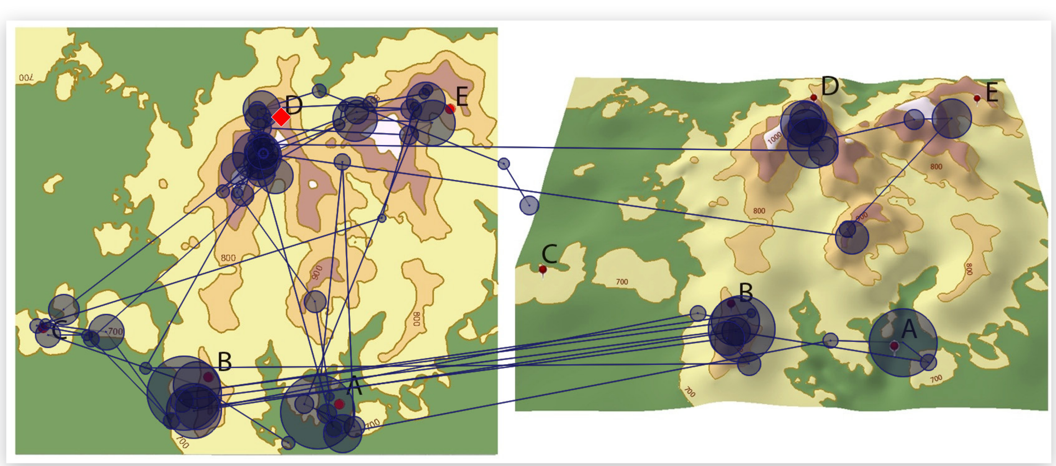
Table 1: Two-sample t-test p-values for eye-tracking metrics.
AFD - Average fixation duration, SVA - Saccade velocity average, FC - Fixation count, SC - Saccade count, SCR - saccade/fixation ratio, SA - Sacade amplitude, TTA - Time to correct answer

2D and 3D map comparison	**AFD**	**SVA**	**FC**	**SC**	**FSR**	**SA**	**TTA**
Example 1	0.591	0.802	0.360	0.371	0.930	0.924	0.559
Example 2	0.593	0.919	0.778	0.754	0.927	0.556	0.575
Example 3	0.837	0.469	0.464	0.483	0.965	0.325	0.356

Double map stimuli experiment

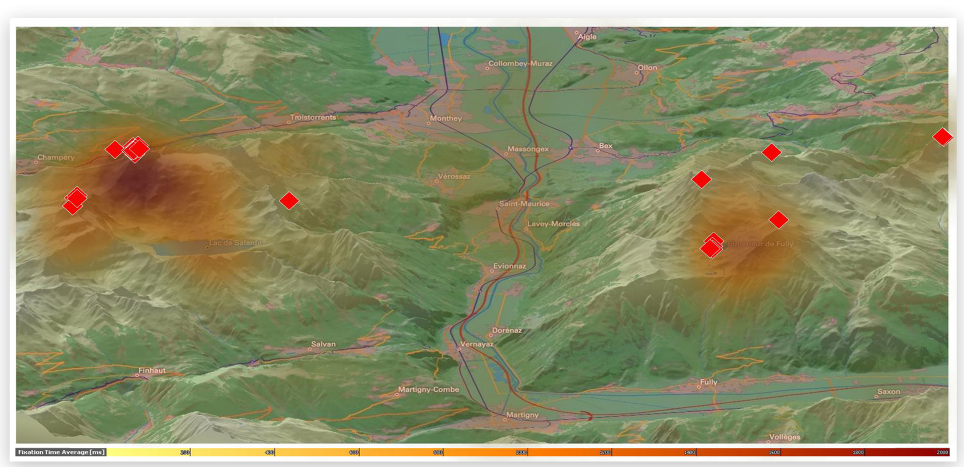
By visual investigation of scanpaths of two respondents, large differences can be seen while searching for the the highest peak in the double map stimuli.
In presented example, contrary to expectations, users were looking for the highest peak rather on 2D map. In the first presented case respondent did not look at the 3D map at all, while the second respondent has controled the 3D map and marked the correct result on the 2D map.
Together with double map stimuli experiment a questionaire research was performed. According to questionaire results the 3D visualization was more attractive and understandable than 2D.

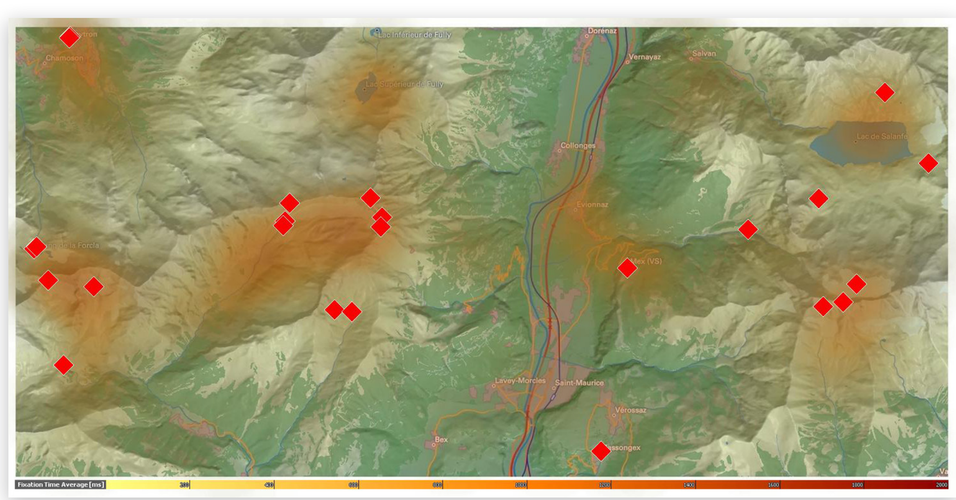




Perspective vs. Orhtogonal View

Viewing following stimuli, participants were asked to mark a highest peak. Maps don't contain any labelling, therefore the only guideline to distinguish between upper and lower parts of relief was hillshading. Stimuli were taken from At las of Switzerland. Mapped area was selected in order to visualize hilly landscape.
Based on perspective view participants were able to detect peaks or at least mountain ridges. Orthogonal view was more difficult to interpret. More than half of participants were not able to distinguish between valleys and ridges.





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