Exploring the Influence of Color Distance on the Map Legibility

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Abstract. The contribution deals with the color distance of map symbols, which is introduced as one of the issues of visual distance. In order to provide quickly and correctly legible map, it is necessary to emphasize the sufficient difference of map symbols parameters of all visual variables – size, shape, color value, color hue, texture and orientation. The aim of the case study was to detect the influence of color distance between two elements depicted on the map on its legibility applying an eye-tracking technology. By statistical analyses of eye-tracking metrics was proven that color distance has evident influence on map legibility.

Keywords: Visual distance, Color distance, CIE Lab, Digital maps, Legibility, Eye-tracking

1. Introduction

Map is the medium, which graphically presents entities of the world, their characteristics and spatial relations (Robinson et al., 1995). For centuries, maps were created and used as an abstraction of the real world with the ability to give the map users compact image of the complex environment that surrounds them (Fairbairn, 2006). Map should give users quick and precise answer to a specific question (Brodersen et al., 2001, Tuček et al., 2009). As a tool of communication and information transfer, the map is in the permanent interest of cartographers who evaluate its information content, effectiveness and usability and tries to define the line between 'good' and 'bad' map.

According to Stigmar and Harrie (2011) legibility of maps measures can be subdivided into three types concerned with the amount of information that is transferred by map objects, spatial distribution and density of map objects and by their shape and size.

In common usage, legibility refers to a sensation of ease in performing a reading task. Relative 'ease' can be reported by subjects, but so far no one has found a way to measure it in objective fashion (Bartz, 1970). Legibility of maps largely dependent on semiotics – the science of signs (MacEachren, 1995). In a cartographic context, perception of maps is the immediate reaction to symbols on it, their colors, shapes, sizes and so on, and the processing of these to construct an environmental image (Stigmar, Harrie, 2011). In order to communicate meaning of map symbols as unambiguously as possible it is necessary to ensure that each individual symbol is distinguishable from all other symbols in the map key.

2. Research Task

The aim of the case study was to detect the influence of color distance between two elements depicted on the map on its legibility. For study purposes an eye-tracking technology was applied.

2.1. Color distance and its quantification

Color distance allows to quantify the ability to recognize difference between two colors. The distance between two colors was computed with the method $CIEDE_{2000}$. The $CIEDE_{2000}$ color distance formula is based on CIE 1976 L*a*b*. The specification of the formula is published for example by Sharma et al. (2004). L*a*b* values were related to CIE standard illuminant D65.

2.2. Design of eye-tracking experiment

Experimental stimuli were arranged so that they cover different values of the color distances between elements on a map in order to determine differences in their perception.

Eye-tracking experiment consists of map stimuli which were distinguished by color distance between map labeling and background and by the font size (see examples on the *Figure 1*). Totally 15 stimuli with ΔE_{00} 30, 50, 70, 85 and 100 color distance and 8, 11 ad 14 pt. font size were prepared. The color on stimuli varies in its value only.

Figure 1. Example of experimental stimuli with increasing color distance between map labeling and background and font size: $\Delta E_{00} = 30$ color distance, 8 pt. font size (left), $\Delta E_{00} = 70$ color distance, 11 pt. font size (middle), $\Delta E_{00} = 100$ color distance, 14 pt. font size (right).

Stimuli were screened to participants who were asked to identify and mark by the mouse click the right answer. Questions were asking to find a concrete administrative unit by its name. The order of the stimuli within the experiment was arranged randomly.

Gaze data from a total of 50 respondents were used. The participant age ranges between 20–25 years, all of them were students of Geoinformatics (group of 30 respondents with cartographic education) and other study fields (group of 20 laic map users) from Faculty of Science, Palacký University in Olomouc.

Eye movement recordings were performed in the controlled laboratory environment at Palacký University in Olomouc using a remote SMI RED 250 eye-tracker with 120 Hz sampling rate, 0.4°accuracy and 0.03°spatial resolution. The laboratory is equipped by the 21.5" LED monitor Dell P2213. Data capturing, experiment design, gaze event detection and data filtering were processed with SMI Experiment Suite 360°. Statistical analyses were done in the R.

2.3. Results

To reveal the influence of color distance on map legibility several metrics derived from eye-tracking data were analyzed – fixation count (overall number of fixation), average duration of fixations, scanpath length and time to find the right answer on the question. Saccade metrics wasn't taken into account due to the low sampling frequency of the eye-tracker.

Based on results of hypotheses testing several statements can be done:

- highest values of all analyzed metrics were observed on the map with the minimal color distance ($\Delta E_{00} = 30$), which means that respondents had highest difficulties in extracting information from these maps;
- increasing color distance leads to decreasing count of fixations, which can mean that the higher color distance leads to the more successful information reading;
- similar statement can be done for scanpath length and time to answer, except the local maximum of measured metrics for maps with $\Delta E_{00} = 70$ color distance. This local maximum was not statistically explained, because there was no significant difference found;
- color distance has influence on map legibility, but its improvement can be observed only between stimuli with high differences of the color distance;
- font size doesn't have influence on legibility of map labeling. However, in previous research of authors (Brychtová et al., 2012) the influence of font size was proven. This reflects the need to undergo this issue a more thorough exploration.

3. Conclusion and future plans

The contribution is aimed to reveal influence of color distance of map symbols on its legibility. The research was based on eye-tracking experiment determining whether the independent variable (color distance of map symbol) has an influence on the change of the measured eye-tracking metrics and whether it affects the ability of map readers to find the desired information. Resulting eye-tracking metrics (number and duration of fixations, length of scanpath and time to answer) were evaluated by methods of descriptive statistics and hypotheses testing. Research proved that increasing color distance has an influence on increasing ability of users to read the map information.

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