NEOCARTOLINK

Supporting the creation of a national network of new generation of Cartography.

COLOR DISTANCE ON MAPS

Alzbeta Brychtova*, Arzu Coltekin**, Stanislav Popelka*

* Palacký University in Olomouc
Czech Republic

** University of Zurich
Switzerland

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Introduction

- Color represents 2 of 6 Bertin‘s visual variables (hue and value)
- In cartography there is a necessity to emphasize sufficient difference of visual variables
- What is the sufficient color difference?

- Color distance = metric, that allows to quantify perceived difference between two colors
- Demonstration:

Small color distance:

Large color distance:

Tato prezentace je spolufinancována Evropským sociálním fondem a státním rozpočtem ČR.

Background

- Measurement of color distance:
  - Human sensitivity to the light of different wavelenght fluctuates
  - CIELAB perceptually uniform color space
  - Standard illuminant D65 (dylight)
  - CIEDE2000 formula (E_{00})

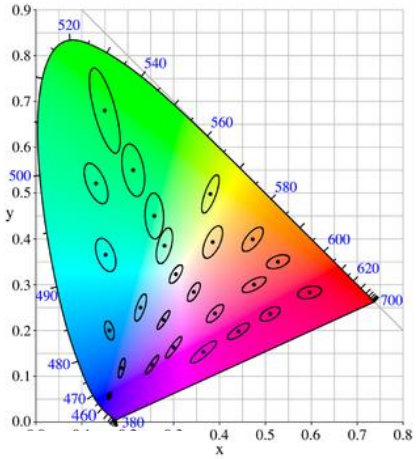

TABLE 1: Subjective assessment metric based on CIEDE2000 Color difference.

k	$\Delta E_{\min}(k)$	$\Delta E_{\max}(k)$	Perception of color difference	Q
1	0.0	0.5	Hardly	5
2	0.5	1.5	Slight	$5-(\Delta\overline{E}-0.5)$
3	1.5	3.0	Noticeable	$4-(\Delta\overline{E}-1.5)/1.5$
4	3.0	6.0	Appreciable	$3-(\Delta\overline{E}-3)/3$
5	6.0	12.0	Much	$2-(\Delta\overline{E}-6)/6$
6	12.0	24.0	Very much	$1-(\Delta\overline{E}-12)/12$
7	24.0	∞	Strongly	0

Background

- Laboratory:

  - Remote eye-tracker
  - SMI RED 250
  - Sampling Frequency 120 Hz

  - Experiment design - SMI Experiment Center
  - Analyses – SMI BeGaze, OGAMA, R Studio

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Three experiments

- Common aim of experiments : discover how color distance of map elements (symbols, labels) influences their legibility

- Common hypotheses: increasing color distance will have positive impact on map legibility

1. color distance influence on labels legibility (on Wednesday)
2. color distance on choropleth maps
3. color distance and map legend

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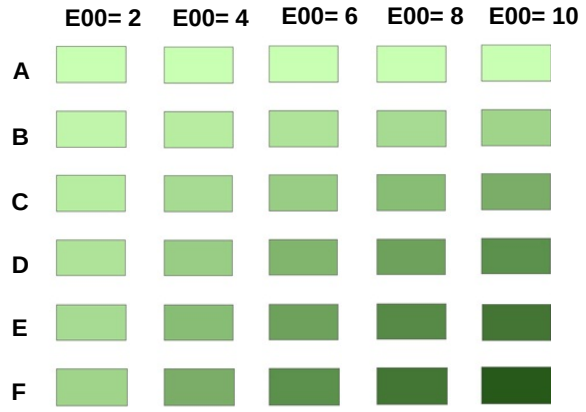
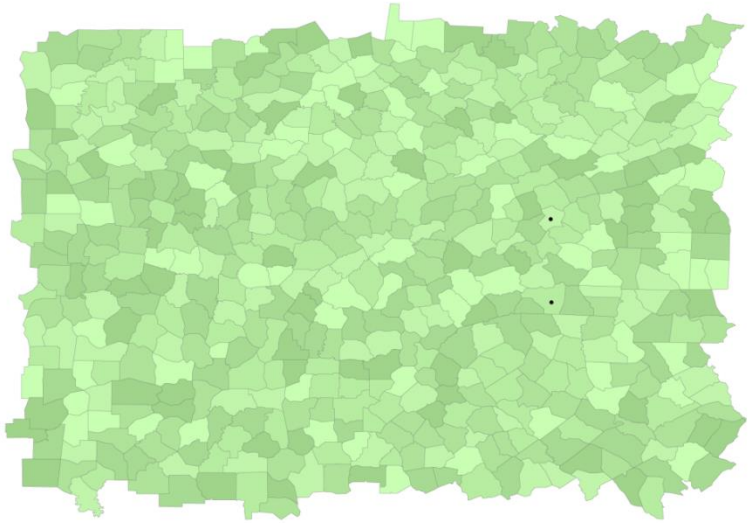
#2 Color distance on choropleth maps

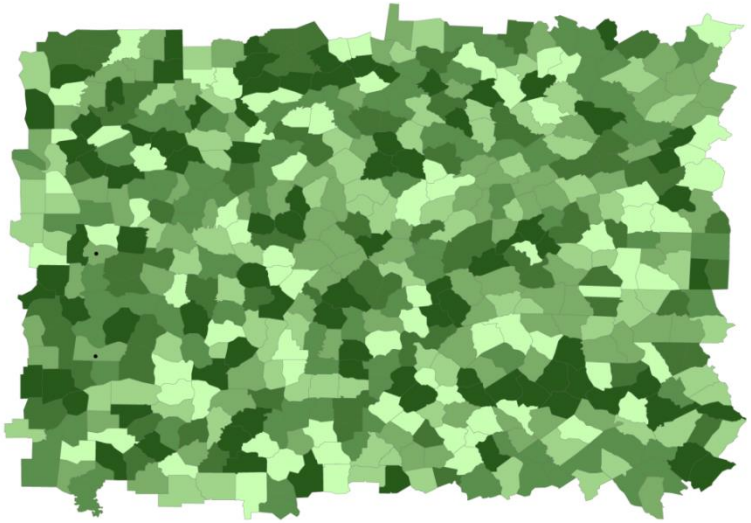
- **Goal:** How is the influence of color distance and viewing angle on users ability to distinguish categories of choropleth maps
- 21 stimuli
- participants were asked to find two marked areas and decide if they are of the same color
- Stimuli parameters
  - 5 color scales with equal step between adjacent categories ΔE_{00}=2, 4, 6, 8, 10
  - 6 categories
  - 2 levels of viewing angles between compared areas 3-4°, 10-13°
  - only shades of green
  - Randomization of colors within stimuli

→ avoiding the negative effect of adjacent colors

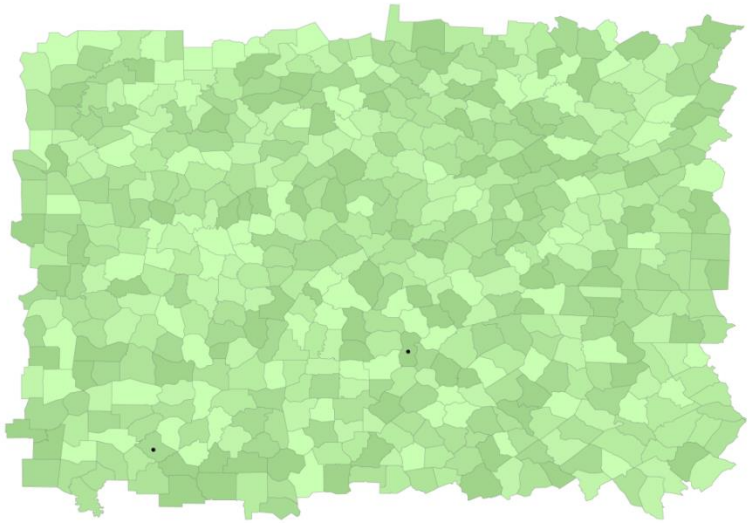




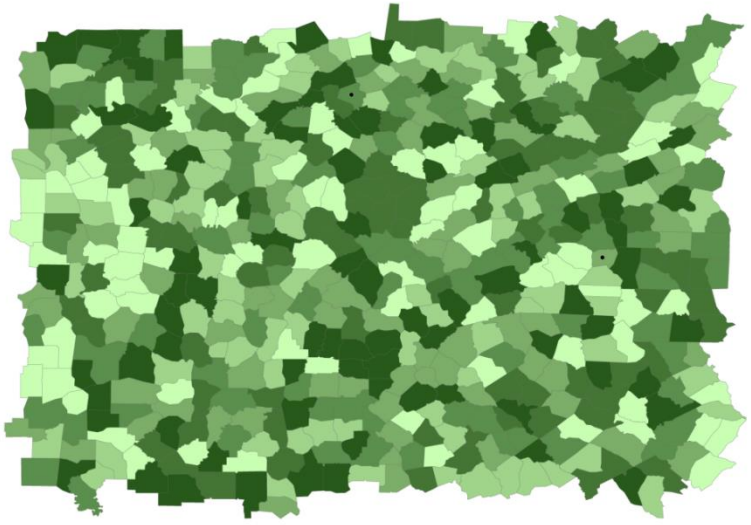
ΔE_{00}=2, viewing angle 3-4°



ΔE_{00}=10, viewing angle 3-4°



ΔE_{00}=2, viewing angle 10-13°



ΔE_{00}=10, viewing angle 10-13°

reduction of the number of independent variables to a minimum → simplified stimuli not similar to real maps

#2 Color distance on choropleth maps

- 38 volunteers with normal color vision
- 6 with tracking ratio less than 90% and calibration accuracy higher than 1° not included
- 13 males + 19 females (20 to 30 years)
- Students and employee of Palacký University

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#2 Color distance on choropleth maps

- hypotheses
  - increasing color distance will have an positive impact on overal legibility of choropleth maps
- we assume, that small color distance and large viewing angle between two compared areas will cause:
  - higher number of incorrect responses
  - longer time to find the answer
  - longer average fixation duration (indicates difficulty in extracting information)
  - higher frequency of fixations (less efficient search)
  - longer scanpath (less efficient search)
  - increasing number of AOI revisits

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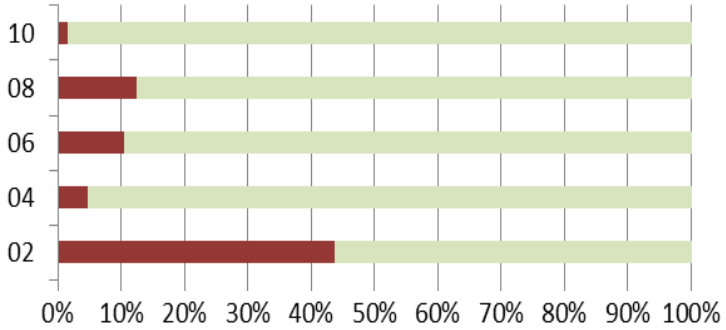
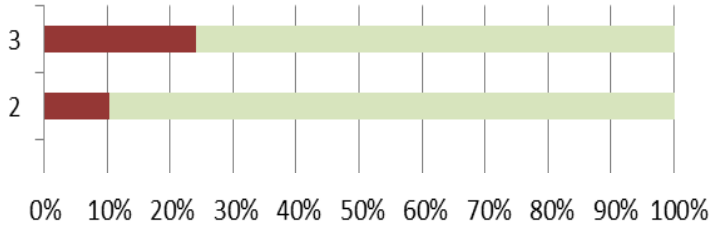
#2 Color distance on choropleth maps

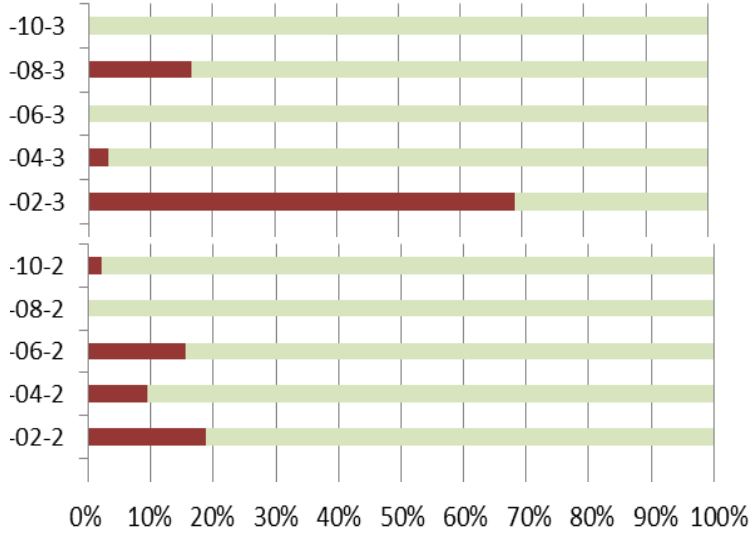
- Incorrectness of responses

Color distance



Viewing angle





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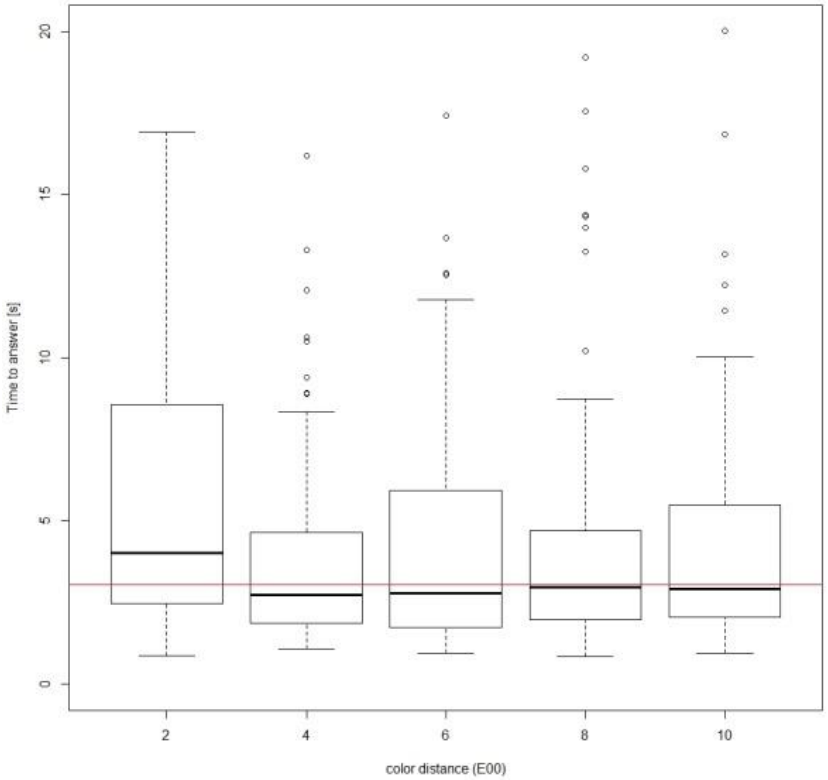
#2 Color distance on choropleth maps

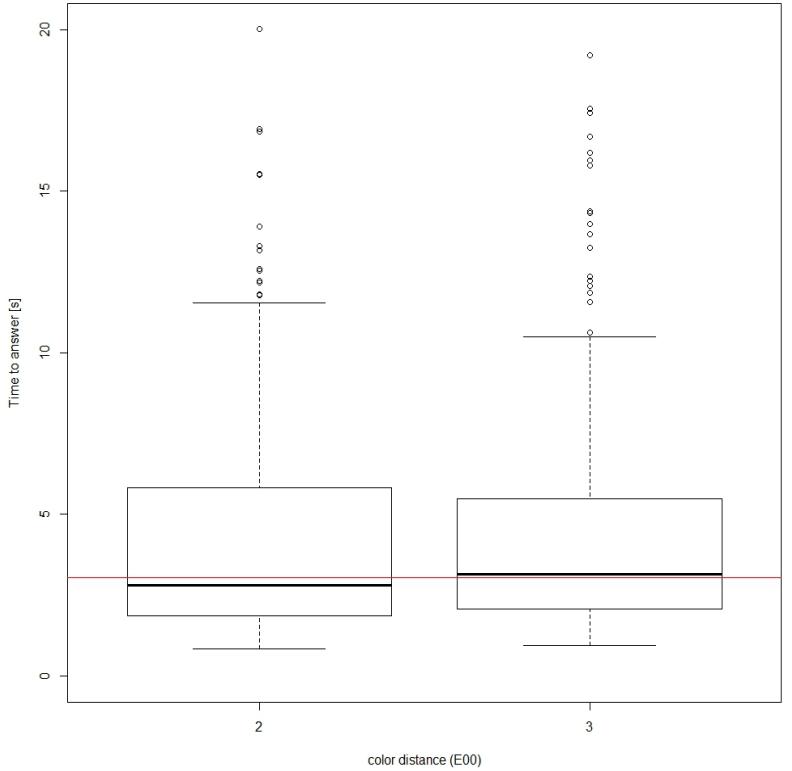
- Time to correct answer

Color distance



Kruskal-Wallis test (alpha=0.05):
Significantly different only ΔE_{00}=2

Viewing angle



Wilcoxon test (alpha=0.05):
Significantly different

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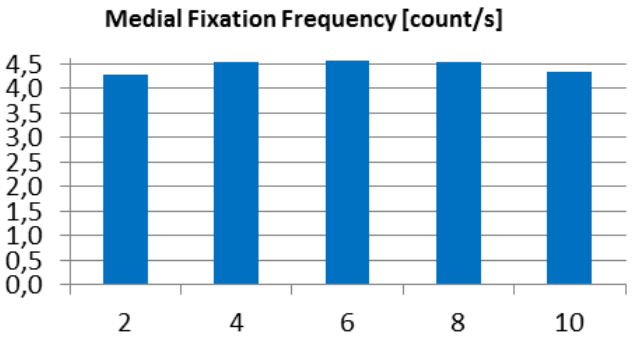
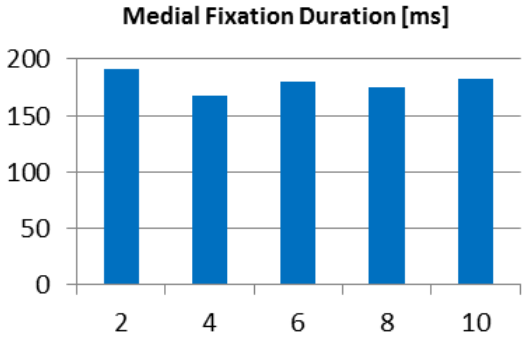
#2 Color distance on choropleth maps

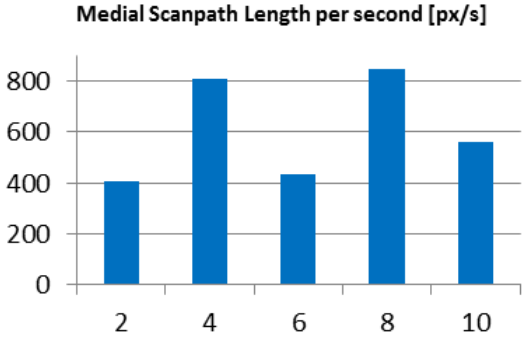
- Eye-tracking metrics:
  - Fixation frequency, average duration, average scanpath length per second



No significant difference



No significant difference



No significant difference

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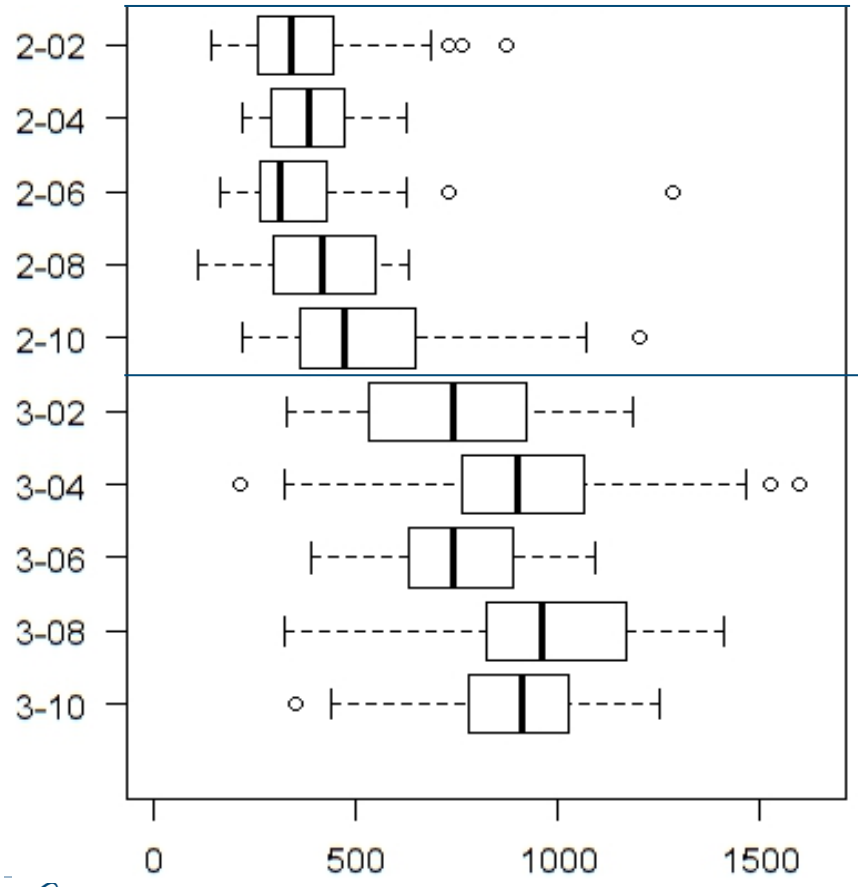
#2 Color distance on choropleth maps

- Eye-tracking metrics:
  - average scanpath length per second



Viewing angle 3-4°

Viewing angle 10-13°

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#2 Color distance on choropleth maps

- Results:
- ΔE00=2 is not suitable for distinguishing categories of choropleth maps
  - the highest incorrectness of answers
  - the longest time to find the correct answer

- it is easier to distinguish color categories while there is a small viewing angle between them
  - less incorrect answers
  - shorter time to find the correct answer
  - slower scanpath (px/s)
  - (but this is not a surprise…)

  - And that is all…
  - No further differences observed

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#3 Color distance, choropleth maps and map legend

- **Goal:** How is the influence of color distance and position of the legend within the map sheet on users ability to distinguish categories of choropleth maps
- 40 stimuli, 12 participants (pilot testing)
- participants were asked to match marked area with the category in the legend
- Stimuli parameters
  - 5 color scales with equal step between adjacent categories ΔE00=2, 4, 6, 8, 10
  - 6 categories
  - 6 legend position
  - only shades of green

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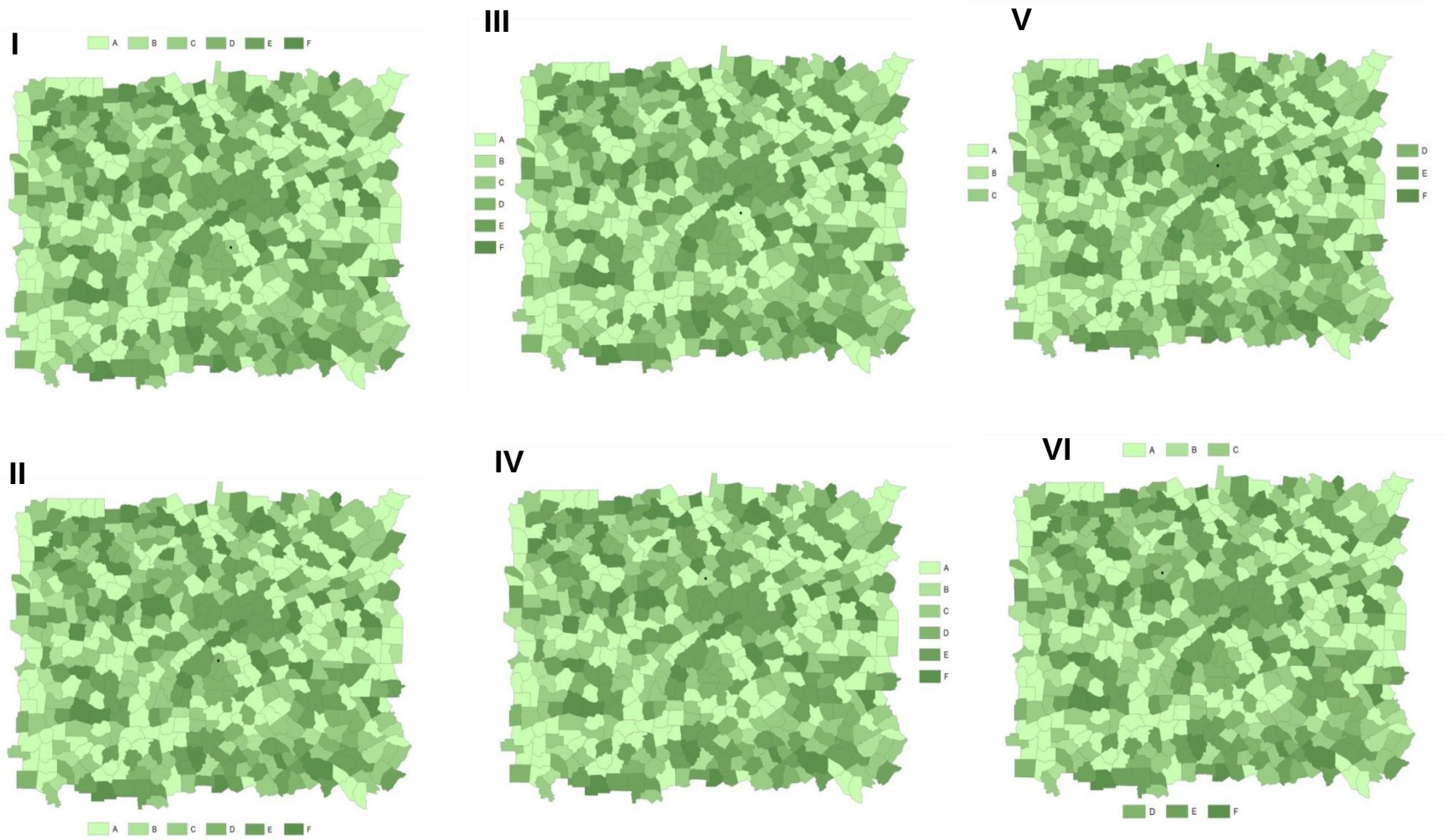
#3 Color distance, choropleth maps and map legend



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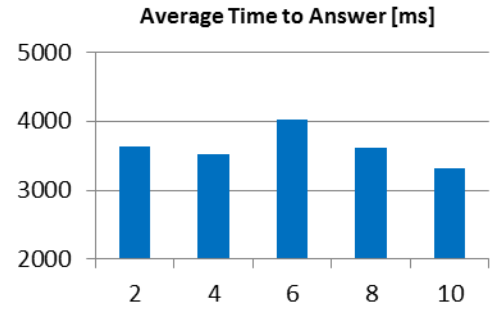
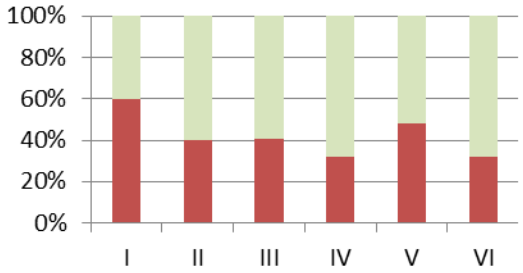
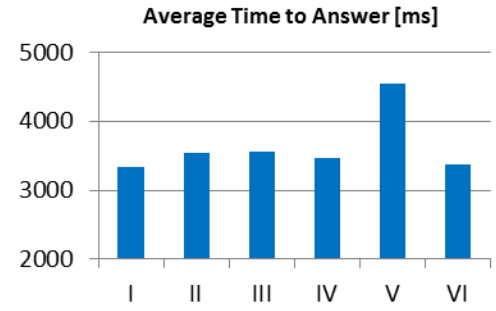
#3 Color distance, choropleth maps and map legend

color distance

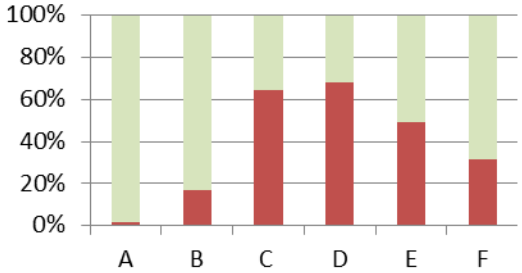


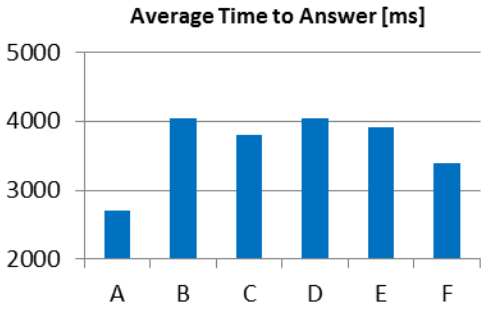
legend position





order of category in the scale





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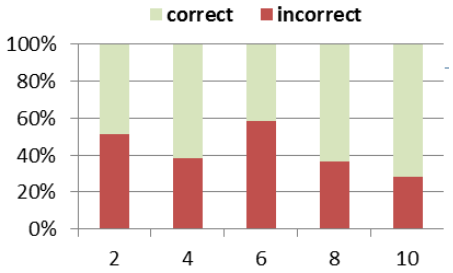
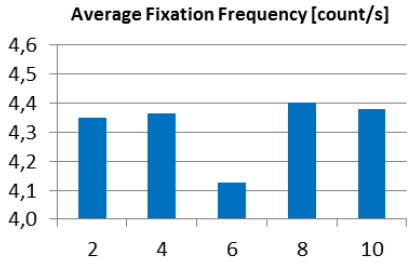
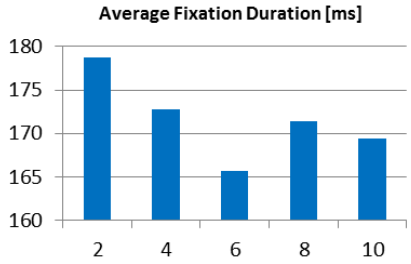
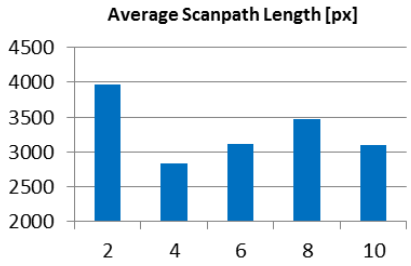
color distance

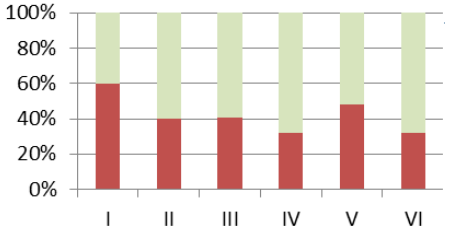


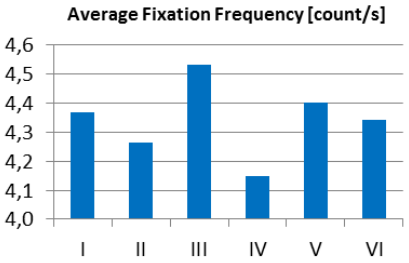


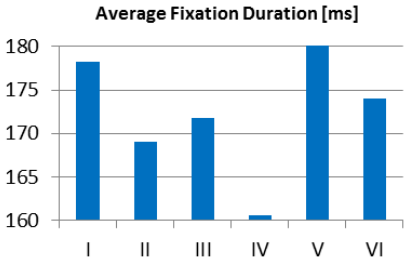


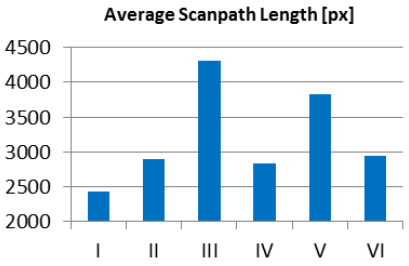


legend position

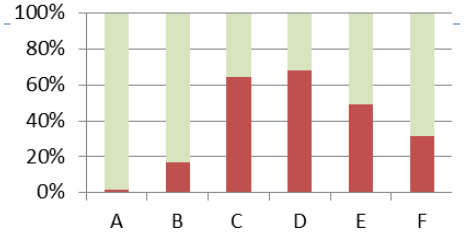


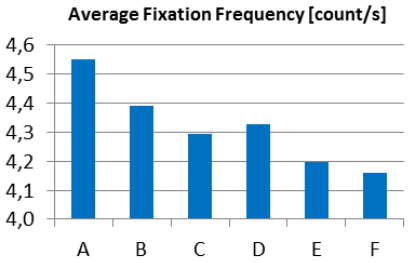


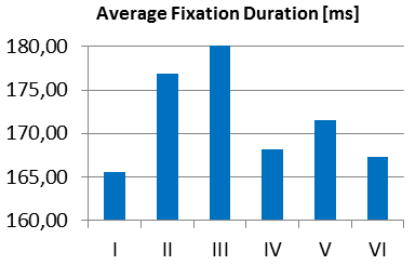


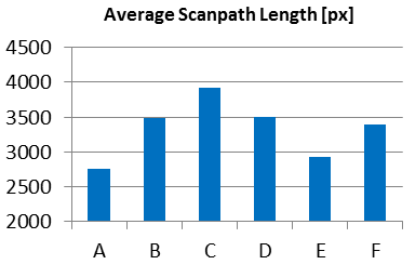


order of category in the scale









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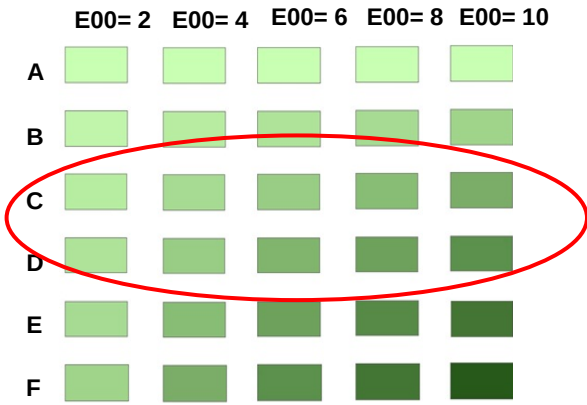
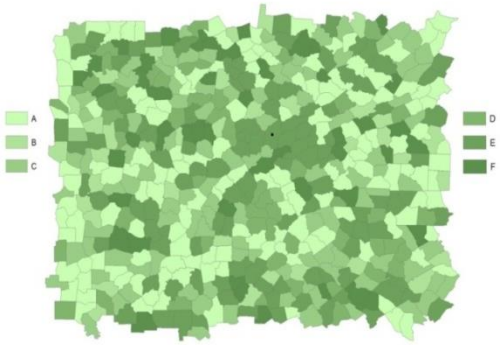
#3 Color distance, choropleth maps and map legend

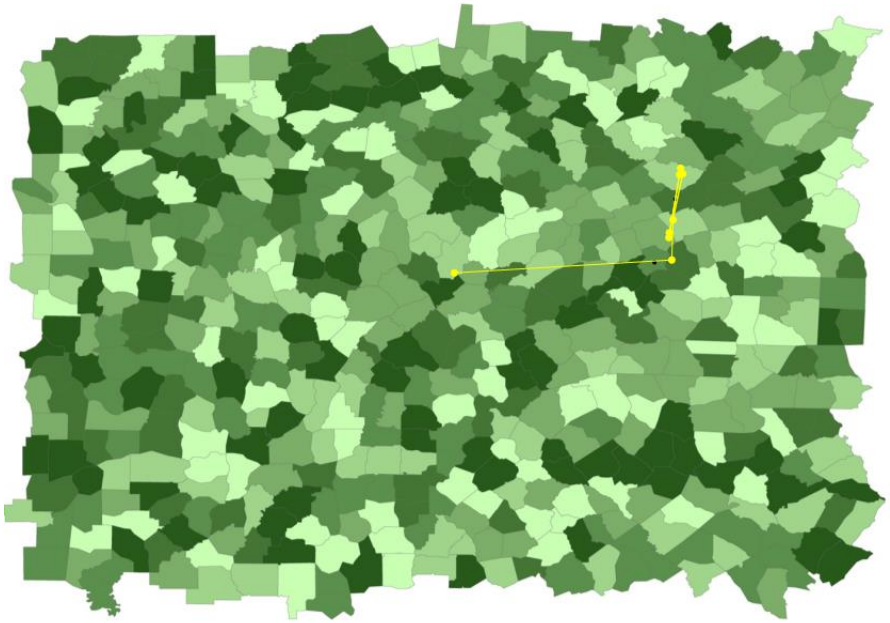


- Results:
- highest incorrectness
  - matching colors in the middle of the color scale to the right category in the legend
  - → equal step of E00 is probably not the best option
- most time consuming
  - legend position #5

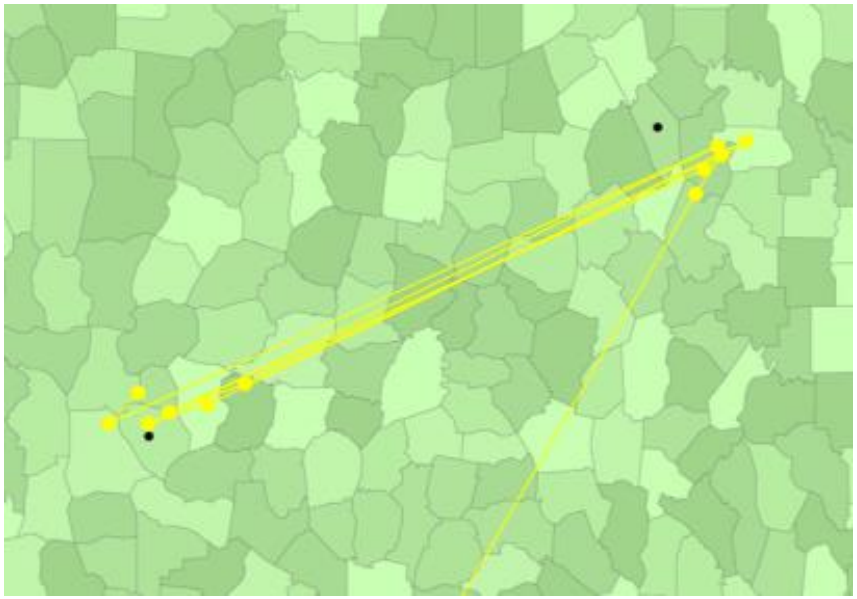


- eye-tracking metrics
  - ???

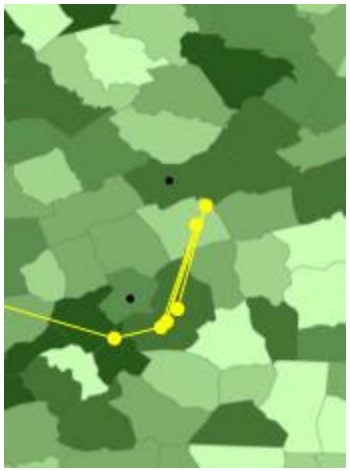
General Findings

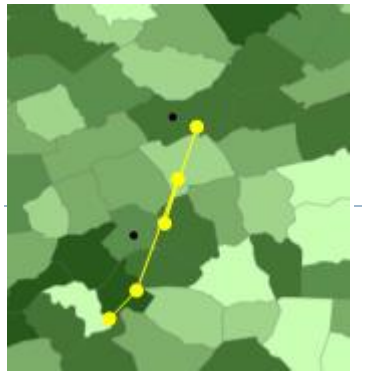


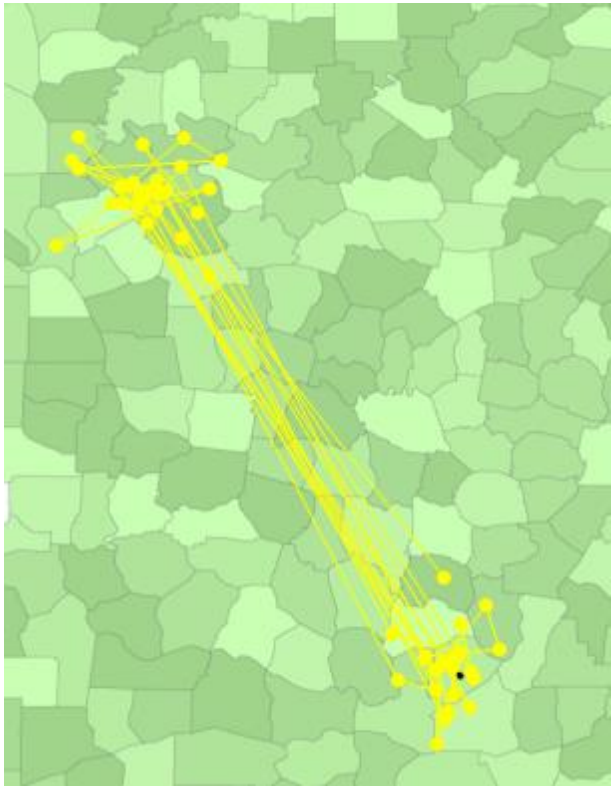
„Boring“ scanpath – participants only compared marked areas, they did not gaze on surrounding areas

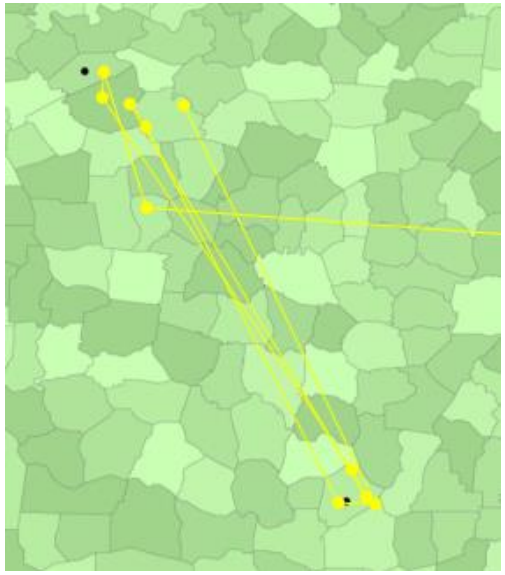


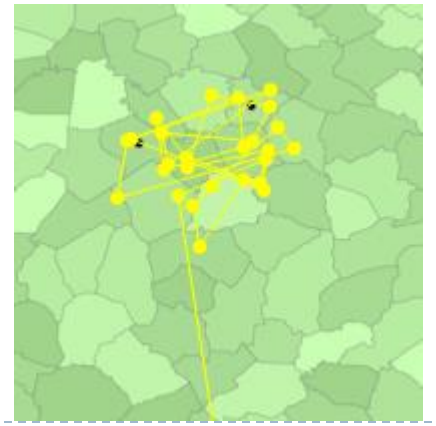
Low frequency eye-tracker + insufficient accuracy → cannot consider small AOI











Future plans

- More complex task → more interesting scanpath
- Bigger areas in the stimuli → relevant AOI
- Chin rest → higher accuracy of data

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Thank you for your attention…

…and saccades

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