Eye Movements in Map Comparison - Preliminary Results and Lessons Learned

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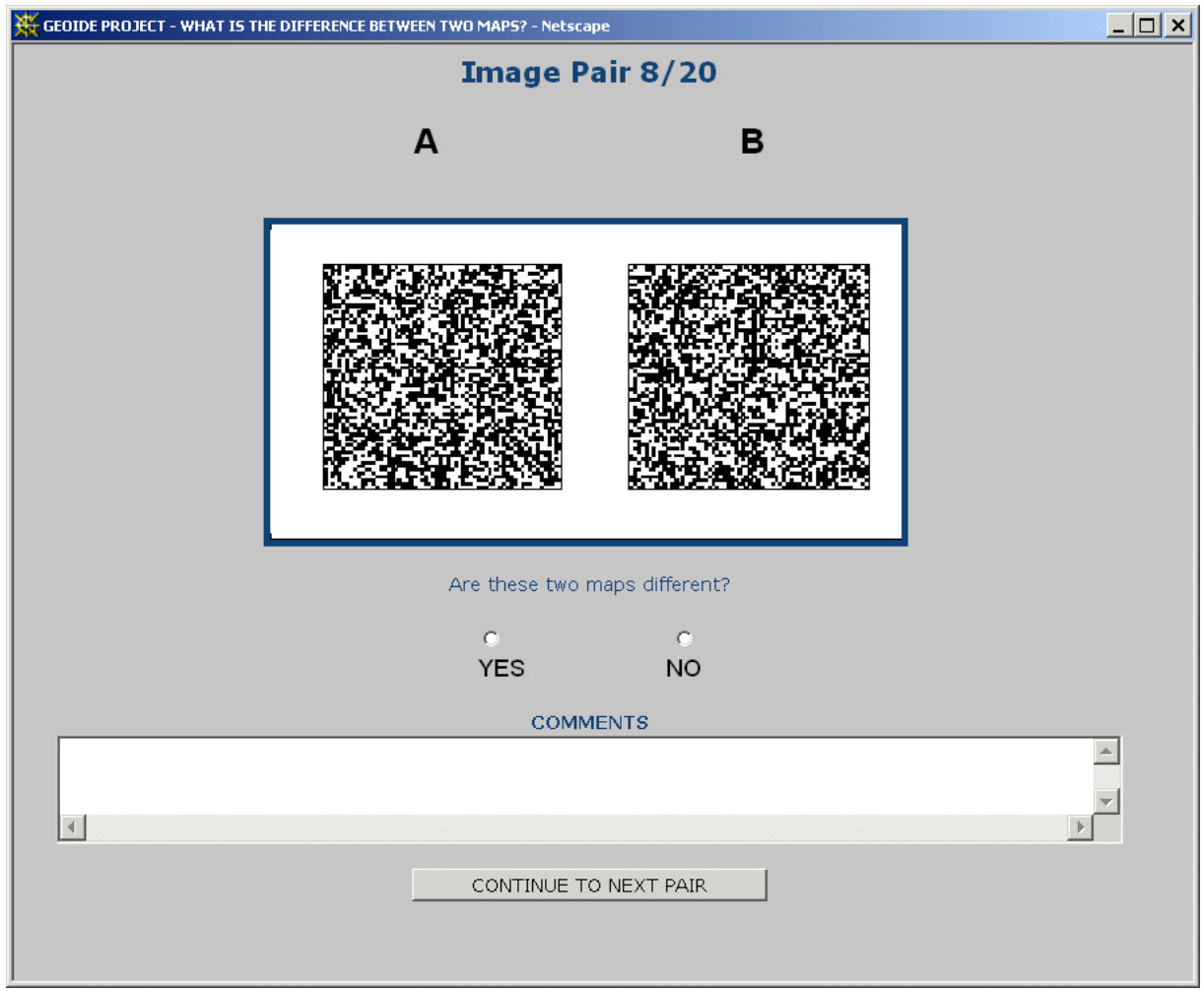
What is the difference between two maps? (Csillag & Boots, 2004)



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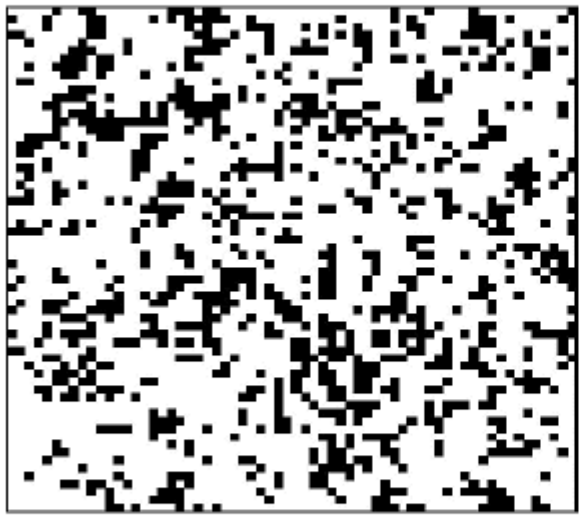
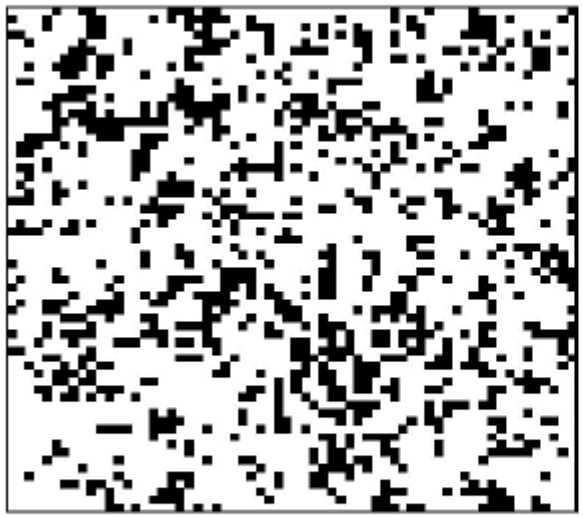


How do we compare two maps?



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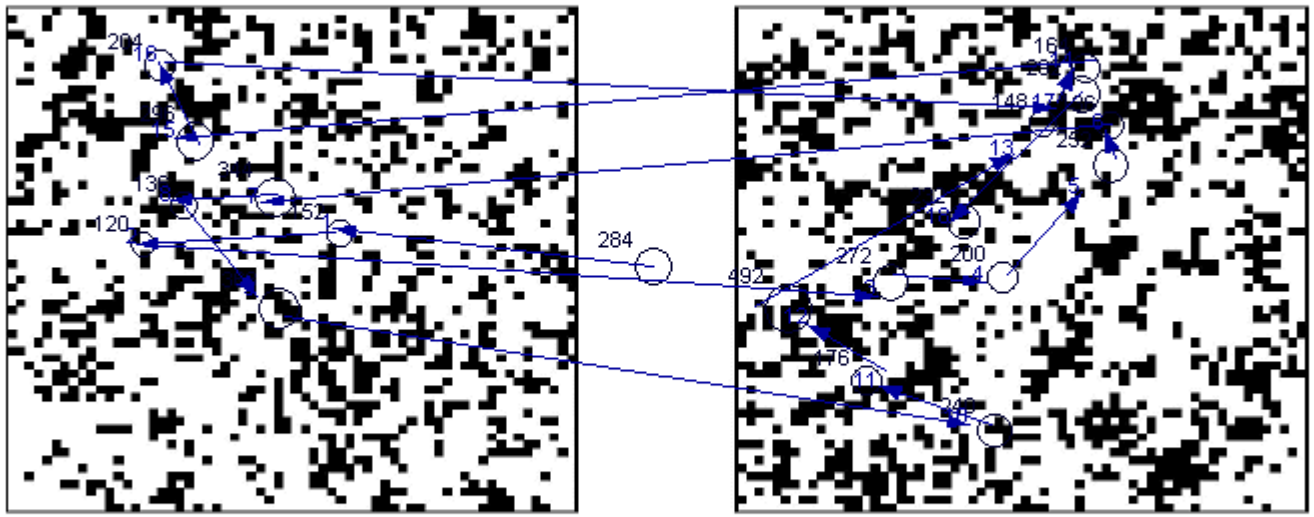
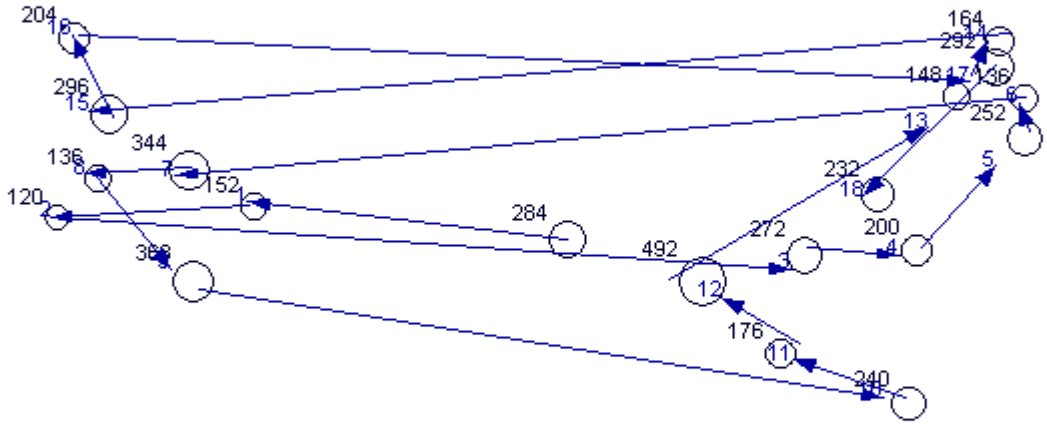


Eye movement recording to study map comparison strategies

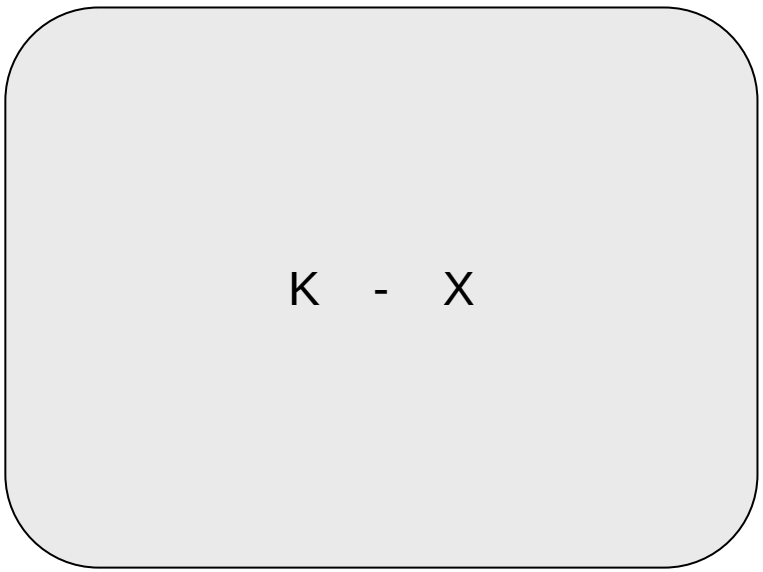


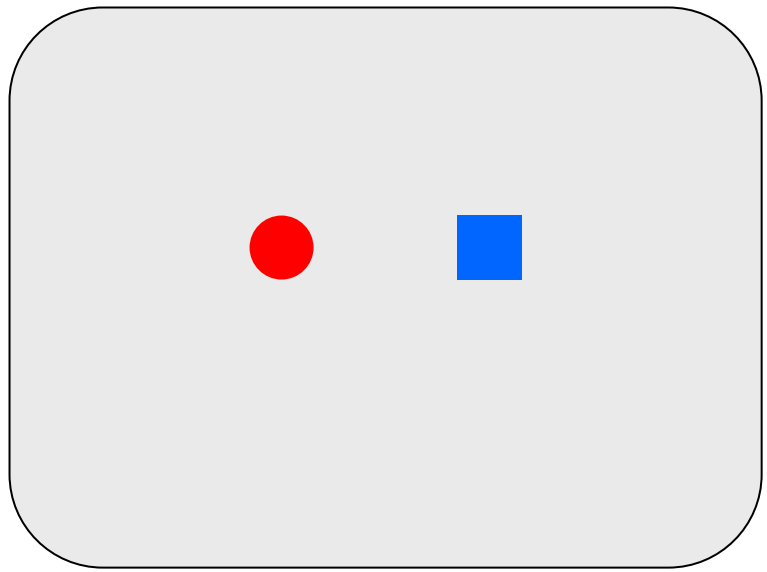
Outline

- Background
  - Visual comparison experiments in psychology
  - Eye movement recording in psychology
  - Map design for comparison of spatial patterns
  - Eye movement recording in cartography
- Methods
  - Participants
  - Experimental procedure
  - Eye tracking technology
- Results
  - by expertise
  - by map type
- Discussion & Outlook

Perceptual comparison/matching in psychology

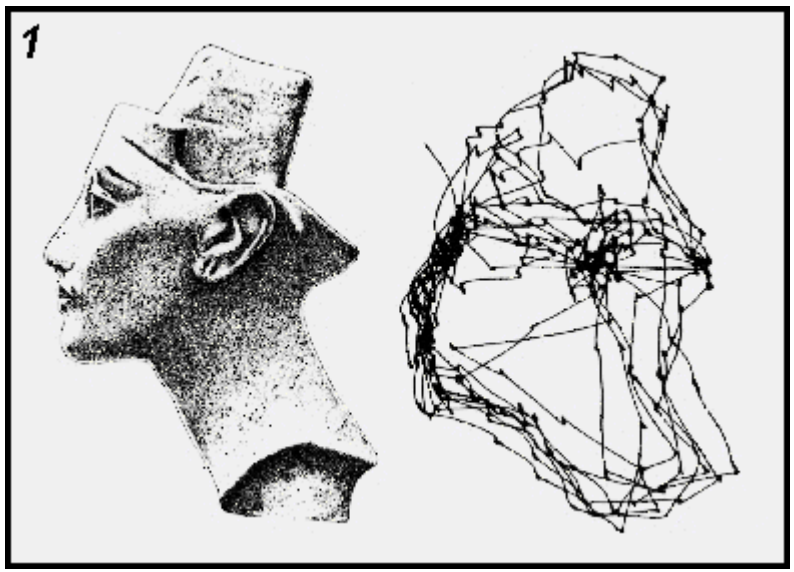
- „Same-different“-judgments
  - evaluated by response time and accuracy





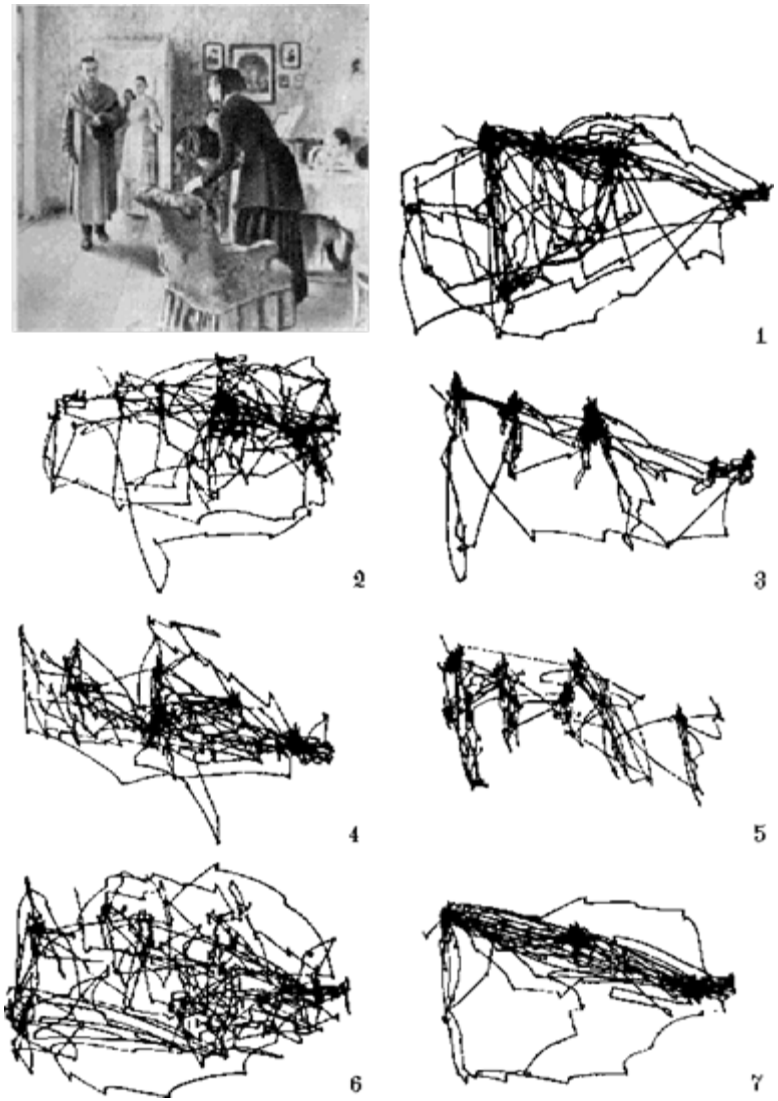
Eye tracking in psychological experiments (1/2)

- Eye movements reflect cognitive processing
  - Depending on task given to participants



(Yarbus, 1967:
free exploration.
From http://web.mit.edu/bcs/schillerlab/)

Eye tracking in psychological experiments (2/2)

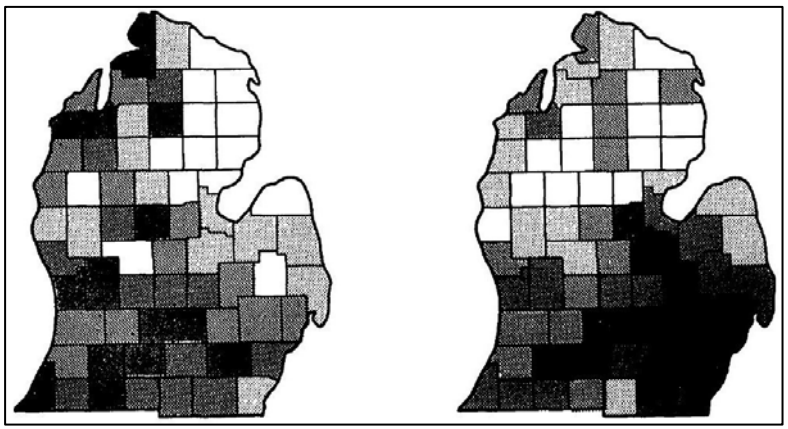


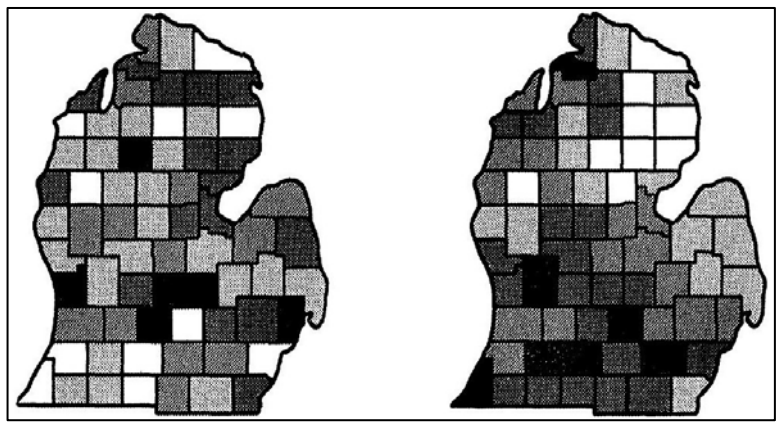
(Yarbus, 1967:
1. free exploration;
2. estimate wealth of the family;
3. estimate the ages of the people;
4. what did the family do before the arrival of the "unexpected visitor";
5. remember the clothes worn by the people;
6. remember the position of the people and objects in the room;
7. estimate how long the "unexpected visitor" had been away from the family.
From http://www.diku.dk/~panic/eyegaze)

Map design for comparison of spatial patterns (1/2)

- Lloyd & Steinke, 1976
  - Blackness level affects perceived correlation between choropleth maps

  => use equal-area classification





Map design for comparison of spatial patterns (2/2)

- Olson, 1972
  - Quantiles, mean-standard deviation, and nested-means classifications most effective in portraying attribute correlations
- Petersen, 1979; Muller, 1980
  - Perceived correlation independent from classified vs. unclassed choropleth maps
- Brewer & Pickle, 2002
  - Quantiles most effectively facilitate map comparison

Eye tracking in cartography (1/2)

- Jenks, 1973
  - Relative attention paid to different parts of a dot map => more "informative" regions

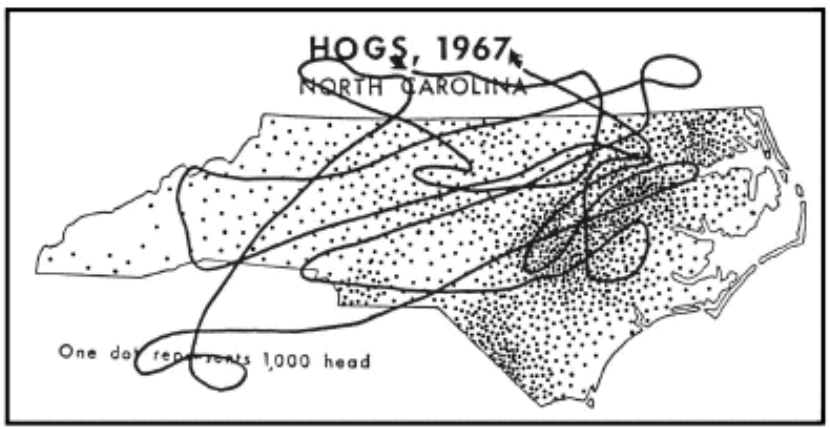


Figure 1. Hog map of North Carolina with overlaid scan path recorded from the eye movements of a person studying the map (Jenks 1973).

(Montello, 2002)

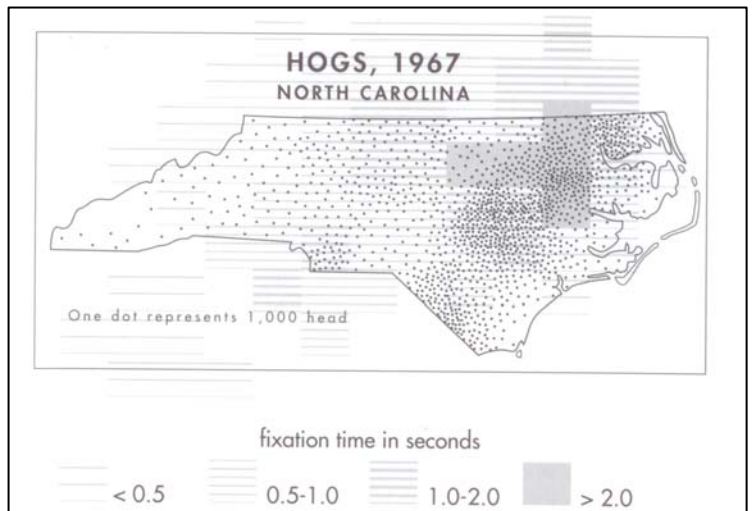


FIGURE 3.45. A map of attention to locations on a dot map. *Reproduced from Jenks (1973, Fig. 9, p. 34). Reprinted by permission of Universitätsverlag Ulm GmbH.*

(MacEachren, 1995)

Eye tracking in cartography (2/2)

- Phillips et al., 1978
  - Searching for names on maps
- Antes et al., 1985
  - Evaluating alternative map designs (layout, balance)
- Castner & Eastman, 1985
  - Influence of map complexity on map reading
- Chang et al., 1985
  - Relief map reading, grouped by expertise
- Brodersen et al., 2002
  - Improving topographic symbol design

Methods: Participants

- Pilot study
- 15 participants from two groups
- "Novices" (6 female, 2 male):
  - psychology students
  - age 18-21, median 20.5
  - self-rated expertise 2-7 (out of 10)
- "Experts" (4 female, 3 male):
  - geography and cartography staff and students
  - age 21-53, median 32
  - self-rated expertise 6-10 (out of 10)

Methods: Experimental procedure

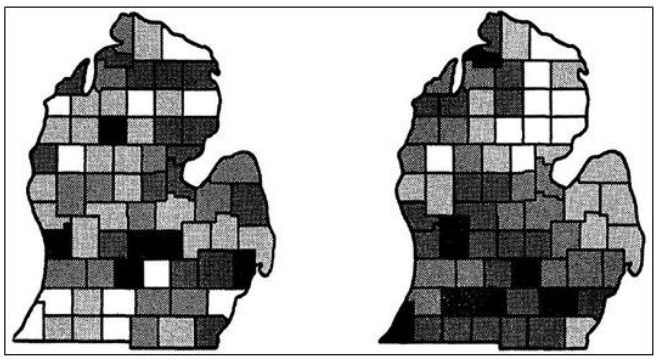
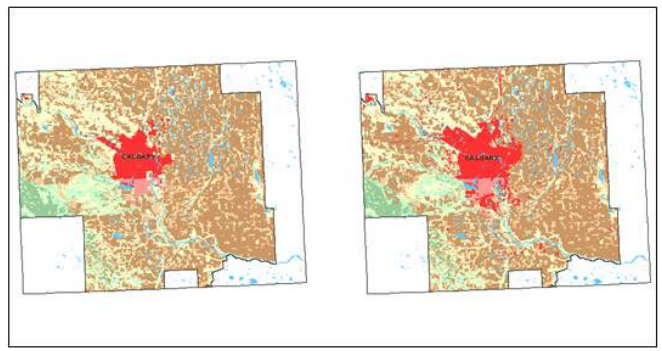
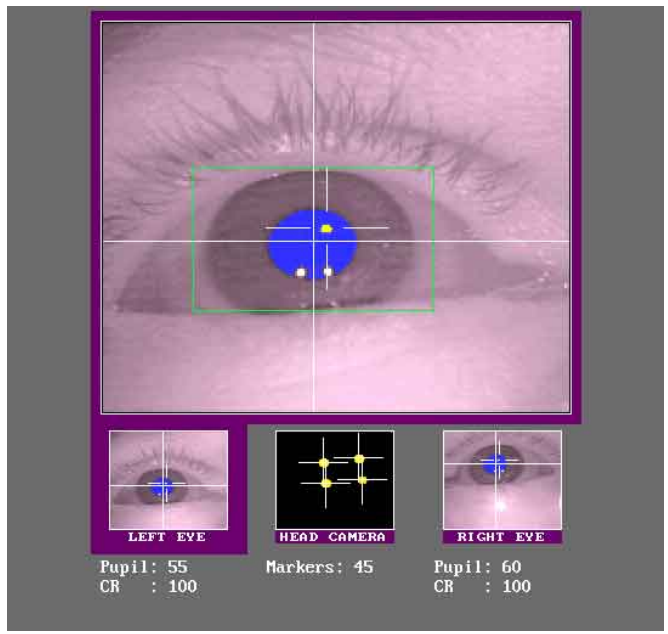
Test	Sample map pair and question asked
A	"Are these two maps similar?"
B	 "Are these two maps similar?"
C	 "Are these two maps different?"

Fig. 1. Types of stimuli and questions asked in tests A, B, C. Sources: A) Prof. F. Csillag; B) Lloyd & Steinke 1976; C) Canada Land Use Monitoring Program (CLUMP).

Methods: Eye tracking technology

- EyeLink II head-mounted binocular eye tracking device, 250/500 Hz sampling rate, resolution 0.025° of visual angle



Methods: Raw data

1344330	385.9	344.9	6216.0	366.7	326.6	6721.0	.		
1344332	386.0	344.8	6218.0	366.7	326.5	6722.0	.		
1344334	386.0	344.6	6219.0	366.7	326.5	6723.0	.		
1344336	386.0	344.6	6221.0	366.7	326.0	6728.0	.		
1344338	386.0	344.6	6222.0	366.7	325.4	6728.0	.		
1344340	386.0	344.4	6222.0	366.8	325.0	6728.0	.		
1344342	386.0	344.2	6222.0	366.9	325.0	6729.0	.		
1344344	386.1	344.1	6227.0	367.0	325.1	6729.0	.		
EFIX L	1344170	1344344	176	386.5	345.5	6165			
EFIX R	1344170	1344344	176	368.9	328.1	6664			
SSACC L	1344346								
SSACC R	1344346								
1344346	386.3	344.3	6227.0	367.2	325.2	6729.0	.		
1344348	388.5	344.5	6234.0	369.4	325.5	6742.0	.		
1344350	392.5	345.7	6240.0	373.9	326.6	6745.0	.		
1344352	399.4	346.3	6240.0	382.5	329.0	6748.0	.		
1344354	410.1	347.2	6244.0	393.9	333.2	6749.0	.		
1344356	424.1	348.3	6247.0	408.6	334.6	6751.0	.		
1344358	440.4	351.6	6264.0	425.8	341.6	6783.0	.		
1344360	457.7	353.9	6265.0	444.7	346.5	6800.0	.		
1344362	475.6	356.4	6290.0	463.8	350.9	6800.0	.		
1344364	495.3	358.9	6298.0	482.3	351.0	6813.0	.		
1344366	516.0	360.2	6318.0	501.5	352.3	6827.0	.		
1344368	536.2	360.7	6326.0	520.5	355.6	6839.0	.		
1344370	555.7	361.6	6328.0	539.6	356.9	6845.0	.		
1344372	576.5	362.3	6329.0	559.4	359.1	6851.0	.		
1344374	597.1	363.2	6330.0	578.8	363.4	6845.0	.		
1344376	618.4	363.7	6333.0	596.8	364.8	6845.0	.		
1344378	638.7	366.6	6333.0	614.6	372.0	6846.0	.		
1344380	659.0	369.3	6332.0	630.9	373.8	6845.0	.		
1344382	676.7	371.9	6332.0	646.0	377.6	6845.0	.		
1344384	693.2	373.7	6330.0	658.9	380.6	6843.0	.		
1344386	705.8	374.6	6320.0	668.8	383.3	6841.0	.		
1344388	716.6	374.8	6318.0	675.6	383.9	6838.0	.		
1344390	723.3	374.7	6318.0	680.5	383.5	6838.0	.		
1344392	725.0	374.6	6318.0	681.7	383.1	6840.0	.		
1344394	725.7	374.0	6318.0	682.2	382.8	6843.0	.		
1344396	725.6	371.4	6320.0	682.3	380.9	6845.0	.		
ESACC L	1344346	1344396	52	386.3	344.3	725.7	374.0	12.81	385
ESACC R	1344346	1344396	52	367.2	325.2	682.2	382.8	12.04	365
SFIX L	1344398								
SFIX R	1344398								
1344398	725.5	370.8	6322.0	682.1	379.1	6847.0	.		
1344400	723.5	370.6	6332.0	682.0	378.9	6851.0	.		
1344402	721.5	371.0	6335.0	681.7	378.7	6854.0	.		
1344404	720.4	371.3	6335.0	681.7	378.7	6856.0	.		
1344406	719.2	372.1	6335.0	681.7	378.6	6856.0	.		
1344408	719.1	373.0	6335.0	681.7	379.0	6857.0	.		

Methods: Parameters analyzed

- Response time (RT)
- Fixation count (FC)
- Fixation duration (FD)
- Proportion of saccades between maps
  - Averages per participant over 15-20 random-sequence trials

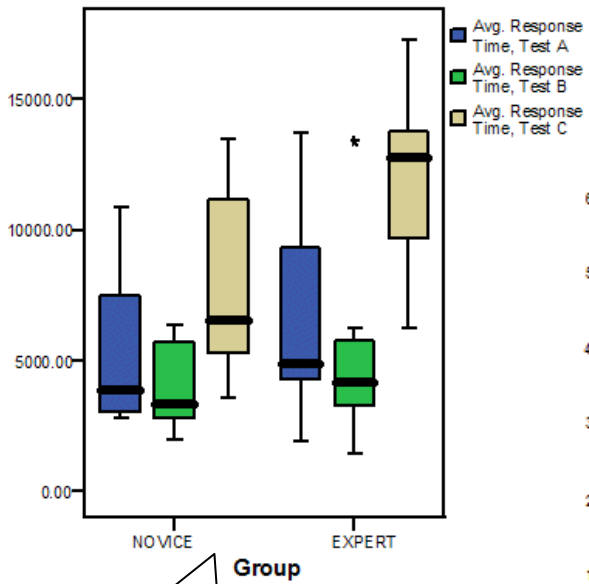
Results: Eye movements and expertise

- No significant differences between experts and novices in RT (table), FC*, FD

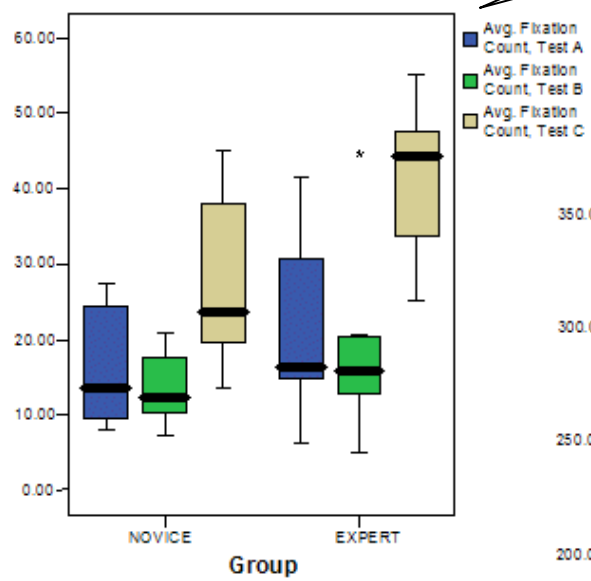
Group	Avg. Response Time, Test A	Avg. Response Time, Test B	Avg. Response Time, Test C
NOVICE	5322.11	4004.97	7884.09
Std. Dev.	*2976.05*	*3563.44*	*3640.76*
EXPERT	6807.47	5312.92	11882.90
Std. Dev.	*4233.57*	*3887.96*	*3622.73*
Total	6015.28	4615.35	9750.20
Std. Dev.	*3563.44*	*2891.39*	*4064.03*
Between groups significance (ANOVA)	.441	.402	.053

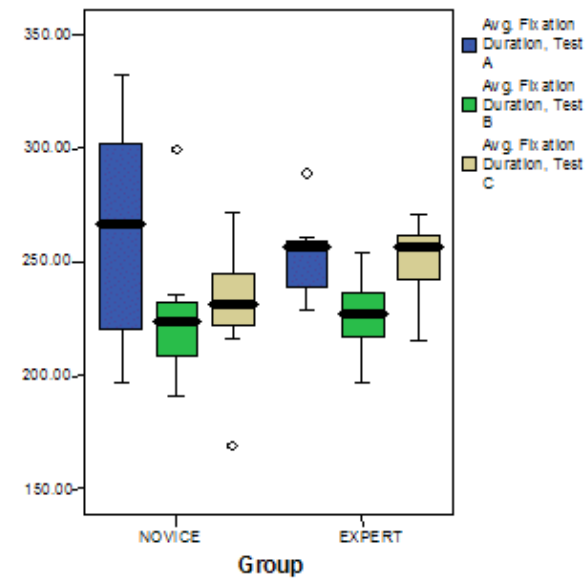
*except for Test C, land-use maps, where $FC_{expert} > FC_{novice}$

Results:
Eye movements and map type



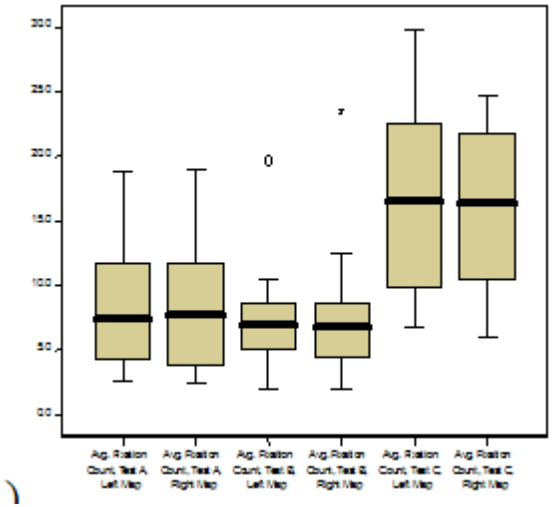
For both groups, $FC_C > FC_A > FC_B$

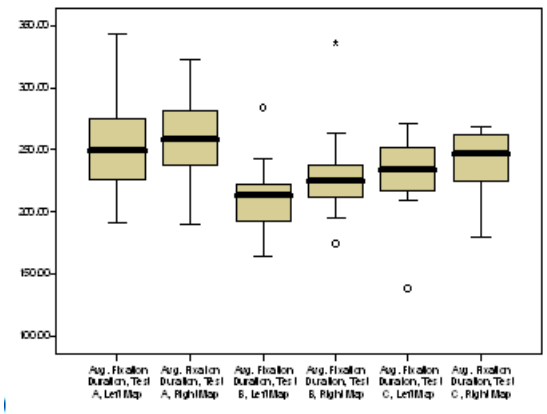


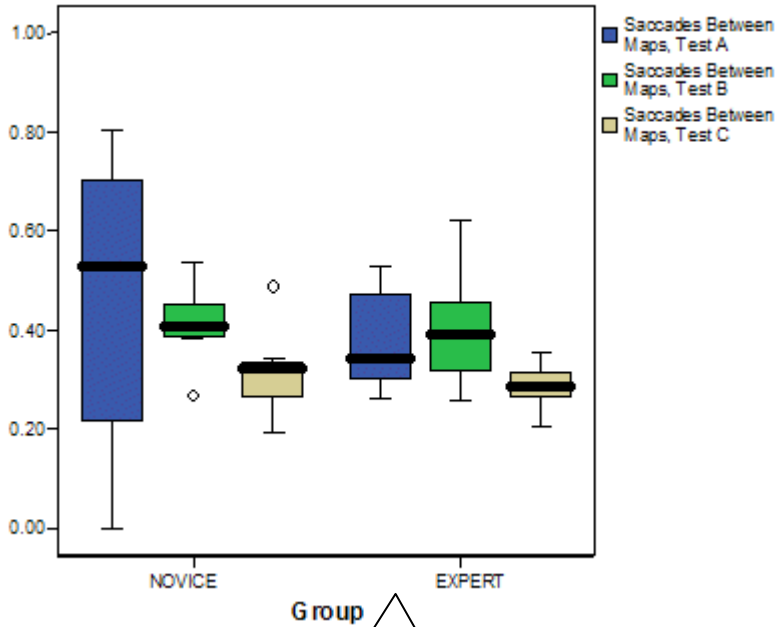


RT_C (land-use maps) > RT_A (random grids) > RT_B (county maps) for both groups

Results: Eye movements between maps







$FD_{B,left} < FD_{B,right}$ (county maps)
$FD_{C,left} < FD_{C,right}$ (land-use maps)

Fewer cross-saccades for land-use maps than county maps

Discussion (1/2)

- Different types of maps prompt different exploration approaches, or different level of accuracy
  - Land-use maps: more fixations = more difficult to compare
- Different comparison approaches based on proportion of cross-saccades
  - Random grids, county maps: unit-by-unit comparison
  - Land-use maps: pattern memorization

Discussion (2/2)

- Problems
  - Individual scan paths cannot be analyzed
    - No measure of similarity
  - Motivation of student participants?
    - Experts had more & longer fixations on last test
  - Land-use maps: Effects of non-randomized test sequence and change of question?
  - Random grids, county maps: What is the correct answer?

Conclusion & Outlook

- Develop tools for map comparison in GIS, with special features for different map types
- Eye tracking = useful method for map design, GIS user interface design

- For this experiment:
  - Remove outlier trials, participants
  - Create "heat maps" (highlighting most visited areas)
  - Analyze results by map similarity
  - Re-run tests in random sequence

Acknowledgements

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- Simona Mindy, Stephenie Harrison
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- Canada Foundation for Innovation (CFI)

Thank you

- Questions?
- Comments?

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