Evaluating different Cartographic Design Variants for visually communicating Route Efficiency

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Motivation

- Increasing traffic volume leads to consequences like congestion, air pollution, noise and accidents (negative effects on the environment)
- Important to develop effective approaches for better distributing the road traffic
  - Avoid heavily affected areas and thus protect citizens and environment
- Many route decisions are made based on maps provided by routing applications
- But: Drivers tend to prefer individually beneficial or familiar routes [2]

Research Idea:

- Nudge users towards a less selfish decision in favor of the environment
- Cartographic visualization helps communicating routes and traffic situations more intuitively
- Test effectiveness of different cartographic methods for visually communicating route efficiency
Influencing driver’s route choice

► Transportation planning perspective [1, 7]
  ▪ Traveler information systems (variable message signs)
  ▪ Algorithms for efficiently distributing drivers (limit number of vehicles that pass along road)

► Our approach: Visually communicating route efficiency based on digital, cartographic representations
  ▪ Users evaluate the traffic situation themselves
Current Routing Services - Visualization

Directions from "HERE Maps": wego.here.com
Visual variables in cartography

<table>
<thead>
<tr>
<th>Points</th>
<th>Lines</th>
<th>Areas</th>
<th>Best to show</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shape</strong></td>
<td>possible, but too weird to show</td>
<td>cartogram</td>
<td>qualitative differences</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td></td>
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</tr>
<tr>
<td><strong>Color Hue</strong></td>
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<tr>
<td><strong>Color Value</strong></td>
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<tr>
<td><strong>Color Intensity</strong></td>
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<tr>
<td><strong>Texture</strong></td>
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</tbody>
</table>

Visual variables according to Bertin [6]
User study
Objective and Hypotheses

► Test suitability of different cartographic design variants for communicating route efficiency in terms of traffic density
  ▪ Focus on potential for influencing route choice behavior

► Recommend a longer, but temporarily less congested route to the map-reader
  ▪ Contributes best to a more even distribution of traffic -> benefits the whole traffic system

► Communication of route efficiency using cartographic design variants is expected to affect route choice behavior

► Different design variants contribute to a varying extent to the map-reader’s ability to assess a traffic situation and the efficiency of route options.

► Map-reader is expected to intuitively choose the route that is visually communicated as most efficient
Study design

► Within-subject design

► Measure participants’ route choices

► 18 routing scenarios within 18 different German cities of comparable size

► For each routing scenario one map without any modification (→ 18 baseline maps)

► 18 modified maps for the same routing scenarios
  ▪ 6 design variants (color hue, distortion, length distortion, spacing, size and symbols)
  ▪ 3 levels of intensity for modification (weak, medium, strong)
  ▪ Each design variant represented once using each level of intensity

→ 36 maps (conditions) in total
Baseline maps vs. Modified maps

Baseline map

Modified map using symbols
Design variants of visual variables

- **Color hue**
- **Size**
- **Length distortion**
- **Distortion**
- **Spacing**
- **Symbols**
## Visual metaphors

<table>
<thead>
<tr>
<th>Design variant</th>
<th>Visual metaphor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low traffic density</strong></td>
<td><strong>High traffic density</strong></td>
</tr>
<tr>
<td>color hue</td>
<td>Green color hue</td>
</tr>
<tr>
<td>spacing</td>
<td>Short gaps between dashes</td>
</tr>
<tr>
<td>size</td>
<td>Wide line (much capacity)</td>
</tr>
<tr>
<td>symbols</td>
<td>Small amount (car symbols)</td>
</tr>
<tr>
<td>length distortion</td>
<td>Visually shorter route</td>
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<tr>
<td>distortion</td>
<td>Simplified line</td>
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</tbody>
</table>
Calculation of graphical differences

\[
\begin{align*}
    r &= \frac{\text{dens}(s)}{\varnothing\text{dens}(s)} \\
    s &= \text{road segment} \\
    \text{dens}(s) &= \text{observed traffic density} \\
    \varnothing\text{dens}(s) &= \text{average traffic density}
\end{align*}
\]

High Traffic Density = inefficient

Low Traffic Density = efficient

\[
r < 1
\]

\[
r > 1
\]
Levels of intensity for modification

- **a) weak**
  - Subtle use of visual variables
  - Visualized differences in traffic density reduced

- **b) medium**
  - Based on original traffic density distribution

- **c) strong**
  - Distinct use of visual variables
  - Visualized differences increased
Participants

- 151 participants (80 females, 70 males, 1 diverse; $M = 26.20$, $SD = 6.49$)
- Online experiment
- German residents
- 91.1% own a driver’s license, but the majority of the participants (35.8%) drive less than once a week
Procedure

Task 1

- Participant made a route choice decision for each map right after shortly observing it.

- For the decision between route A and B, we used a slider, providing five steps:
  1) Definitely A, 2) Rather A, 3) No preference, 4) Rather B, and 5) Definitely B.
Procedure

Task 2

- Presented the baseline and modified visualizations for the same city side by side
  - “How did the relation between the routes change?”

- Assign characteristics to the visually recommended route
  - faster, more direct, shorter, more comfortable to drive, more fluent to drive or none of this
Results
## Route choice

<table>
<thead>
<tr>
<th>Design variant</th>
<th>Intensity</th>
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<tbody>
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<td>medium</td>
<td>strong</td>
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<td>z</td>
<td>p</td>
<td>r</td>
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<td></td>
<td>2.03</td>
<td>2.97</td>
<td>-7.4</td>
<td>.0*</td>
<td>.43</td>
<td>2.6</td>
<td>3.11</td>
<td>-4.22</td>
<td>.0*</td>
<td>.24</td>
<td>2.16</td>
<td>2.91</td>
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<td><strong>distortion</strong></td>
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<td>3.87</td>
<td>4.03</td>
<td>-1.96</td>
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<td>-9.71</td>
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<td>-4.96</td>
<td>.0*</td>
<td>.29</td>
<td>2.6</td>
<td>3.62</td>
<td>-7.05</td>
<td>.0*</td>
<td>.41</td>
<td>2.59</td>
<td>4.11</td>
</tr>
</tbody>
</table>

**small effect**  $0.1 \leq r < 0.3$  **medium effect**  $0.3 \leq r < 0.5$  **large effect**  $r \geq 0.5$
Route choice

Willingness to decide for the *recommended* route in modified visualizations, $n = 151$. Higher difference value = higher willingness.
Decision Time

Time for route decision

Difference

-3 -2 -1 0 1 2 3 4 5

-3 -2 -1 0 1 2 3

color hue  distortion  length distortion  spacing  size  symbols

weak  medium  strong
# Route Characteristics

## Evaluation of route characteristics by the participants in percent

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Faster</th>
<th>More direct</th>
<th>Shorter</th>
<th>More convenient</th>
<th>More fluent</th>
<th>None</th>
<th>Other characteristic</th>
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<tbody>
<tr>
<td>Color</td>
<td>48</td>
<td>5</td>
<td>4</td>
<td>28</td>
<td>40</td>
<td>28</td>
<td>15</td>
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<tr>
<td>Distortion</td>
<td>40</td>
<td>38</td>
<td>17</td>
<td>57</td>
<td>42</td>
<td>12</td>
<td>8</td>
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<tr>
<td>Length distortion</td>
<td>27</td>
<td>50</td>
<td>54</td>
<td>17</td>
<td>11</td>
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<td>3</td>
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<tr>
<td>Line style</td>
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<td>2</td>
<td>25</td>
<td>40</td>
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<td>10</td>
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<tr>
<td>Line width</td>
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<td>6</td>
<td>1</td>
<td>16</td>
<td>18</td>
<td>60</td>
<td>15</td>
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<tr>
<td>Symbols</td>
<td>60</td>
<td>3</td>
<td>4</td>
<td>42</td>
<td>65</td>
<td>19</td>
<td>9</td>
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</tbody>
</table>

Relations: Route choice * Route characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>color hue</th>
<th>distortion</th>
<th>length distortion</th>
<th>spacing</th>
<th>size</th>
<th>symbols</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>36.6</td>
<td>1.8</td>
<td>5.8</td>
<td>18.9</td>
<td>26.7</td>
<td>26.1</td>
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<td>6.0</td>
<td>7.9</td>
<td>9.6</td>
<td>15.2</td>
<td>12.3</td>
<td>35.1</td>
</tr>
<tr>
<td></td>
<td>2.8</td>
<td>4.4</td>
<td>1.2</td>
<td>4.9</td>
<td>0.9</td>
<td>2.0</td>
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<td>11.1</td>
<td>2.0</td>
<td>1.0</td>
<td>9.8</td>
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<td>28.3</td>
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<td>6.7</td>
<td>15.7</td>
<td>26.2</td>
<td>24.6</td>
</tr>
</tbody>
</table>

Pearson chi-square
Discussion: Effectiveness for influencing route choice

- Significantly different influence of visual variables on route choice – depending on the level of intensity for modification

- Variables *length distortion* or using *symbols* seem to be generally efficient for communicating route efficiency

- Unusual findings for variable *color hue*

- Variables *size* and *spacing* less effective for influencing route choice
  - Incorrect decoding of visual metaphors – used visualization less intuitive
  - Ambiguous interpretation

- Route choice may also depend on additional characteristics of the environment
  - Spatial features close to the route
  - Structure of the route
Discussion: Transferability to Real World Applications

- Visual variables that have been found influential, might be suitable for implementation in a real-world routing service.
- Modified visualizations shown as allocentric representations in situations where a route decision has to be made.
- Active route decisions are primarily made based on allocentric maps.
Next steps

► Extend the approach to using dynamic representations, e.g. animations for clarifying the spatio-temporal changes in route efficiency [3, 5]

► Investigate usefulness of additional efficiency information in form of labels (e.g. expected travel time) or audio information for influencing route choice

► Customize this approach to different environmentally relevant scenarios (e.g. reducing air pollution)

► Integrate approach into a routing service application

► Perform further user studies with a focus on the acceptability and intuitiveness of visual representations [4]

► Provide representative collection of suitable visualization methods for recommending route efficiency in different scenarios
Summary

► Evaluated six different visual variables regarding their effectiveness for influencing route choice

► Our method visualizes route efficiency exemplarily based on the variations in traffic density associated with road segments

► For most of the tested routing scenarios, participants’ route choice has been significantly influenced towards choosing a longer, but temporarily more efficient route

► The willingness to decide for the recommended route increased with a higher intensity of modification

► Possible to influence a map-reader’s route choice towards a temporarily efficient route – using visual variables for communicating route efficiency
References


Thanks a lot for your attention!

For further questions, comments or ideas on my topic, please feel free to contact me!

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