Institute of Cartography and Geoinformatics | Leibniz University Hannover

Evaluating different Cartographic Design Variants for visually communicating Route Efficiency

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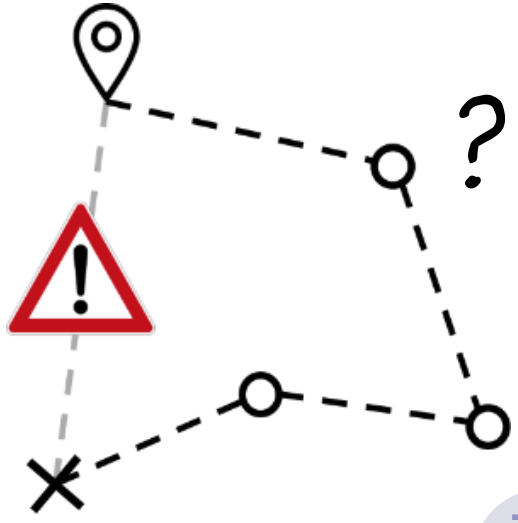
Motivation

- 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

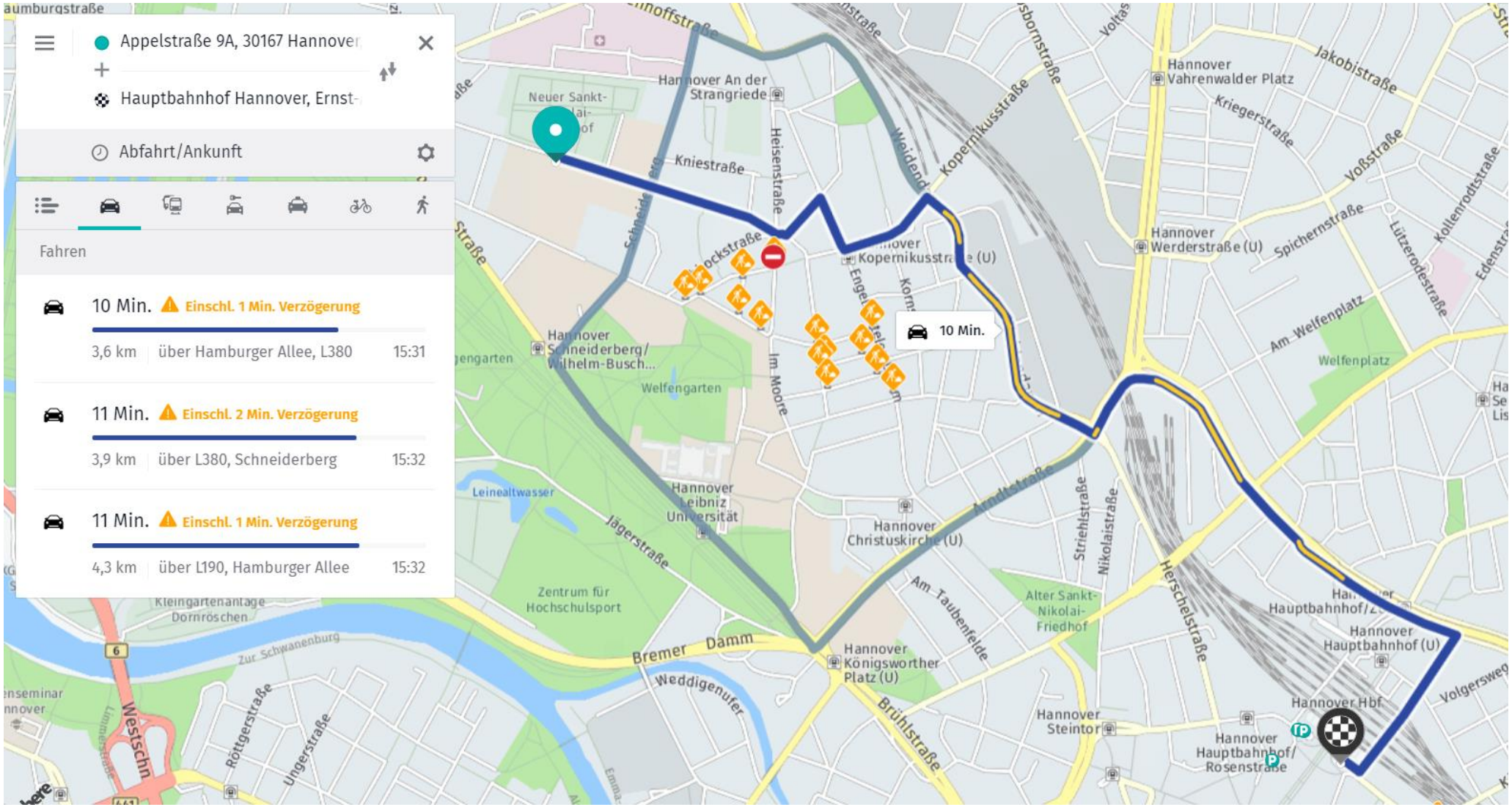


Influencing driver‘s route choice

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

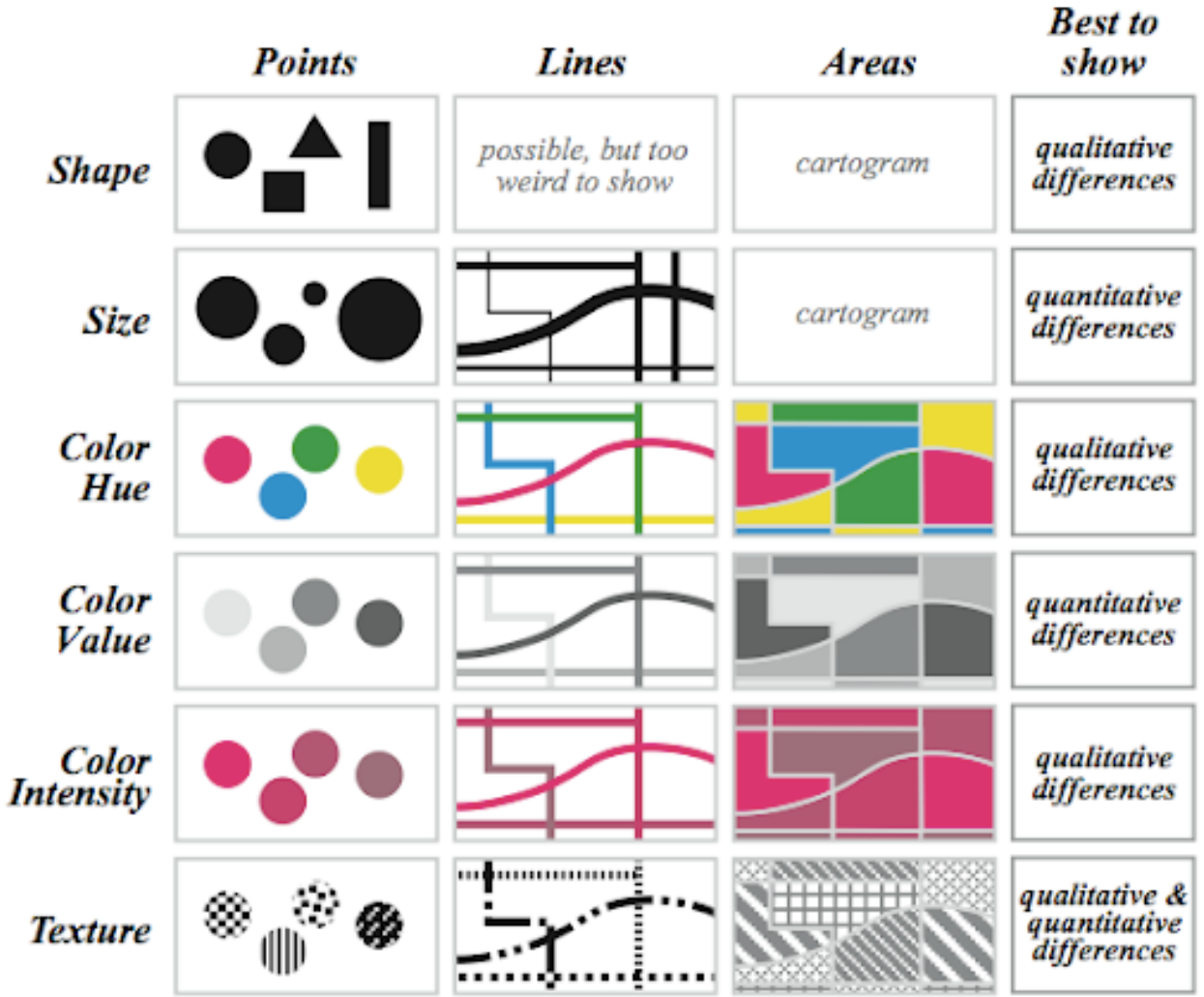
- Our approach: Visually communicating route efficiency based on digital, cartographic representations
  - Users evaluate the traffic situation themselves

Current Routing Services - Visualization



Directions from “HERE Maps”: wego.here.com

Visual variables in cartography



Visual variables according to Bertin [6]

User study

Objective and Hypotheses

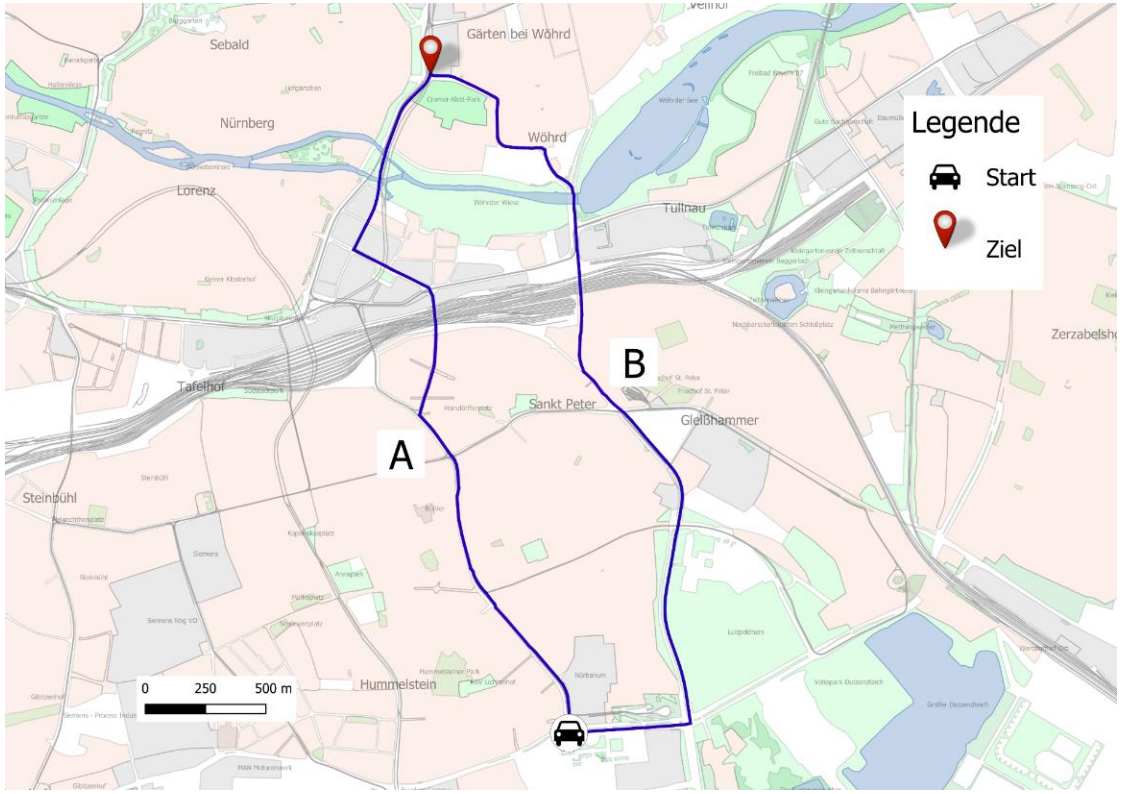
- Test suitability of different cartographic design variants for communicating route efficiency in terms of traffic density
  - Focus on potential for influencing route choice behavior
- Recommend a longer, but temporarily less congested route to the map-reader
  - Contributes best to a more even distribution 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

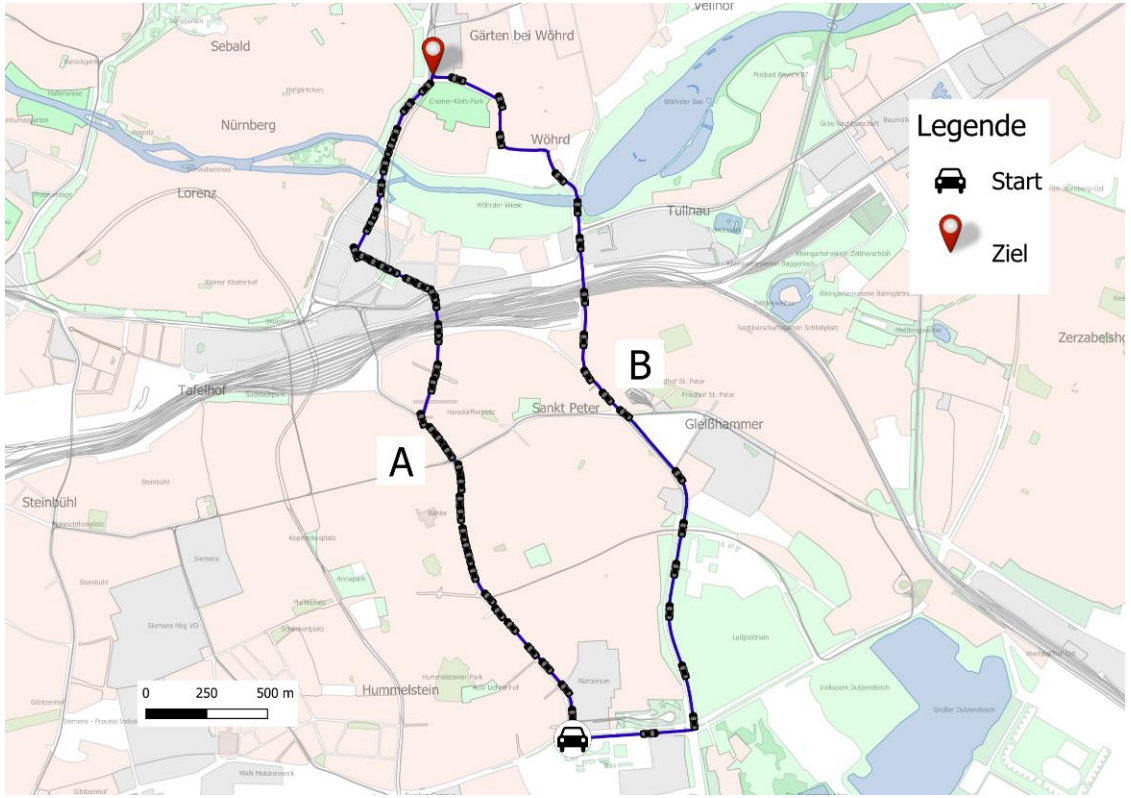
- Within-subject design
- Measure participants‘ route choices
- 18 routing scenarios within 18 different German cities of comparable size
- For each routing scenario one map without any modification (-> 18 *baseline* maps)
- 18 *modified* maps for the same routing scenarios
  - 6 design variants (color 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

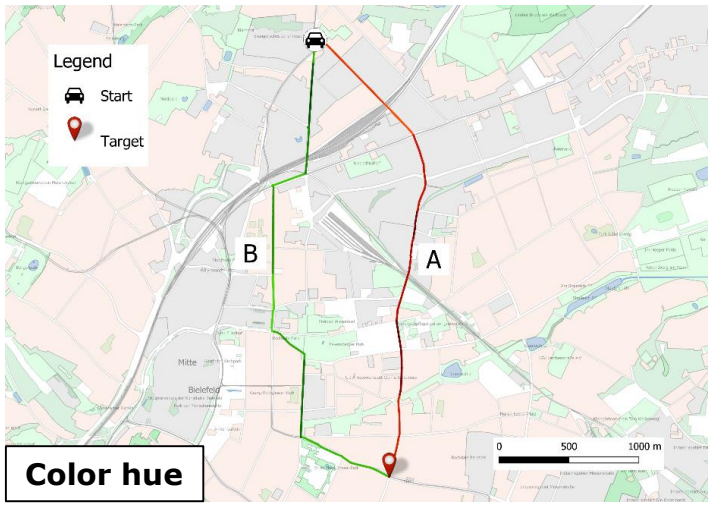


Baseline map

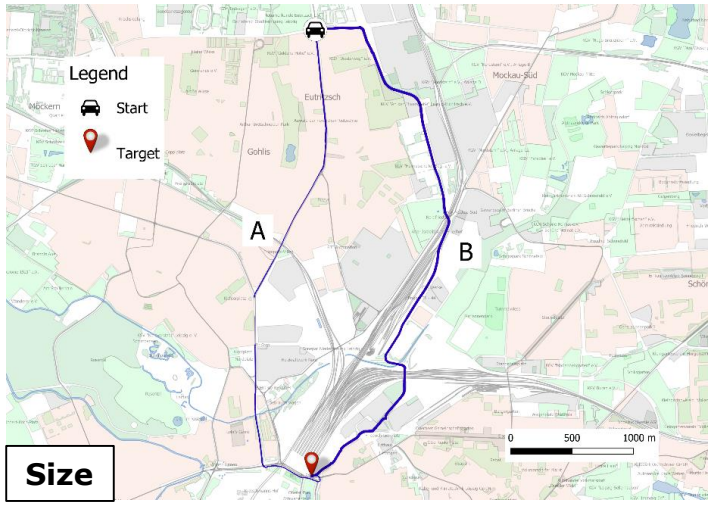


Modified map using *symbols*

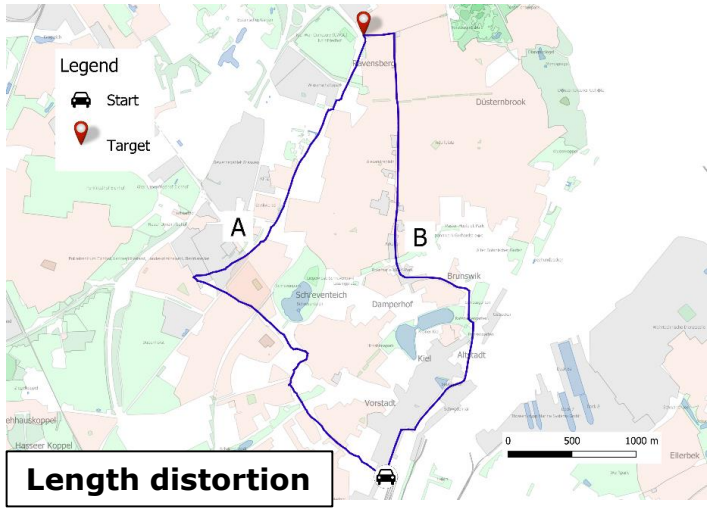
Design variants of visual variables



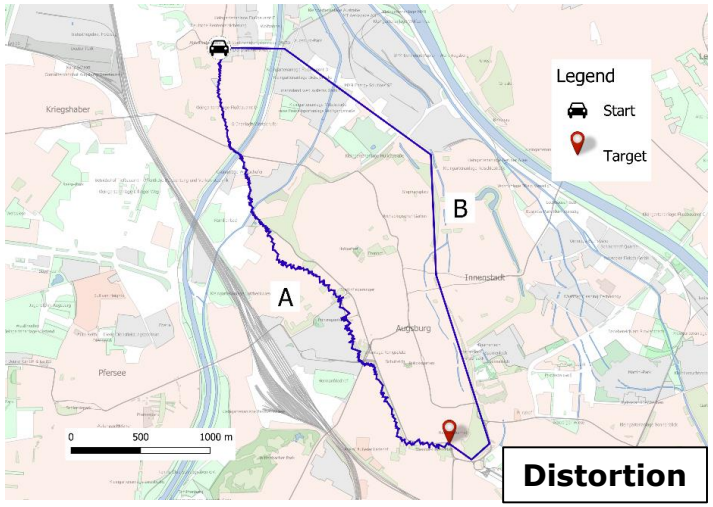
Color hue



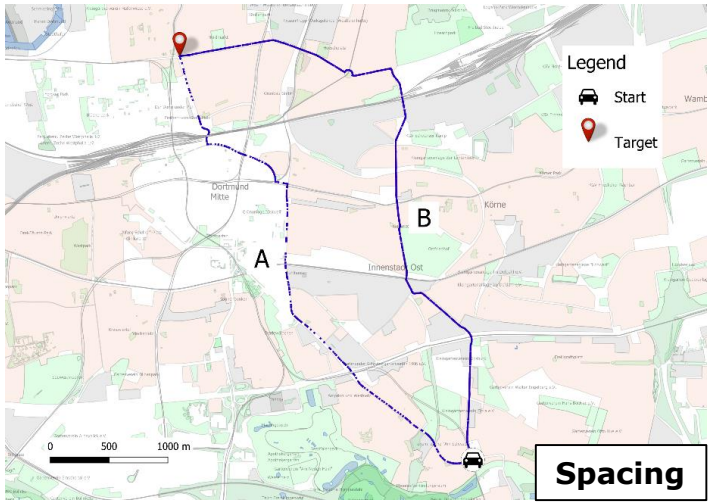
Size



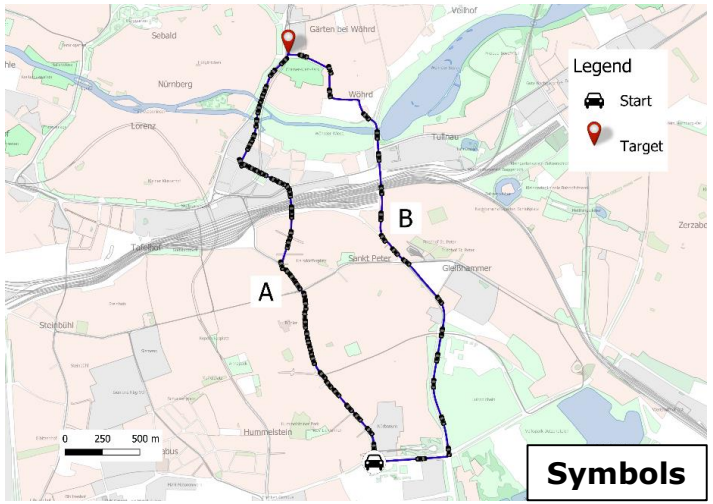
Length distortion



Distortion



Spacing

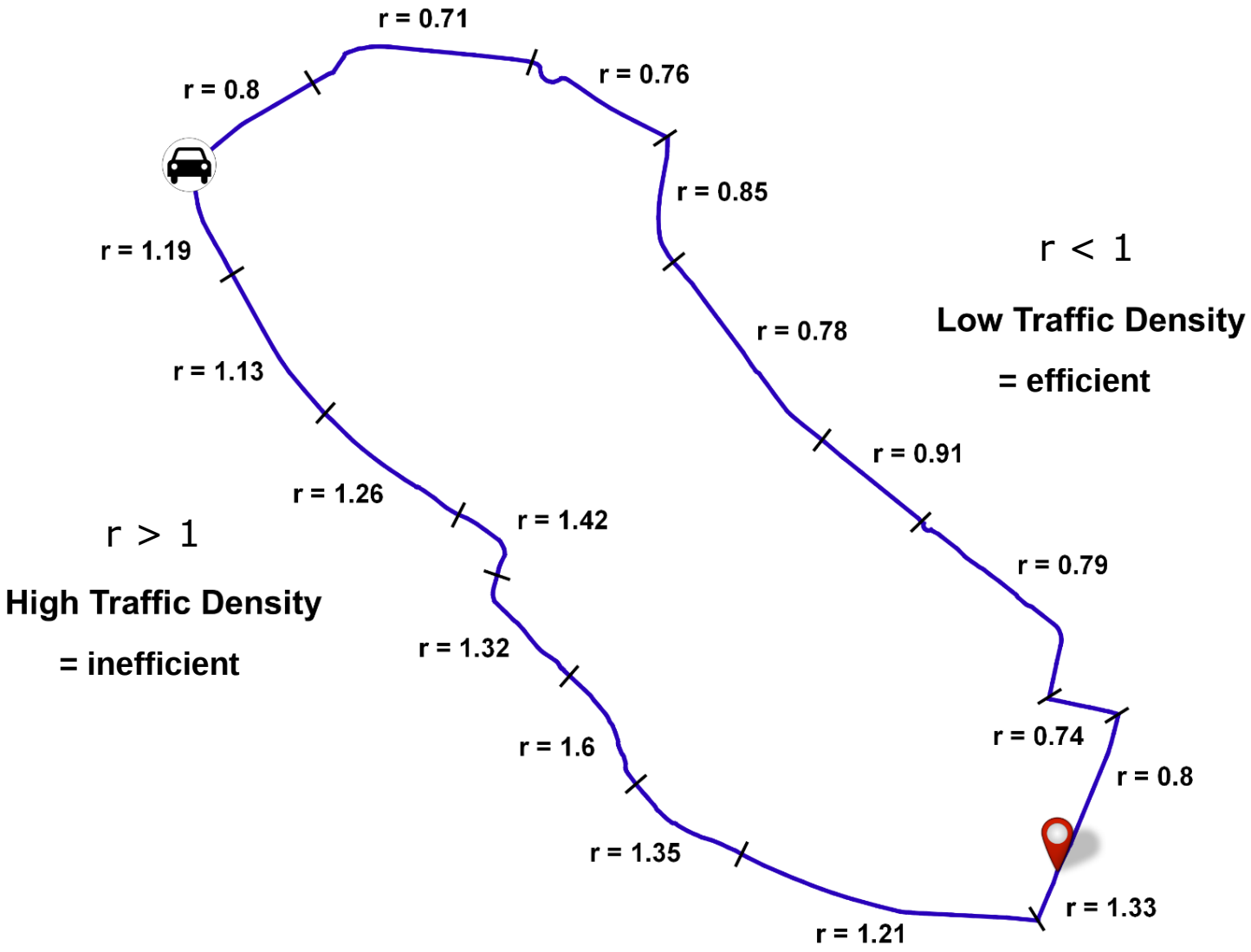


Symbols

Visual metaphors

Design variant	Visual metaphor	
	Low traffic density	High traffic density
color hue	Green color hue	Red color hue
spacing	Short gaps between dashes	Long gaps between dashes
size	Wide line (much capacity)	Narrow line (few capacity)
symbols	Small amount (car symbols)	Large amount (car symbols)
length distortion	Visually shorter route	Visually longer route
distortion	Simplified line	More complex (distorted) line

Calculation of graphical differences



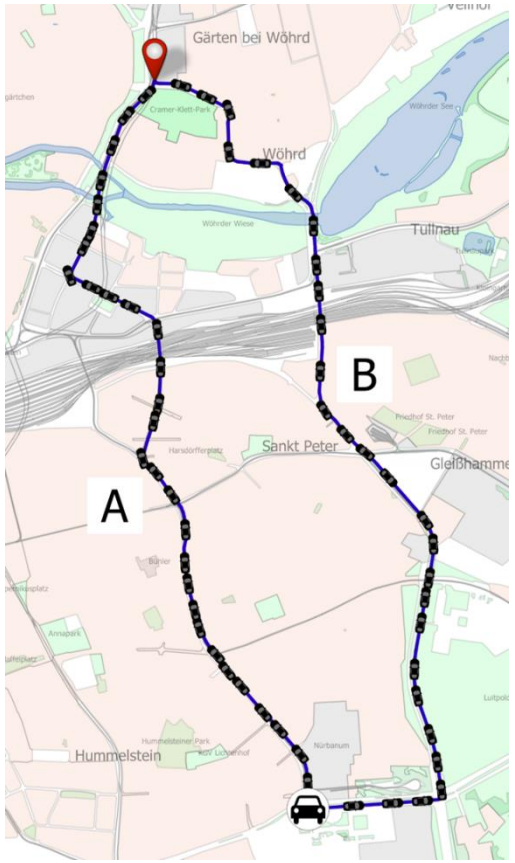
$$r = \frac{dens\ (s)}{ø\ dens\ (s)}$$

s = road segment

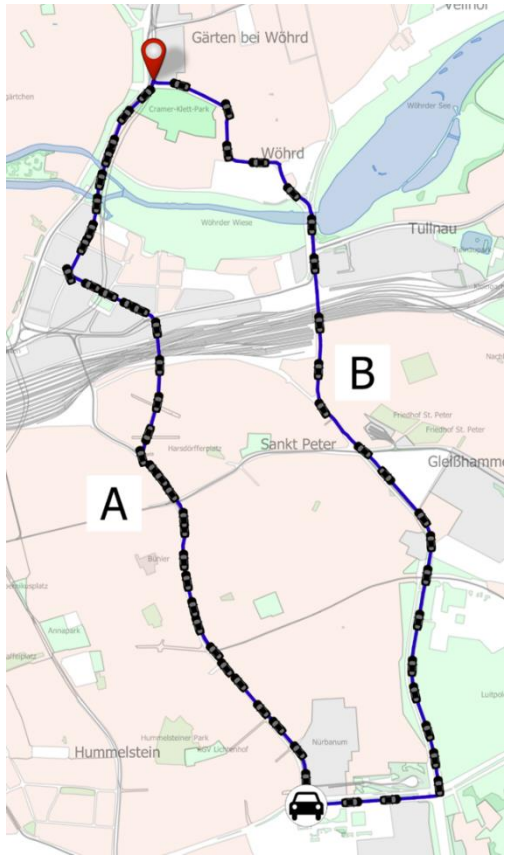
$dens\ (s)$ = observed traffic density

$ø\ dens\ (s)$ = average traffic density

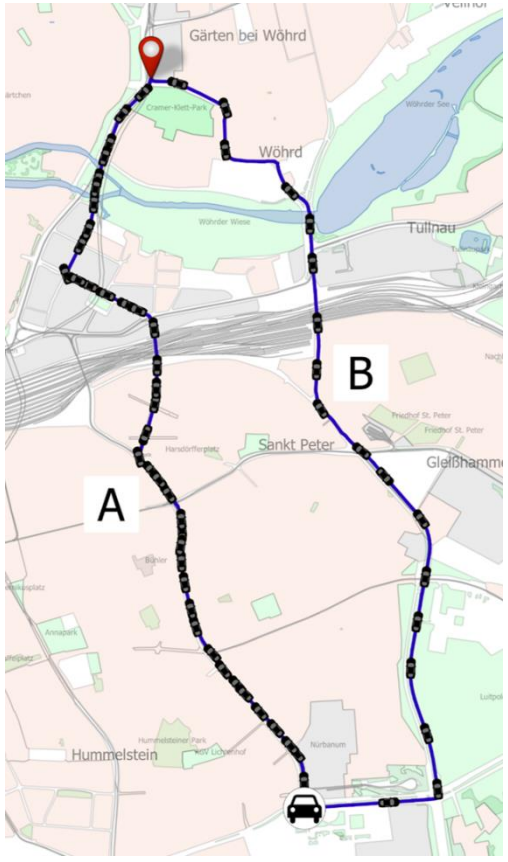
Levels of intensity for modification



a) weak



b) medium



c) strong

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

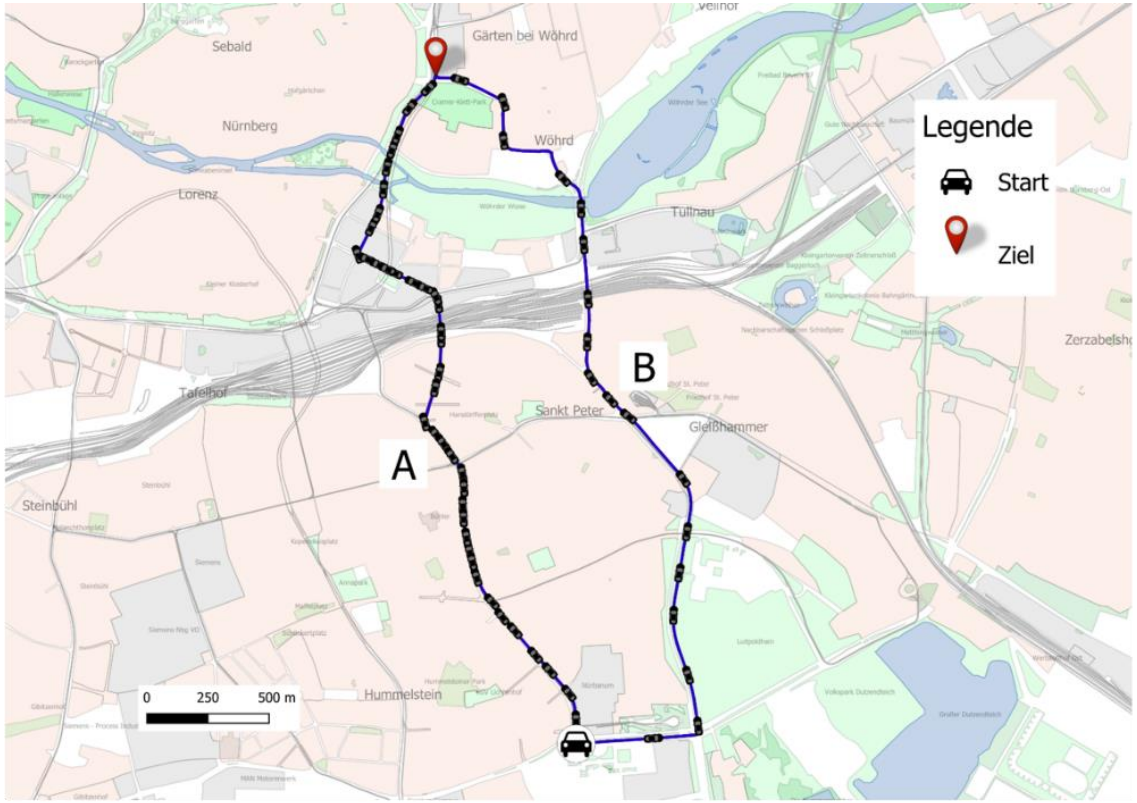
Participants

- 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

Task1

- 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*



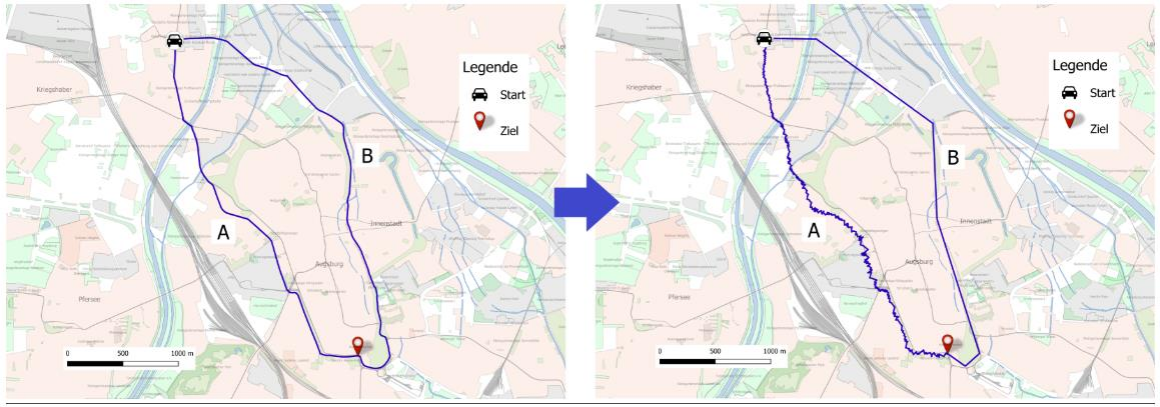
Which route would you prefer to drive?

Definitely A | Rather A | No preference | Rather B | Definitely B

Procedure

Task2

- 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*



Die Route B wirkt nun...
(Mehrfachnennungen möglich)

- ☐ schneller
- ☐ direkter
- ☐ kürzer
- ☐ angenehmer zu fahren
- ☐ flüssiger zu fahren
- ☐ nichts davon
- ☐

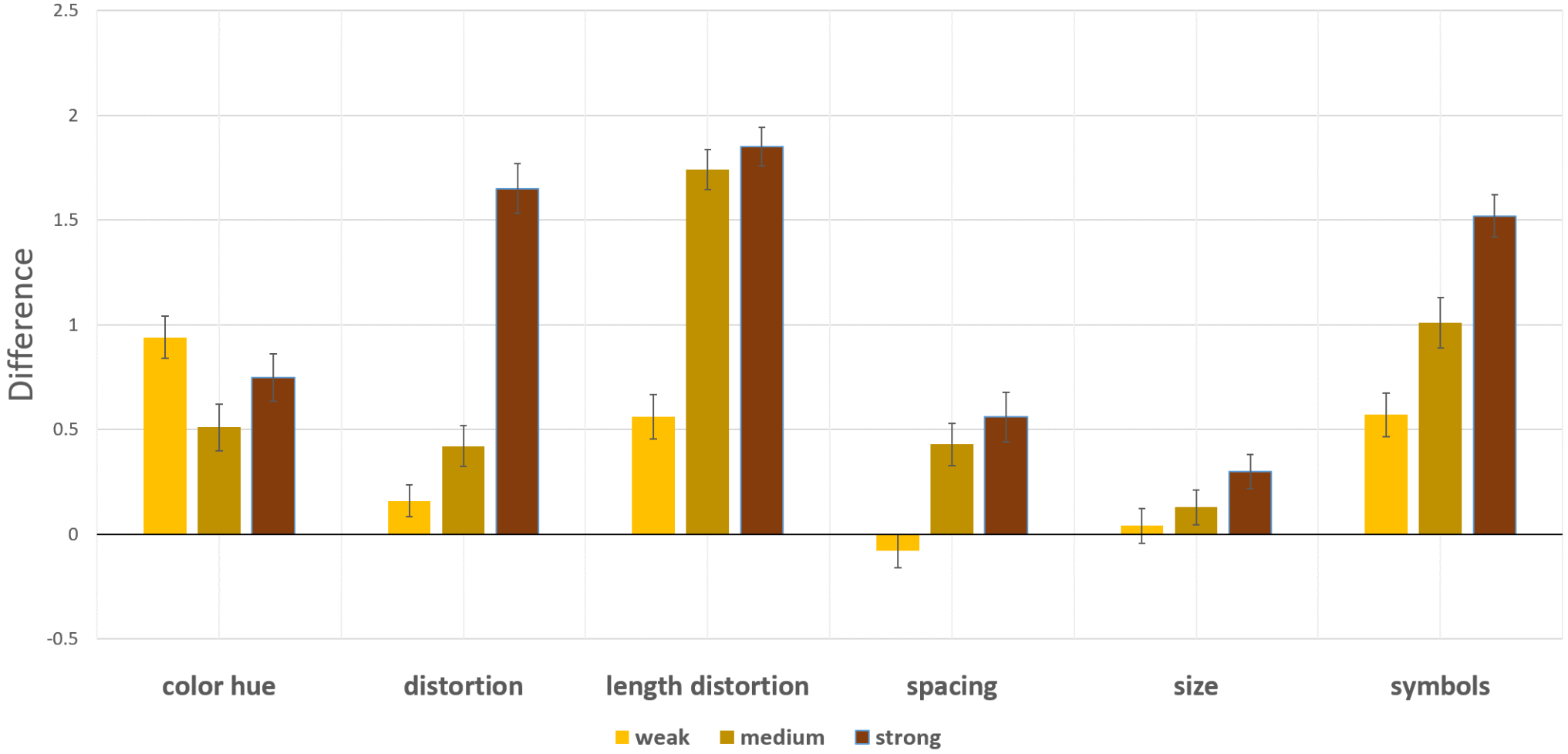
Results

Route choice

Design variant	Intensity														
	weak					medium					strong				
	base.	***mod.***	***z***	***p***	***r***	***base.***	***mod.***	***z***	***p***	***r***	***base.***	***mod.***	***z***	***p***	***r***
color hue	2.03	2.97	-7.4	.0*	**.43**	2.6	3.11	-4.22	.0*	**.24**	2.16	2.91	-6.08	.0*	**.35**
distortion	3.87	4.03	-1.96	.05	**.11**	3.29	3.71	-3.88	.0*	**.22**	2.15	3.8	-8.86	.0*	**.51**
length distortion	2.95	3.52	-4.7	.0*	**.27**	1.97	3.71	-9.71	.0*	**.56**	1.81	3.66	-10.13	.0*	**.58**
spacing	3.30	3.23	-0.92	.36	.05	1.82	2.25	-4.09	.0*	**.24**	2.66	3.22	-4.52	.0*	**.26**
size	3.38	3.42	-0.38	.7	.02	2.42	2.56	-1.64	.1	.09	1.98	2.28	-3.61	.0*	**.21**
symbols	2.77	3.34	-4.96	.0*	**.29**	2.6	3.62	-7.05	.0*	**.41**	2.59	4.11	-9.2	.0*	**.53**

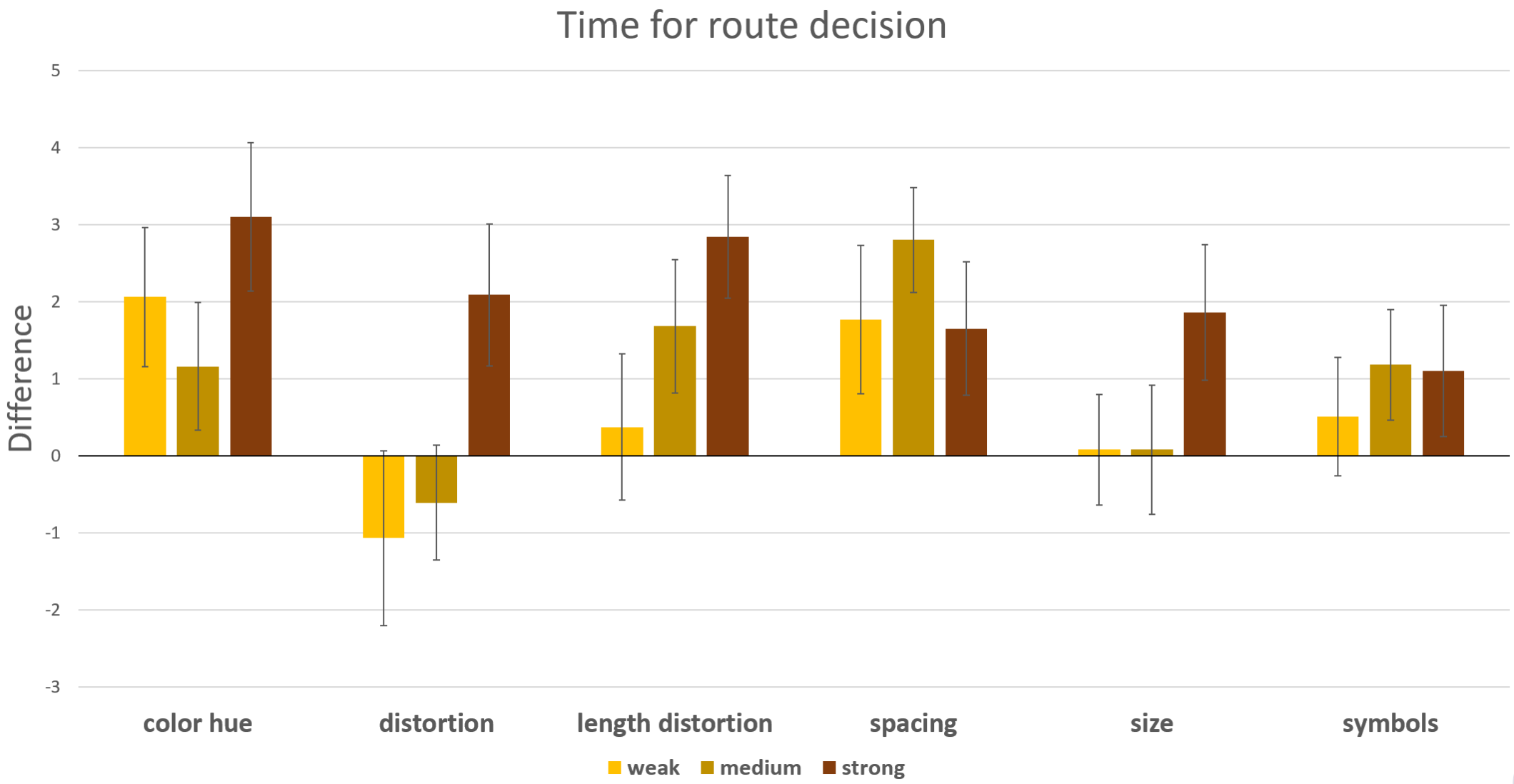
small effect $0.1 \leq r < 0.3$ **medium effect** $0.3 \leq r < 0.5$ **large effect** $r \geq 0.5$

Route choice



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

Decision Time



Route Characteristics

Evaluation of route characteristics by the participants in percent

	Faster	*More direct*	*Shorter*	*More convenient*	*More fluent*	*None*	*Other characteristic*
Color	**48**	5	4	28	**40**	28	15
Distortion	**40**	**38**	17	**57**	**42**	12	8
Length distortion	27	**50**	**54**	17	11	14	3
Line style	17	9	2	25	**40**	**40**	10
Line width	13	6	1	16	18	**60**	15
Symbols	**60**	3	4	**42**	**65**	19	9

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 comminicating 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

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[2] Adoko, K. H., Pel, A. J., Hoogendoorn, R. G., & van Arem, B. (2013). Modelling effects of social navigation on road traffic: The influence of penetration rates, altruism, and compliance. *8th TRISTAN, San Pedro de Atacama, Chile*, 1-4.

[3] DiBiase, D., MacEachren, A. M., Krygier, J. B., & Reeves, C. (1992). Animation and the role of map design in scientific visualization. *Cartography and geographic information systems, 19*(4), 201-214.

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[5] Köbben, B., & Yaman, M. (1995, August). Evaluating dynamic visual variables. In *Proceedings of the seminar on teaching animated cartography, Madrid, Spain*, 45-51.

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[7] Wardman, M., Bonsall, P. W., & Shires, J. D. (1997). Driver response to variable message signs: a stated preference investigation. *Transportation Research Part C: Emerging Technologies, 5*(6), 389-405.

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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