ETH zürich

Gaze-based assistance for wayfinders in the real world

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[INNOLEC Lecture, Masaryk University, Brno]

geoinformation engineering ikg eth zurich

GeoGazeLab

- Chair of Geoinformation Engineering
- Senior Scientist
- Post-doc
- 3 PhD students

- Ergoneers
- SMI
- Tobii
- SmartEye

http://www.geogaze.org/

Wayfinding

Cognitive processes and visual attention during pedestrian wayfinding

GeoHCI

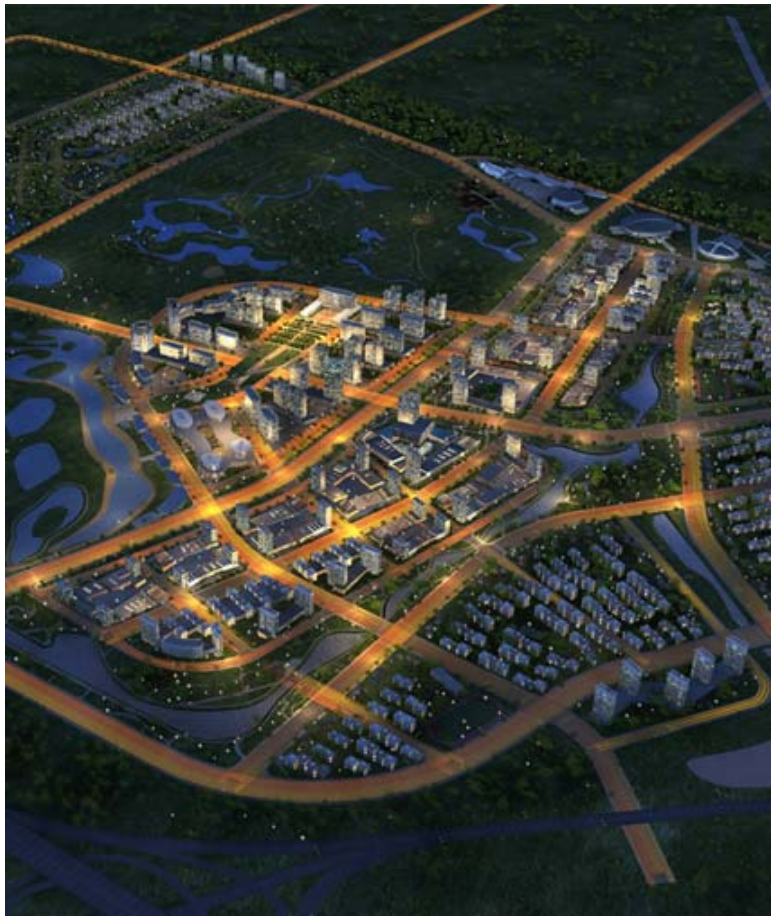
Gaze-based interaction with geographic information

Aviation Safety

Pilot's visual search strategies in the cockpit

Overview

- Mobile decision-making
- Analyzing human wayfinding behavior
  - Location-aware mobile eye-tracking
  - Processes in wayfinding
- Mobile gaze-based decision support
  - Map interaction
  - Environmental interaction
- Conclusions



www.woodsbagot.com

Mobile decisions

Mobile decision-making

- Spatio-temporal constraints relating to
  - people's behavior in large-scale space.
  - interaction with mobile devices.
  - perceptual, cognitive, and social processes.
- Ability to make quick decisions on the spot => fast access to spatial memory.
- Technological limitations of mobile devices, e.g., small screen size => challenge of presenting information to someone on the move.

Technology - Pros & Cons

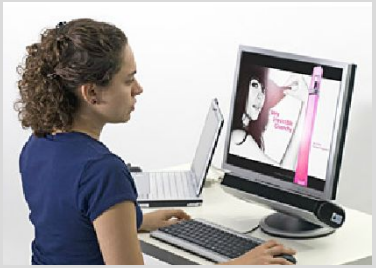
- Services augment people's cognitive abilities
- Compensate for people's deficiencies

- Decreased spatial knowledge acquisition
- Negative impact on people's spatial learning of the environment
  - Insufficient processing of perceived information
  - Lack of attention to the environment
- Differences in mobile devices & presentation

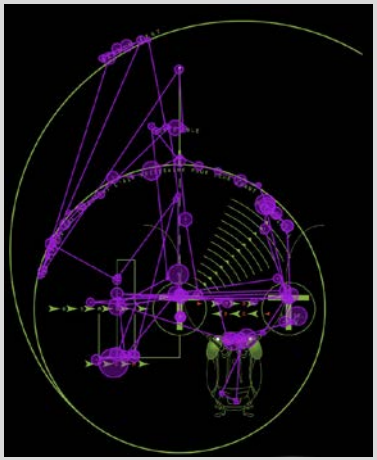
Analyzing human wayfinding behavior

Eye Tracking

- Measuring visual attention
- Application domains
  - Psychology, consumer research, economy, architecture, arts, design, pilot safety training, …



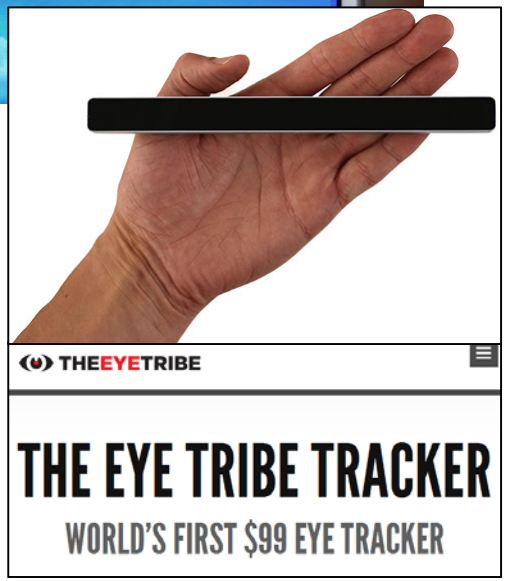
"Remote"
Eye Tracking

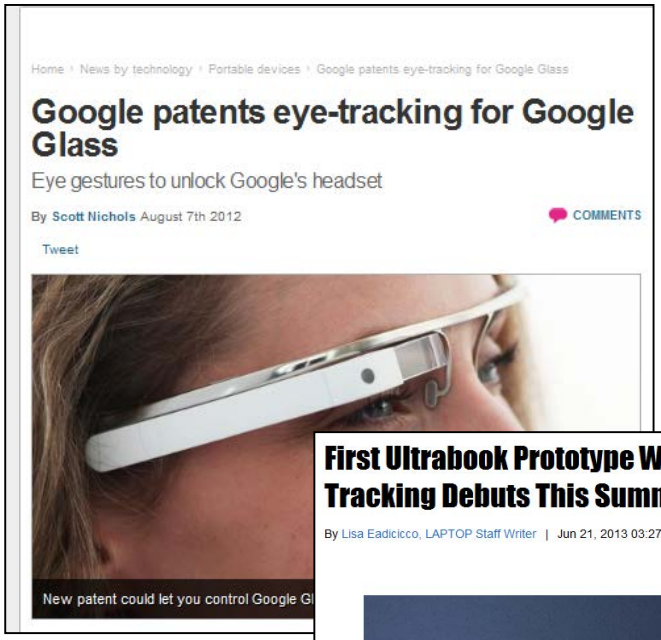


Mobile
Eye
Tracking

Sources: Stationärer Eye Tracker: Sensomotoric Instruments (http://www.smivision.com/)
Kunst von Laura Walde, Gazetrack: Peter Kiefer, Rechts: Geoinformations-Engineering

Eye tracking on the mass market?





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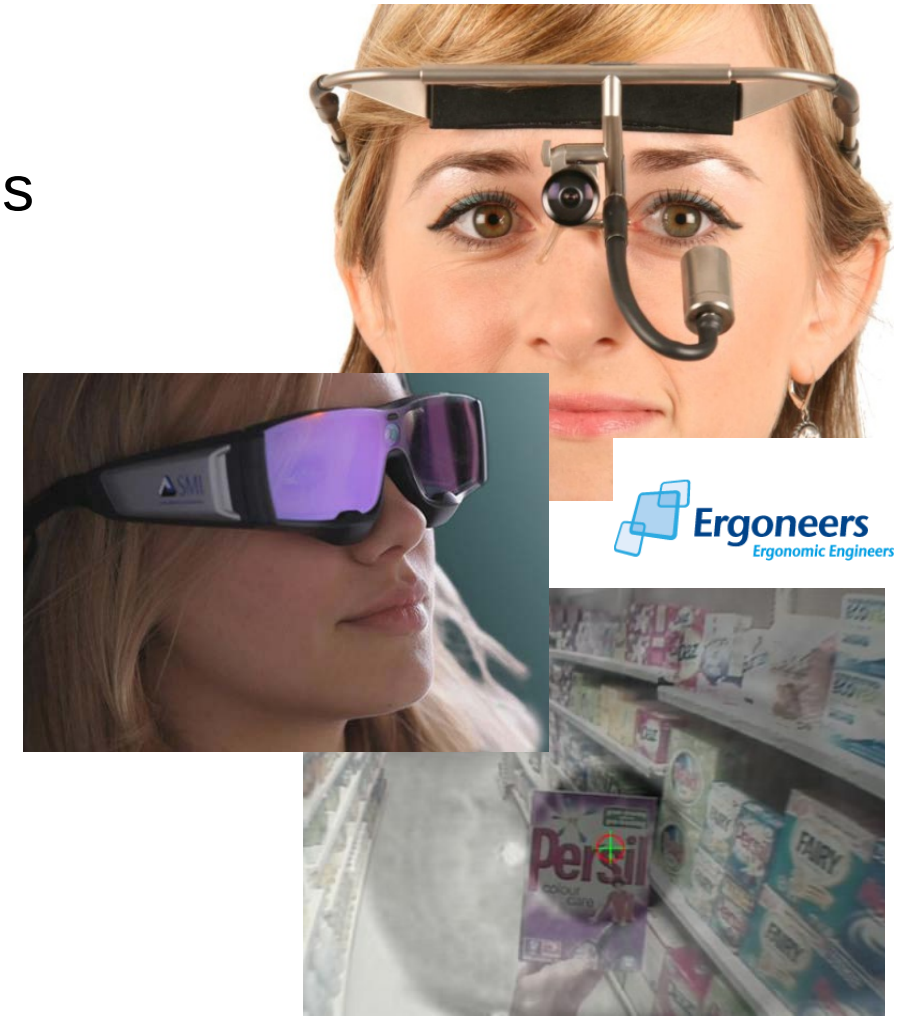
http://www.techradar.com/news/portable-devices/google-patents-eye-tracking-for-google-glass-1091428
http://blog.laptopmag.com/first-ultrabook-eye-tracking

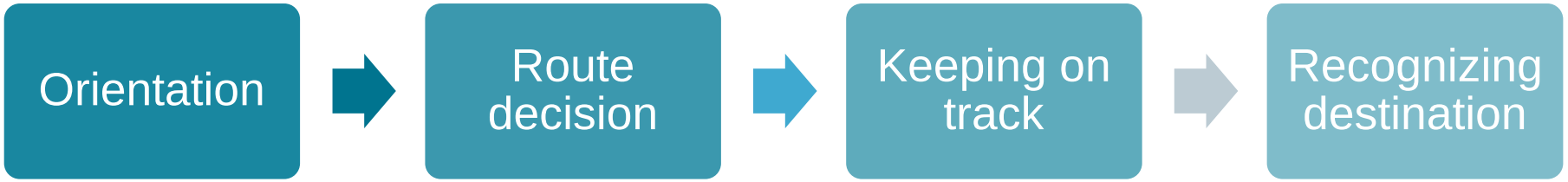
Mobile Eye tracking

- Gaze recording: fixations & saccades
- Head-mounted device
  - Increased mobility
  - Realistic conditions
  - Sunlight & infrared?
- Gaze-overlay video
  - Frame coordinates
  - Visual markers define world-coordinate-system



Cognitive Processes in Wayfinding

- Example (Downs&Stea, 1977)

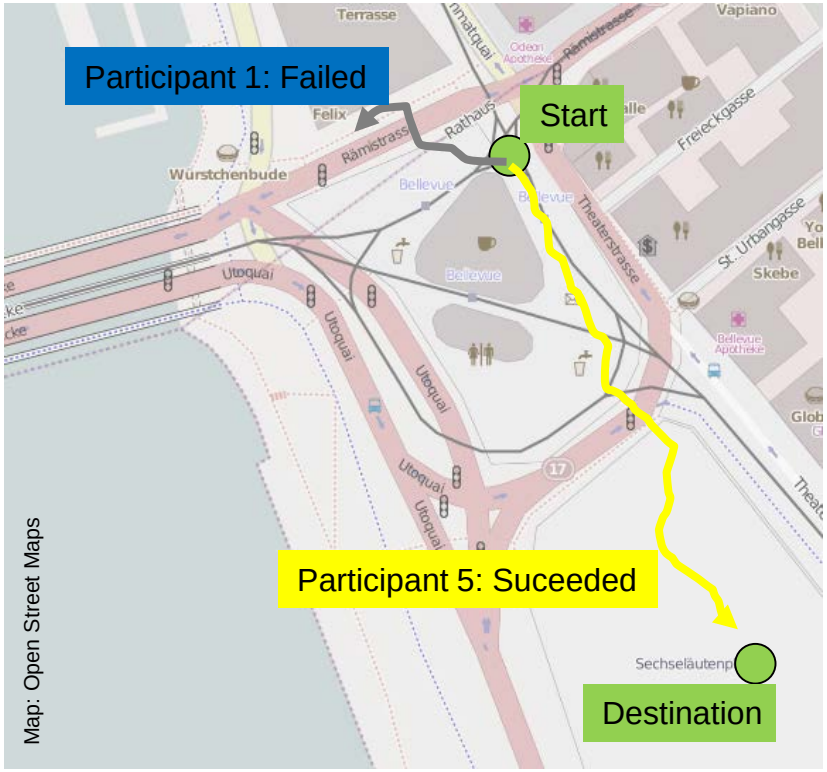


Cognitive Engineering

- Goal
  - Intelligent user interfaces
  - Automated assistance based on user's cognitive states
- Empirical studies
  - Model of user activities and cognitive processes
- Engineering
  - Recognizer using the model
  - Adaptive system

Human wayfinding behavior

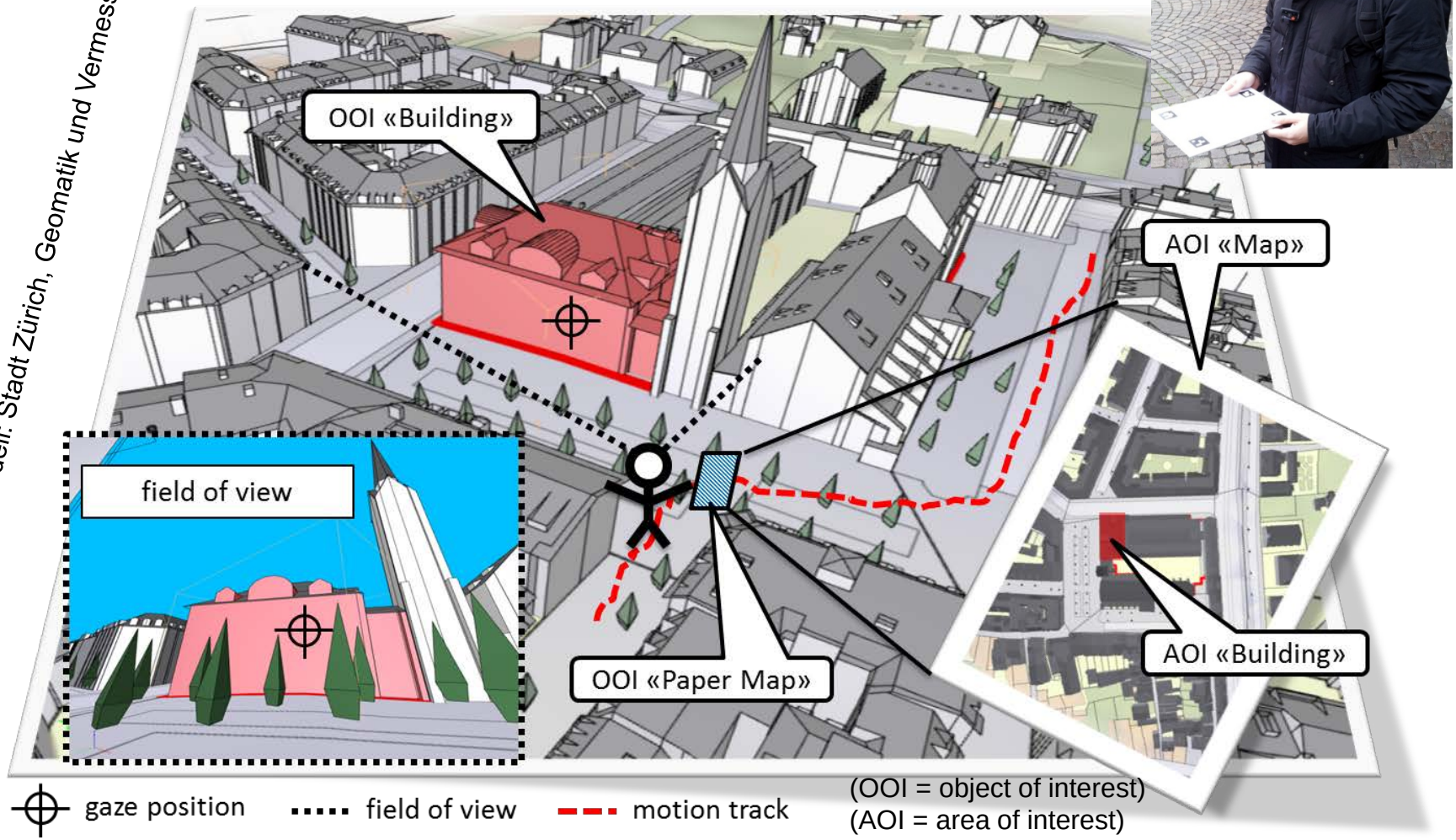
- Where and why do people get lost?
  - Ambiguity, complexity, instructions, map design, etc.
  - Typical approaches: questionnaires, interviews, behavior observation
- Can we get better answers to the ‘why’ question?



[Kiefer, Giannopoulos, Raubal; TGIS 2014]

Location-aware mobile eye-tracking

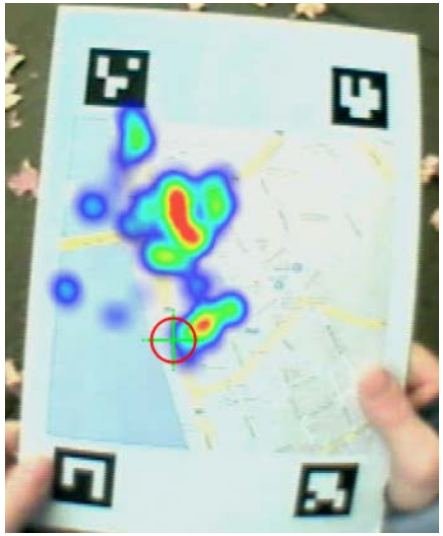
[© 3D Stadtmodell: Stadt Zürich, Geomatik und Vermessung]



(OOI = object of interest)
(AOI = area of interest)

[Kiefer, Straub, Raubal; ETRA 2012]

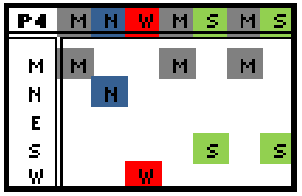
Self-localization



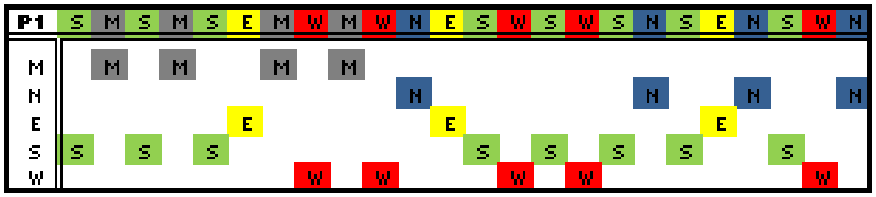
Participant 1:
Success
(heading South)

Participant 5:
Failure
(heading North)

Participant 1:
Success



Participant 5:
Failure
(heading North)



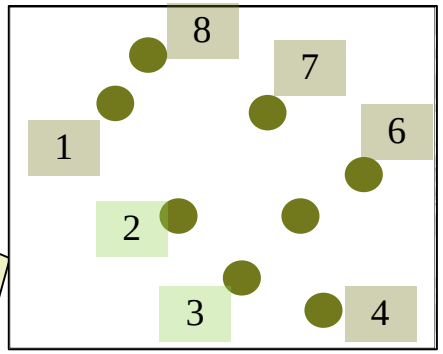
Sequence analysis for cardinal directions (N, E, S, W) and map (M)

Hypothesis:

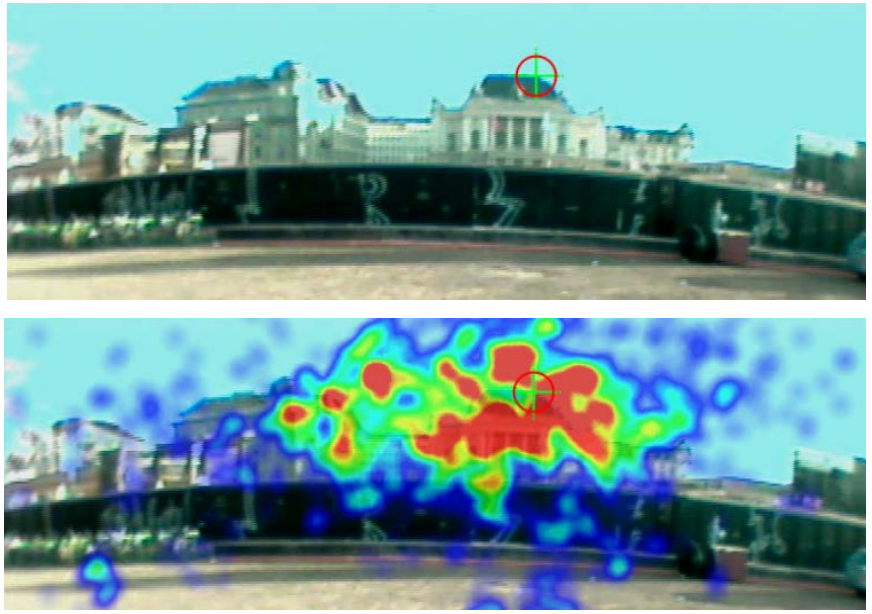
The process of self-localization can be observed from the gaze behavior *on the map* / *in the environment*.

Landmark Identification

«Our next destination is the Opera. The prominent building is located at the Southern edge of ‘Sechseläutenwiese’ where the ‘Seefeld’ quarter starts.»



Other building *Opera*



Gaze distribution for landmarks

Hypothesis:

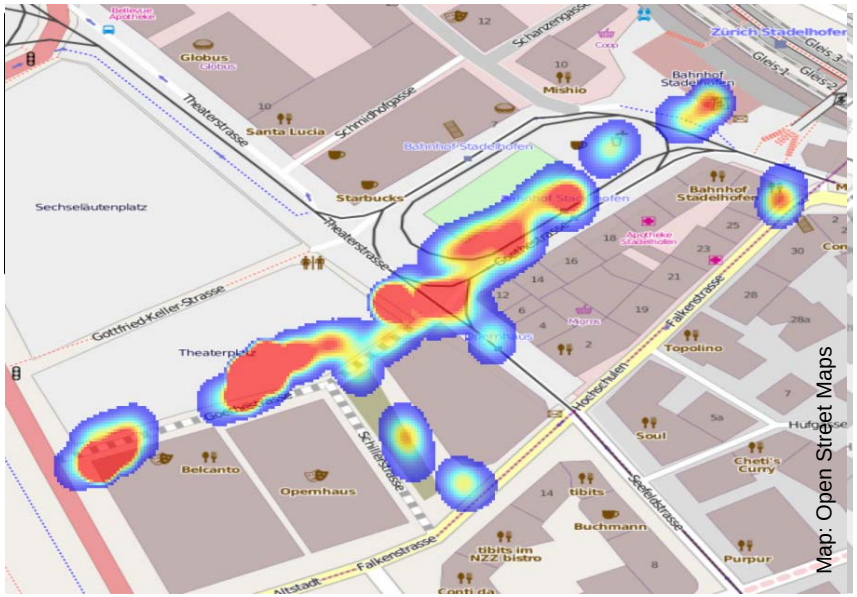
The process of landmark identification can be observed from the gaze behavior in the environment.

Positions of Map Usage

«Our next destination is the old NZZ building at the intersection ‘Theaterstrasse’/’Falkenstrasse’. The building is next to the Opera. The entrance is close to the tram station ‘Opernhaus’ and facing South towards the ‘Seefeld’ quarter.»

Hypothesis:

Critical decision points can be determined from map usage (fixations on the map).



Motion tracks of all participants, annotated with AOI ‘map’ (area of interest)
Red: Fixation on map

A wayfinding study

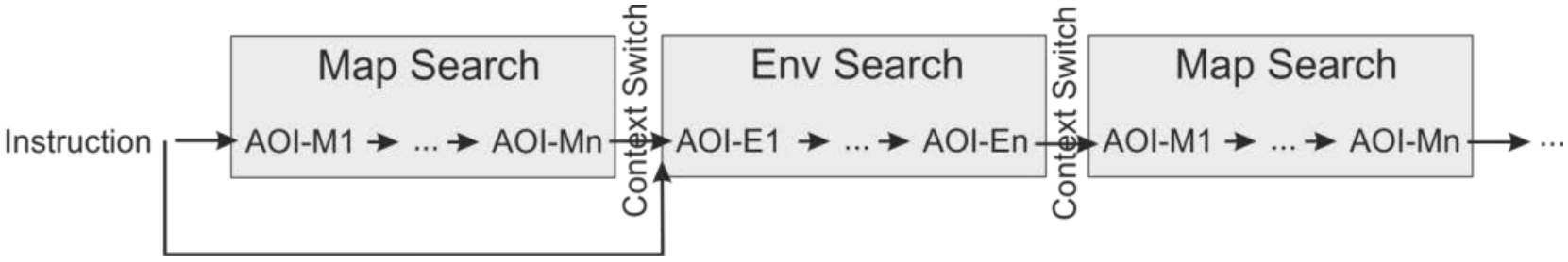
- Self-Localization
  - «Please mark your position on this map»
  - Map symbols and corresponding landmarks
  - Some landmarks visible
- Requires visual search and logical inference
  - Eye tracking measures only search

[Kiefer, Giannopoulos, Raubal; TGIS 2014]

Self-localization

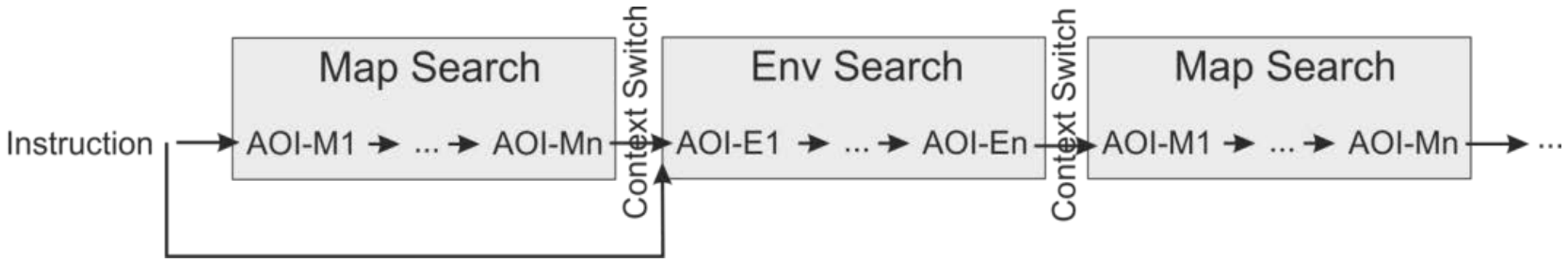
Research Questions

- RQ1
  - Do successful participants spend more visual attention on map symbols that have a visible corresponding landmark than unsuccessful participants?
  - (A distribution measure.)
- RQ2
  - Do successful participants have more switches of visual attention between symbols on the map and their corresponding landmarks in the environment?
  - (A sequence measure.)



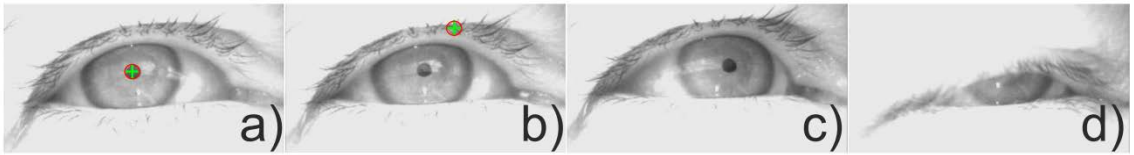
Results

- Successful participants spent significantly more time fixating AOIs from the helpful AOIs category than the unsuccessful participants.
- Successful participants had significantly more switches of visual attention between symbols on the map and their corresponding landmarks in the environment than did unsuccessful participants.



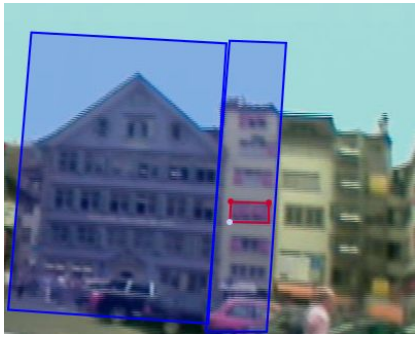
Technological Challenges (1)

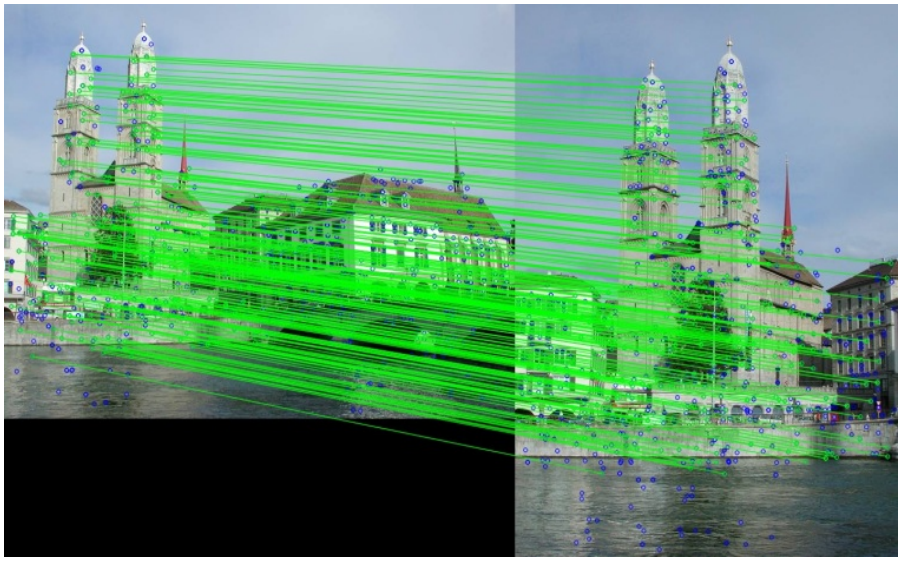
- Sunlight
  - ... interferes with infrared
  - Dikablis
    - Saves two videos, manual post-processing frame-by-frame
    - Labor-intensive!
  - SMI Glasses
    - Sunshades



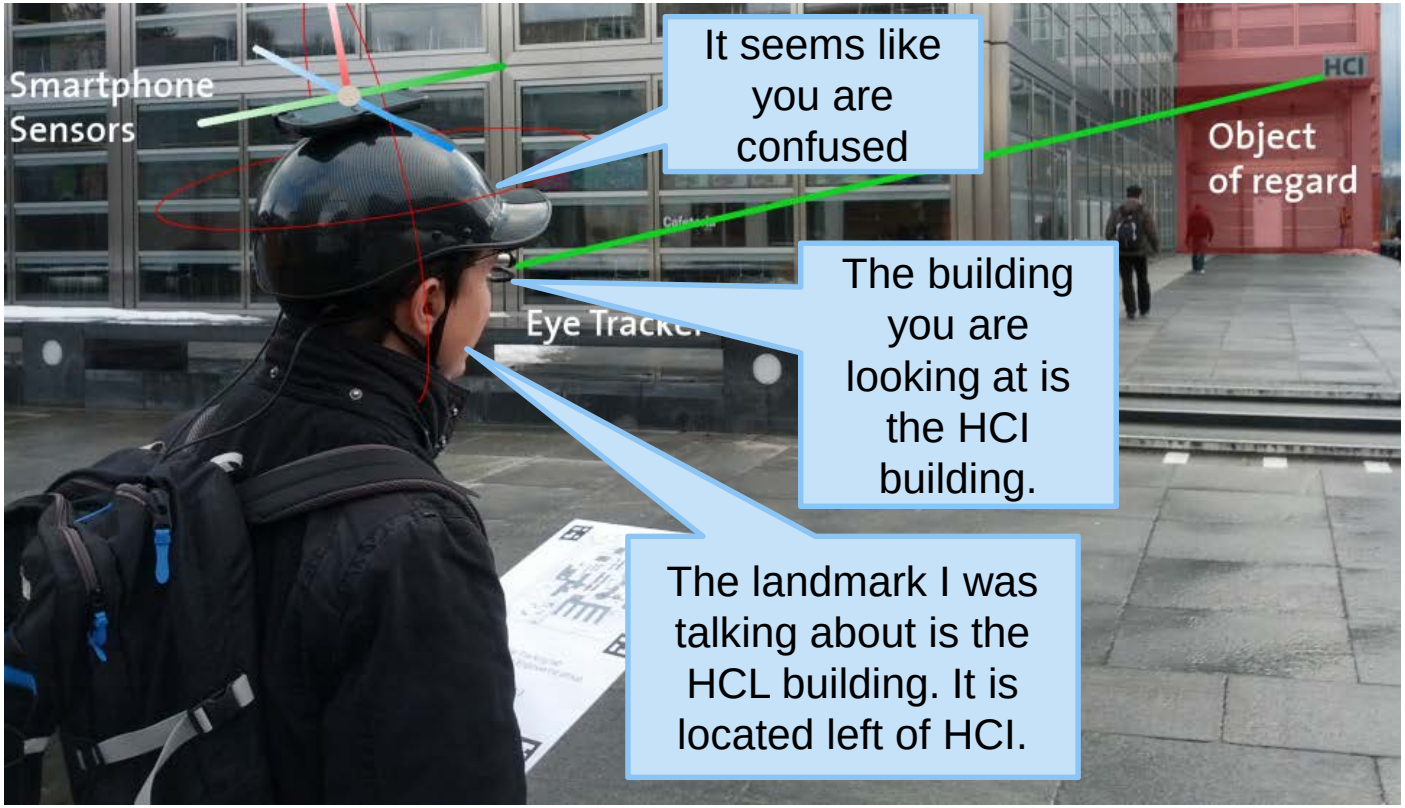
Technological Challenges (2)

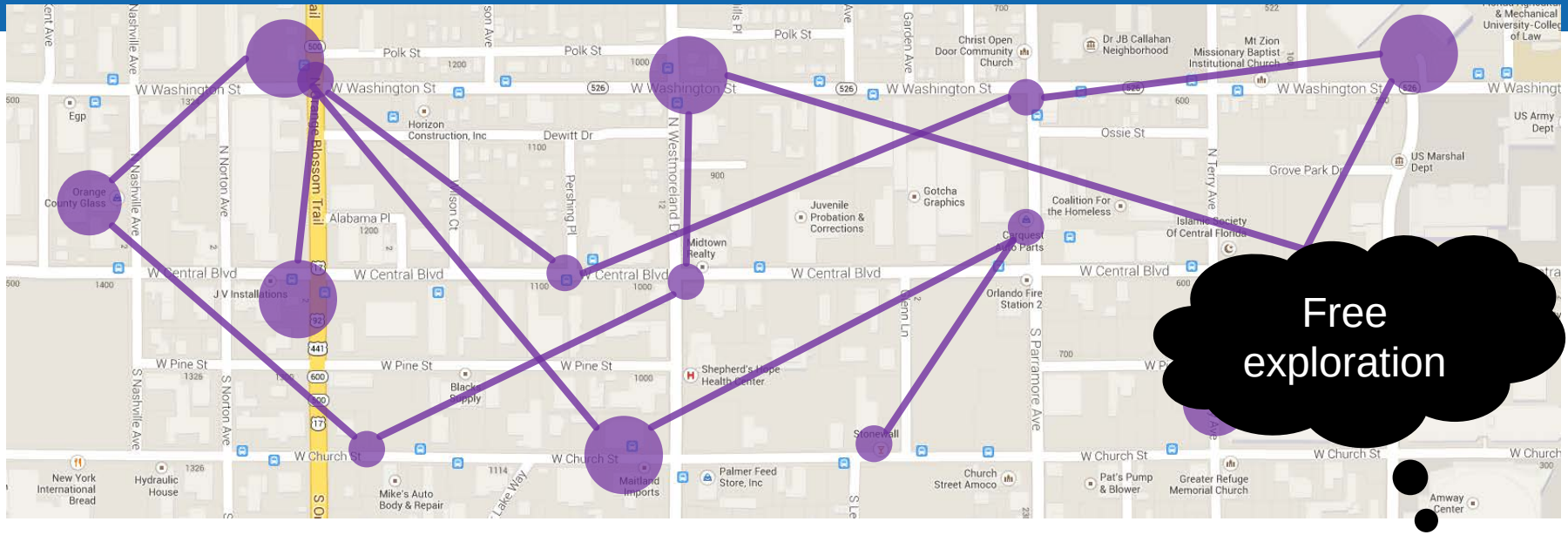
- Determining Object of Interest
  - Dikablis
    - Marker-based solution
    - Labor-intensive!
  - MSc theses
    - Pius Mosimann (2013)
      - Simple head-tracking helmet
      - 3D city model
    - Simon Haesler (2014)
      - Web service for the 3D intersection
    - Yufan Miao (2015)
      - Image-based localization



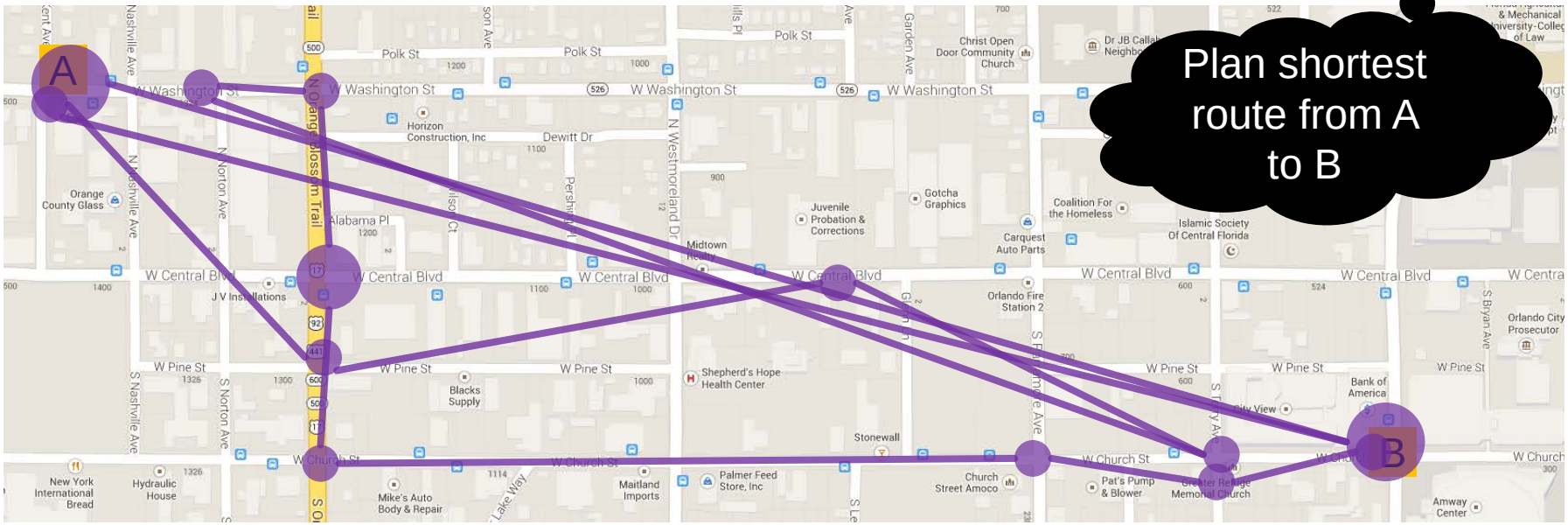


A cognition-aware wayfinding assistant





[Kiefer, Giannopoulos, Raubal; ACM-GIS 2013]



Mobile gaze-based decision support

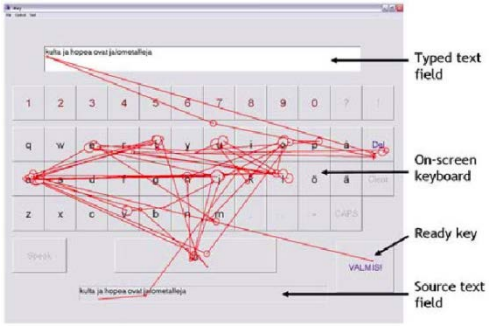
Gaze-Based Interaction

Gaze as input modality

- Real-time gaze processing
- Intelligent assistance
- Midas touch problem

A) Explicit Interaction

«What you look at is what you get»



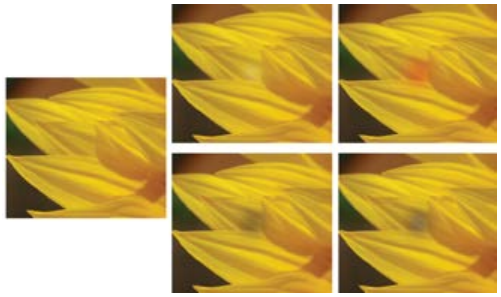
Eye typing (Majaranta et al., 2006)

Zooming/panning (Stellmach, Dachselt, 2012)

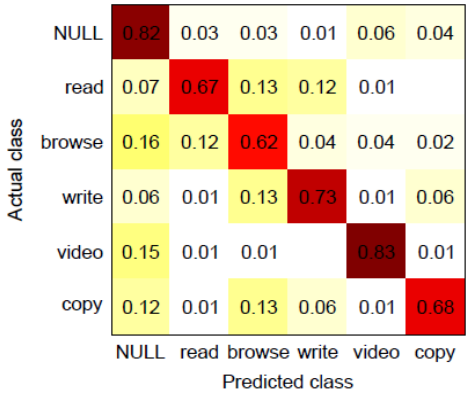
Gaze-Based Interaction (2)

B) Implicit Interaction

- Assistance in the background
- User does not intend to trigger an action



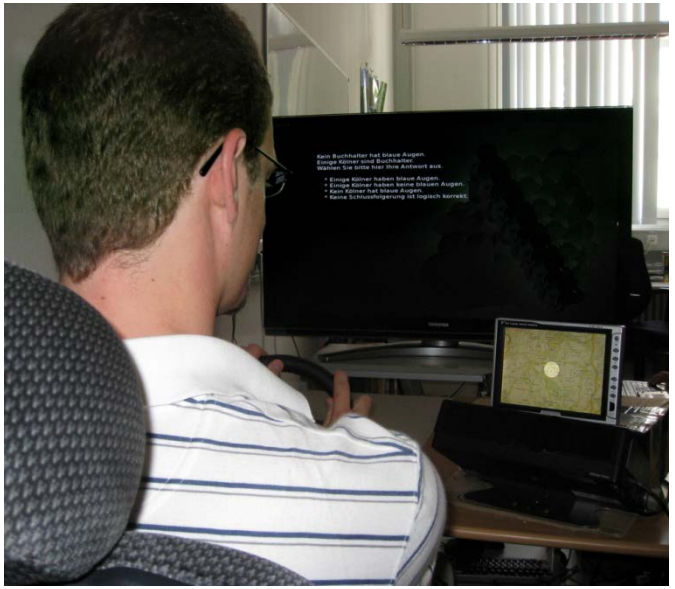
Subtle Gaze Direction (Bailey et al., 2009)



Activity recognition (Bulling et al., 2011)

Human Computer Interaction with eye tracking

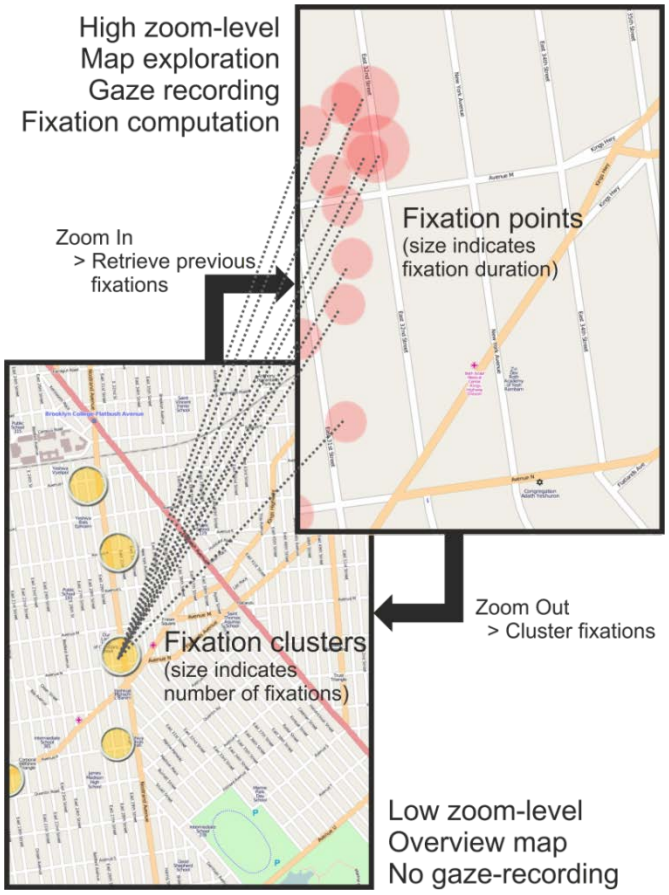
- Attentive Interfaces: content adapted dynamically based on gazes
- Examples:
  - Prediction of information needs (pre-caching)
  - Gazemarks as placeholders during context change



Example: Gazemarks

Kern, D. et al. (2010) Gazemarks: gaze-based visual placeholders to ease attention switching. In: Proc. of the 28th international conference on Human factors in computing systems (CHI'10), ACM, pp. 2093-2102

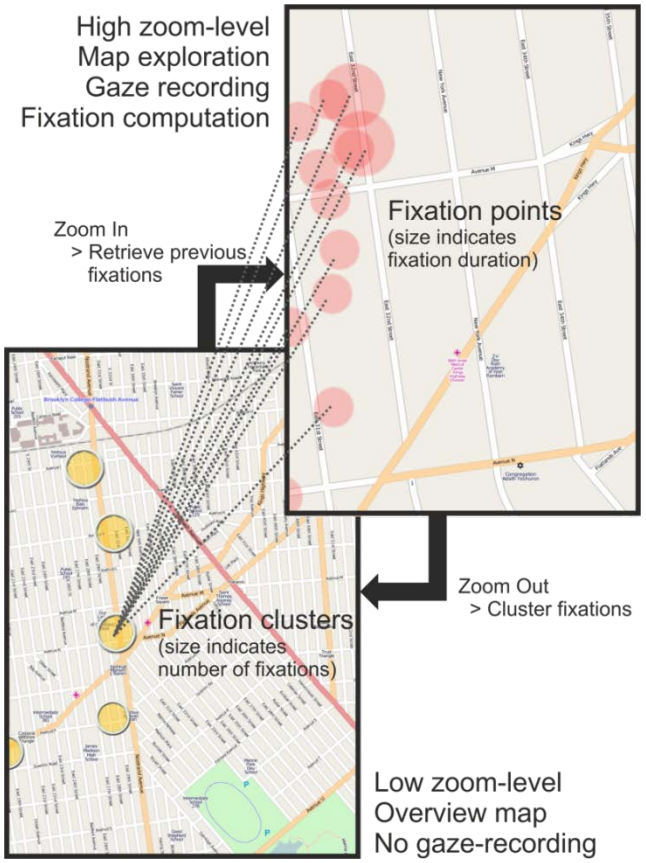
GeoGazemarks



- Providing gaze history for the orientation on small display maps
- History of a user's visual attention on a map as visual clue to facilitate orientation.

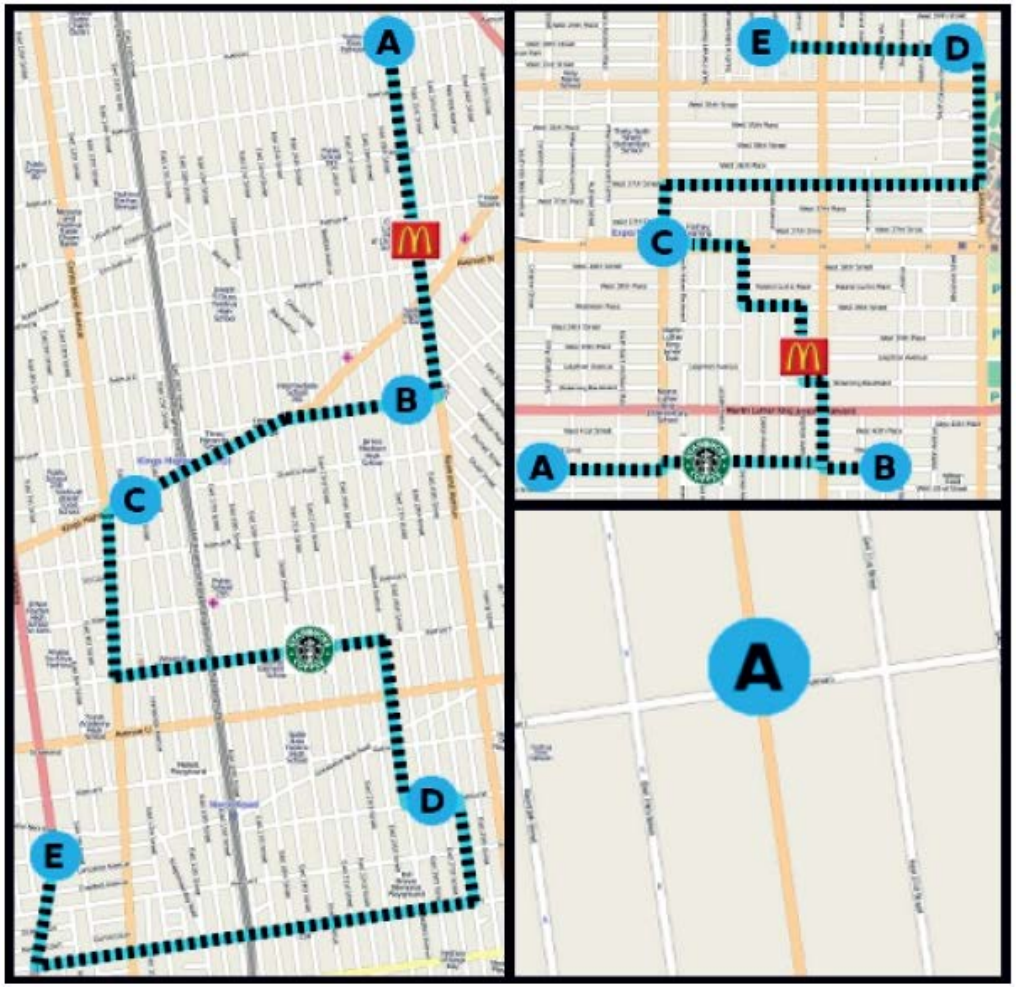
[Giannopoulos, Kiefer, Raubal; ICMI 2012]

GeoGazemarks



[Giannopoulos, Kiefer, Raubal; ICMI 2012]

Experiment



- 7 point objects on each map (5 blue circles, 2 logos)
- Participants traverse vector sequence (A->E) then find their way to logos.

Results

Significant increase in efficiency and an increase in effectiveness for a map search task, compared to standard panning and zooming.

	Interaction Sequence Length	
	Median	Standard Deviation
Ggz	25.5	17.17
Std	75	52.6

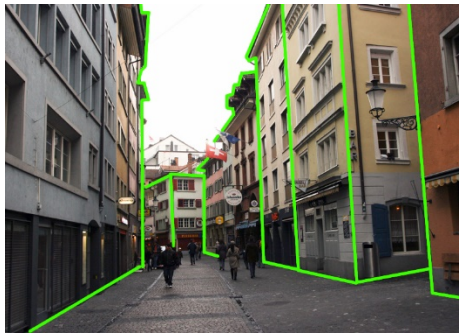
Ggz = with GeoGazemarks, Std = without GeoGazemarks

$\mathbf{p < 0.001, Z = -4.799}$

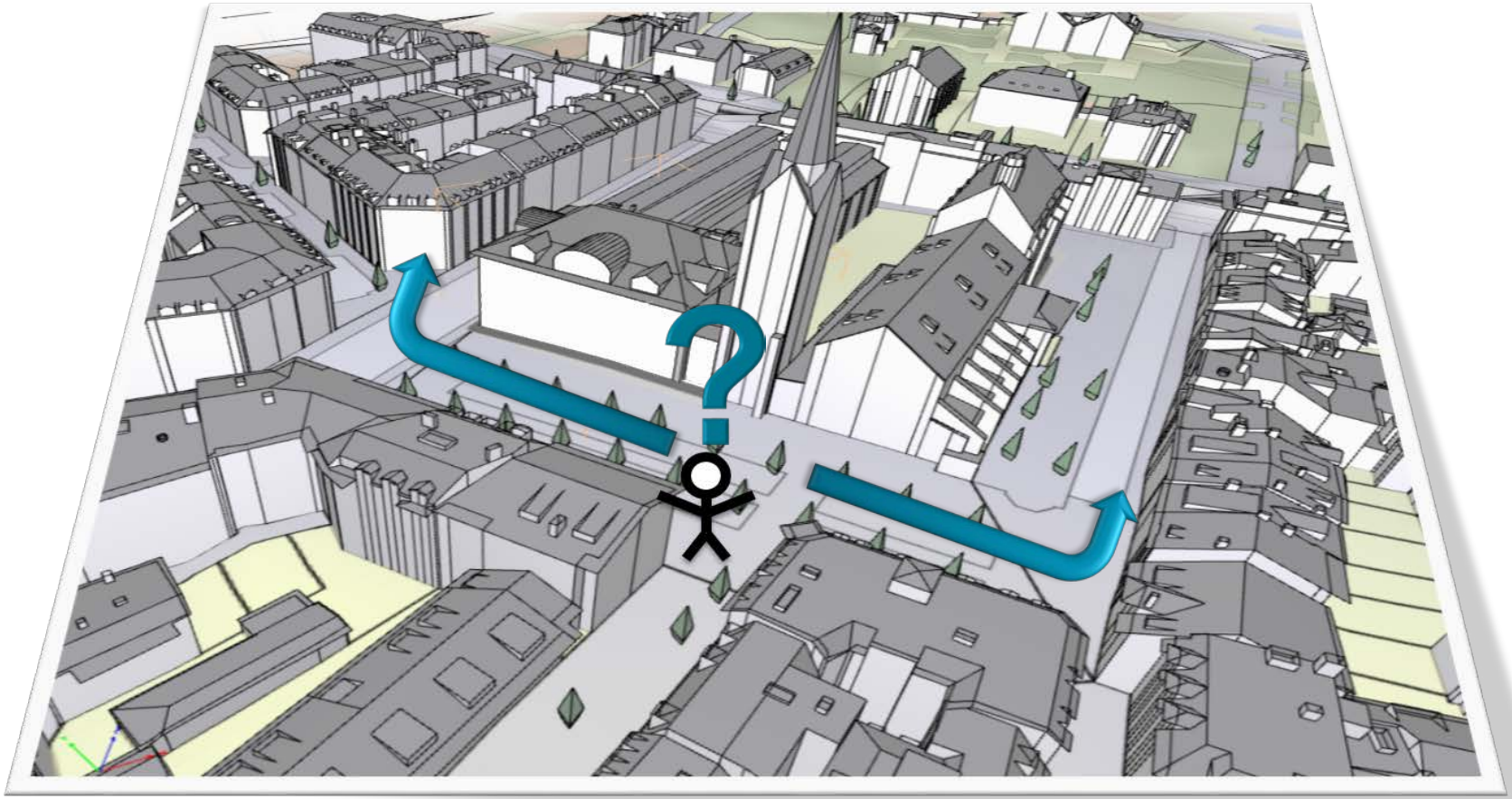
Gaze-Based Pedestrian Navigation (GazeNav)

How can the user's gaze be utilized for navigation?

- Dissolve navigation ambiguities
- Hands-free interaction
- Improve local spatial learning
- Natural interaction with the environment
- Increase usability

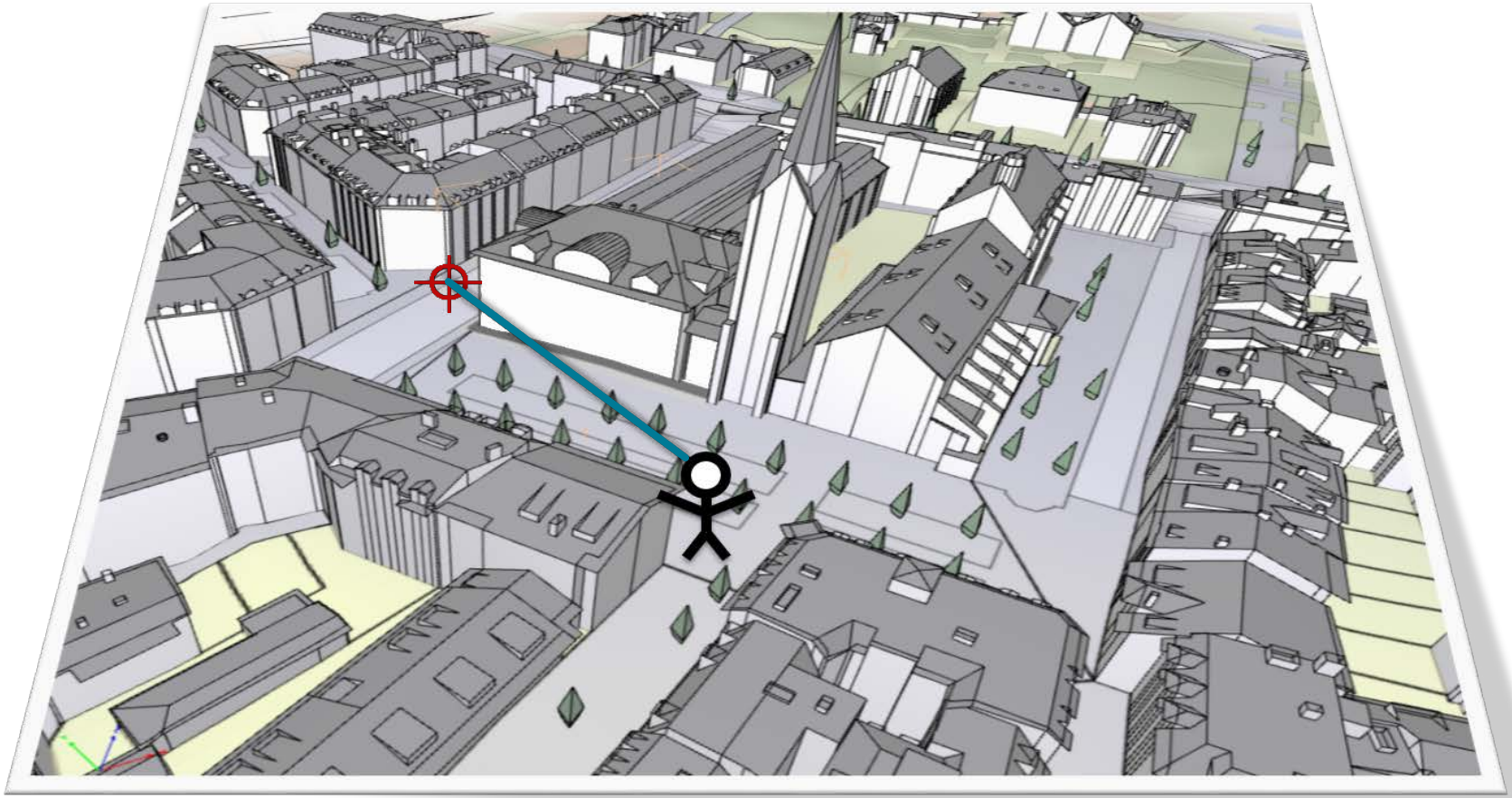


GazeNav



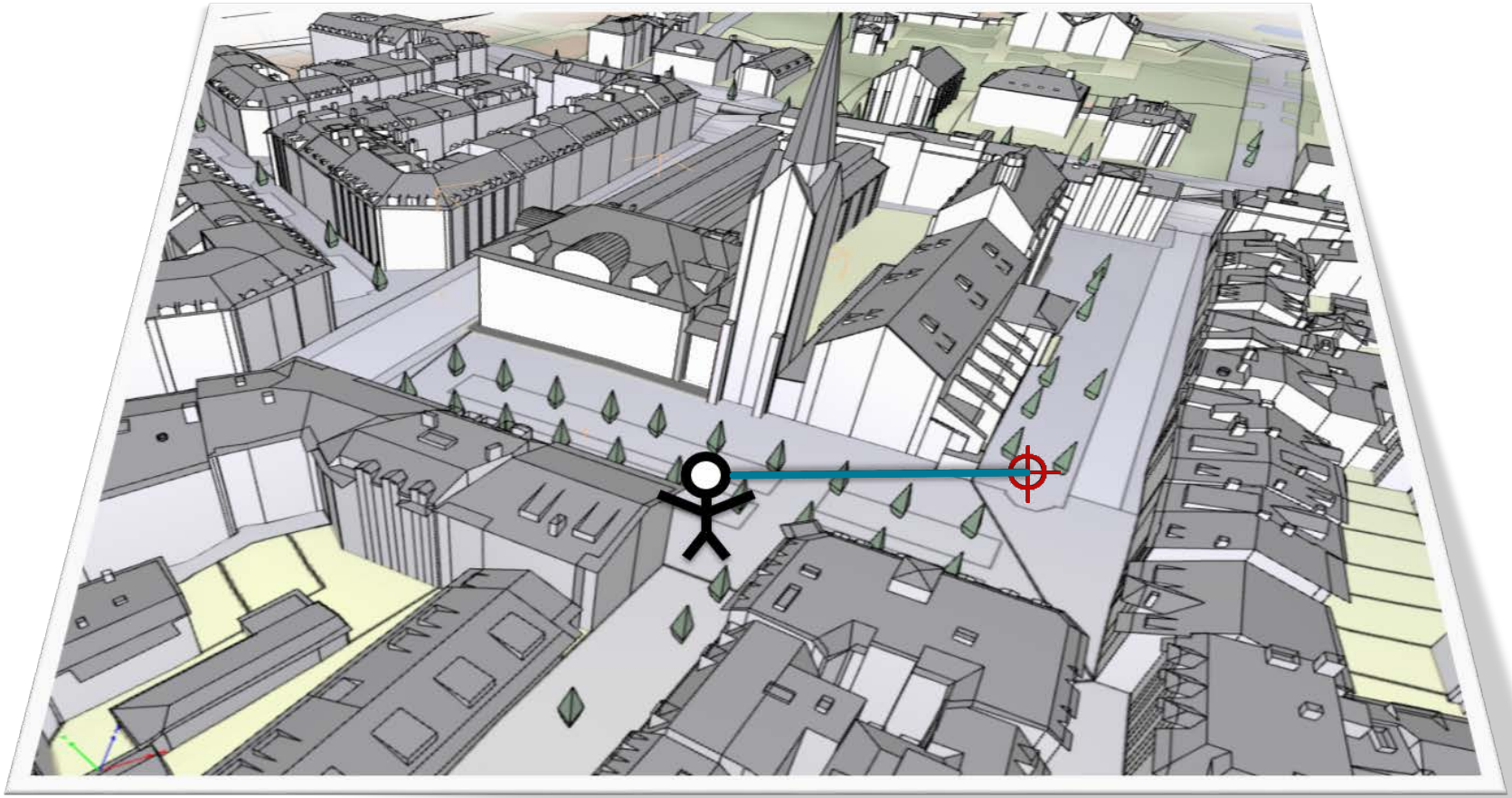
[Giannopoulos, Kiefer, Raubal; MobileHCI 2015]

GazeNav



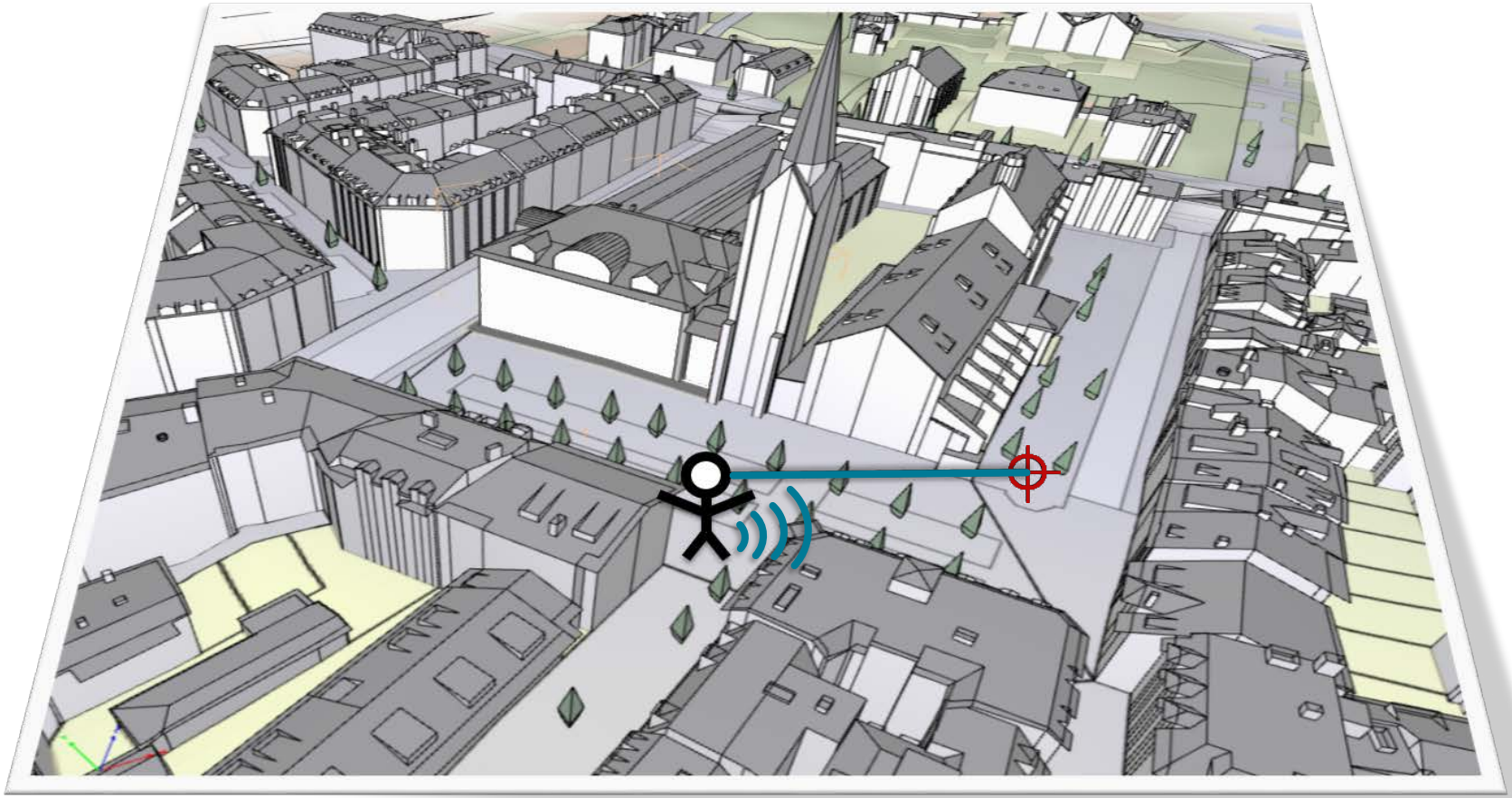
Gaze point

GazeNav



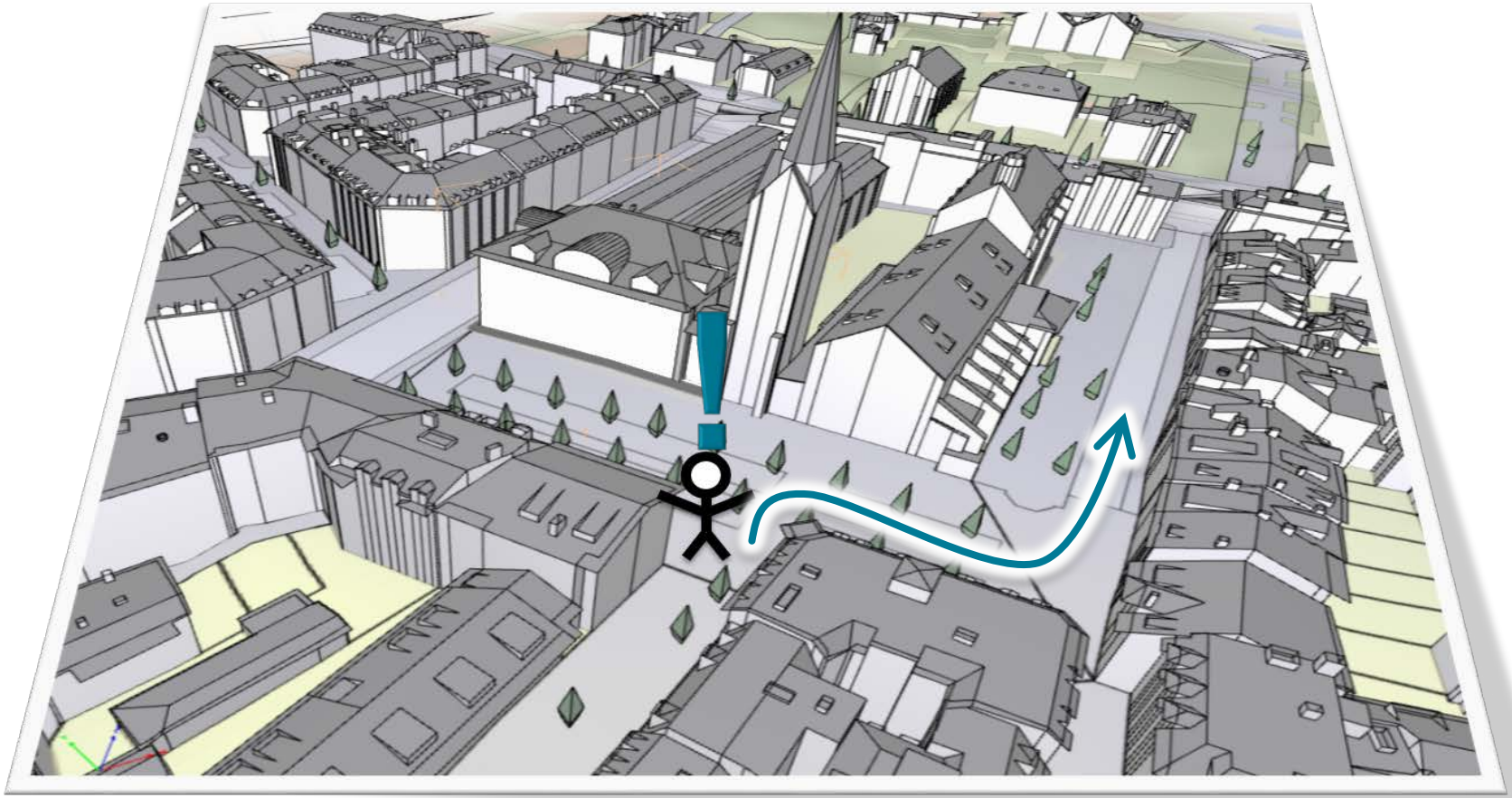
Gaze point

GazeNav

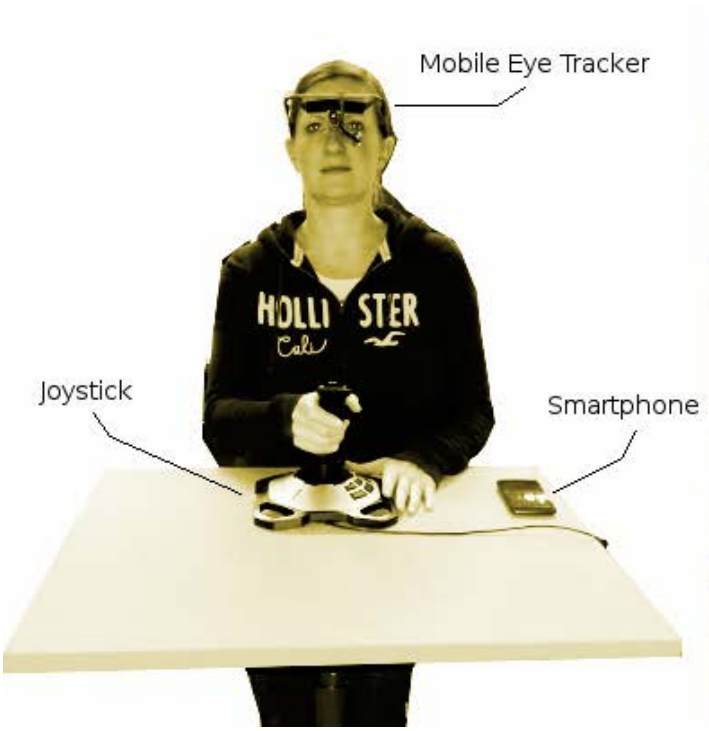


Gaze point

GazeNav



GazeNav: User Study in a Virtual Environment

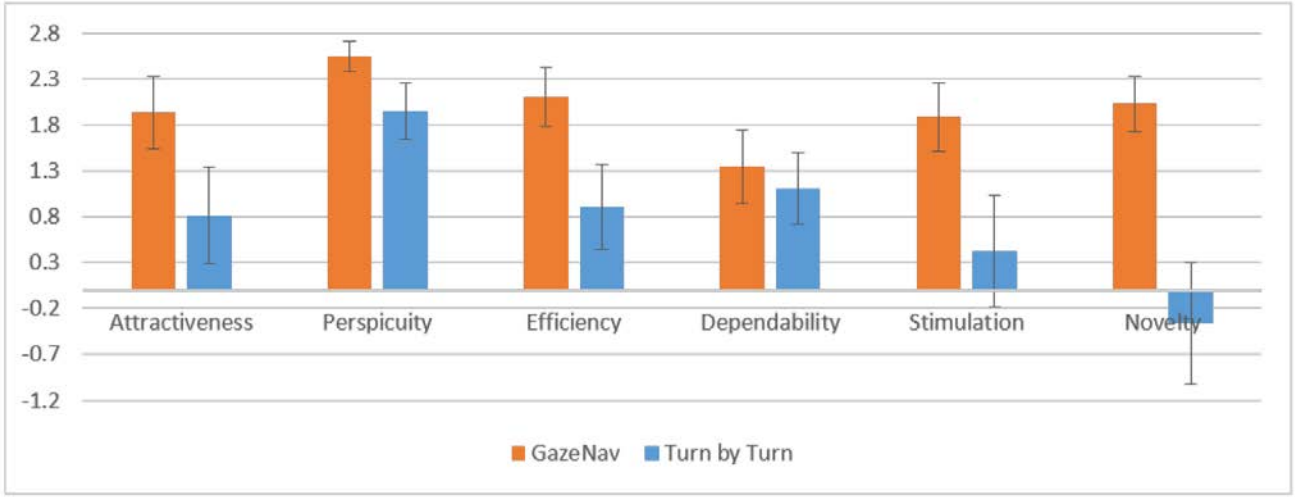


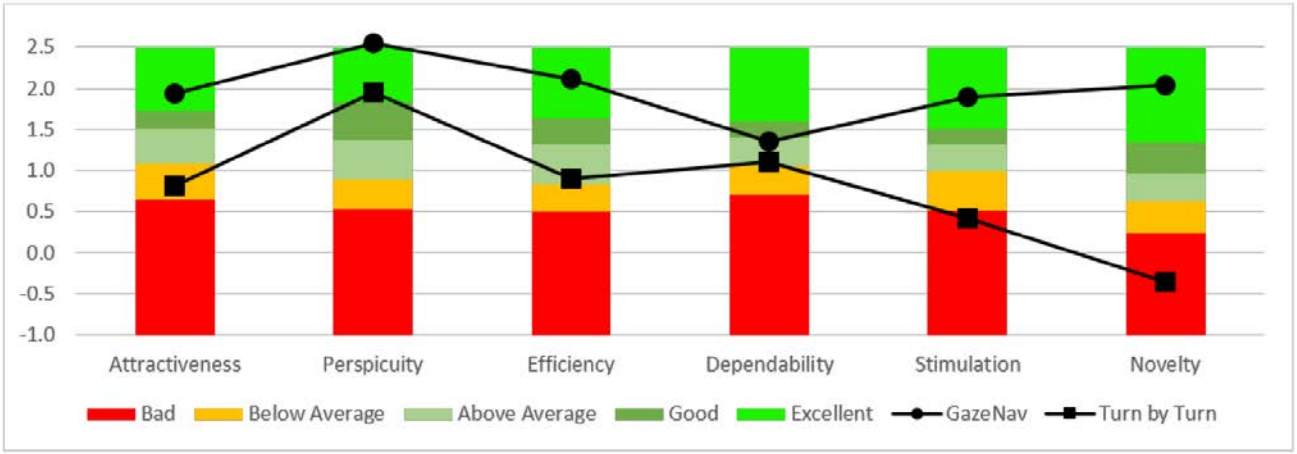
Between-group design; GazeNav vs. turn-by-turn;
32 participants (13f), 16 per condition

Hypotheses & Results

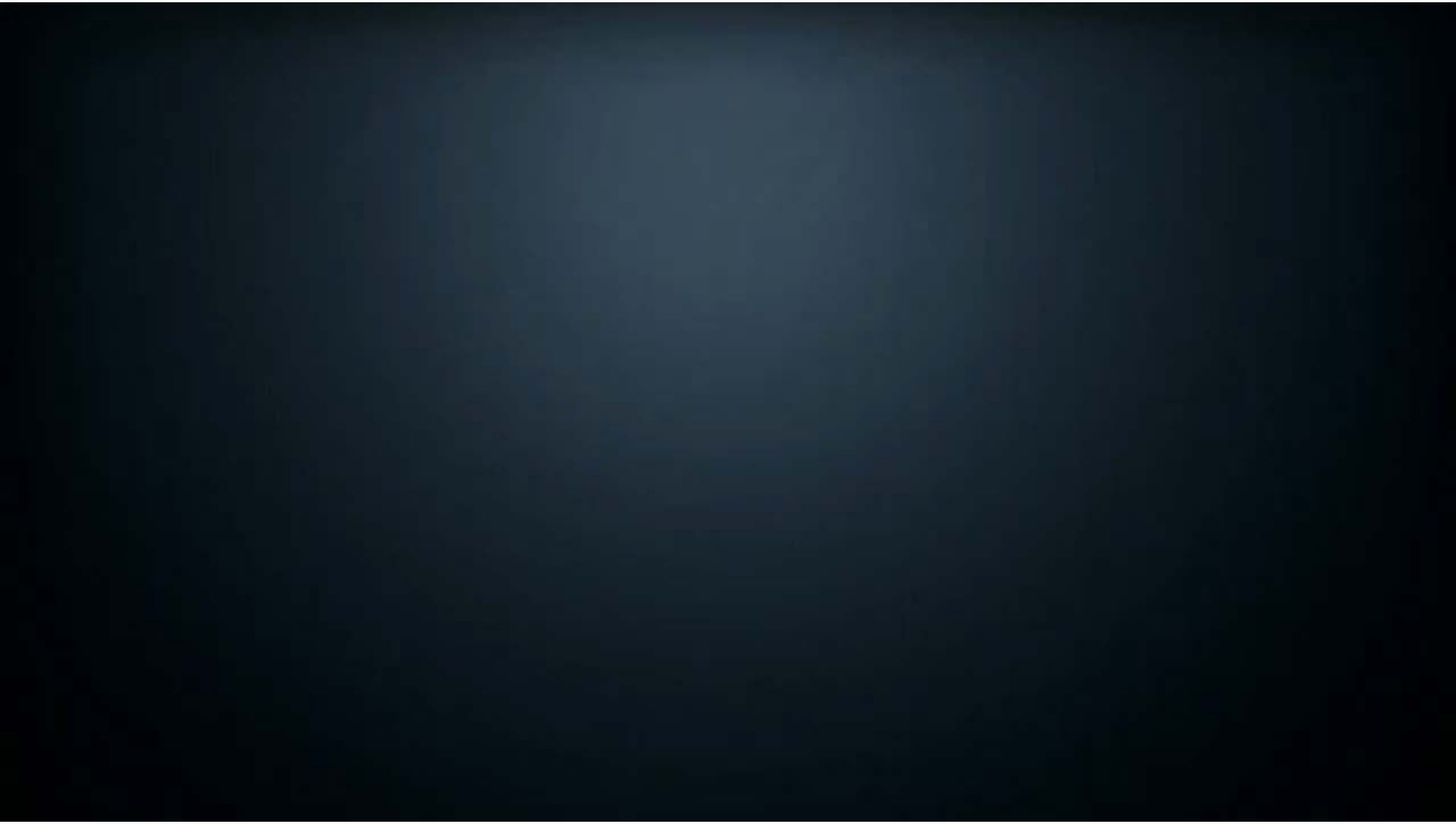
- H1: (Effectiveness)
  - Everyone completed the navigation task successfully.
- H2: (Efficiency)
  - No significant differences concerning the completion times.
- H3: (Spatial learning)
  - GazeNav participants correctly identified significantly more scenes.

H4: (User Experience, UEQ)





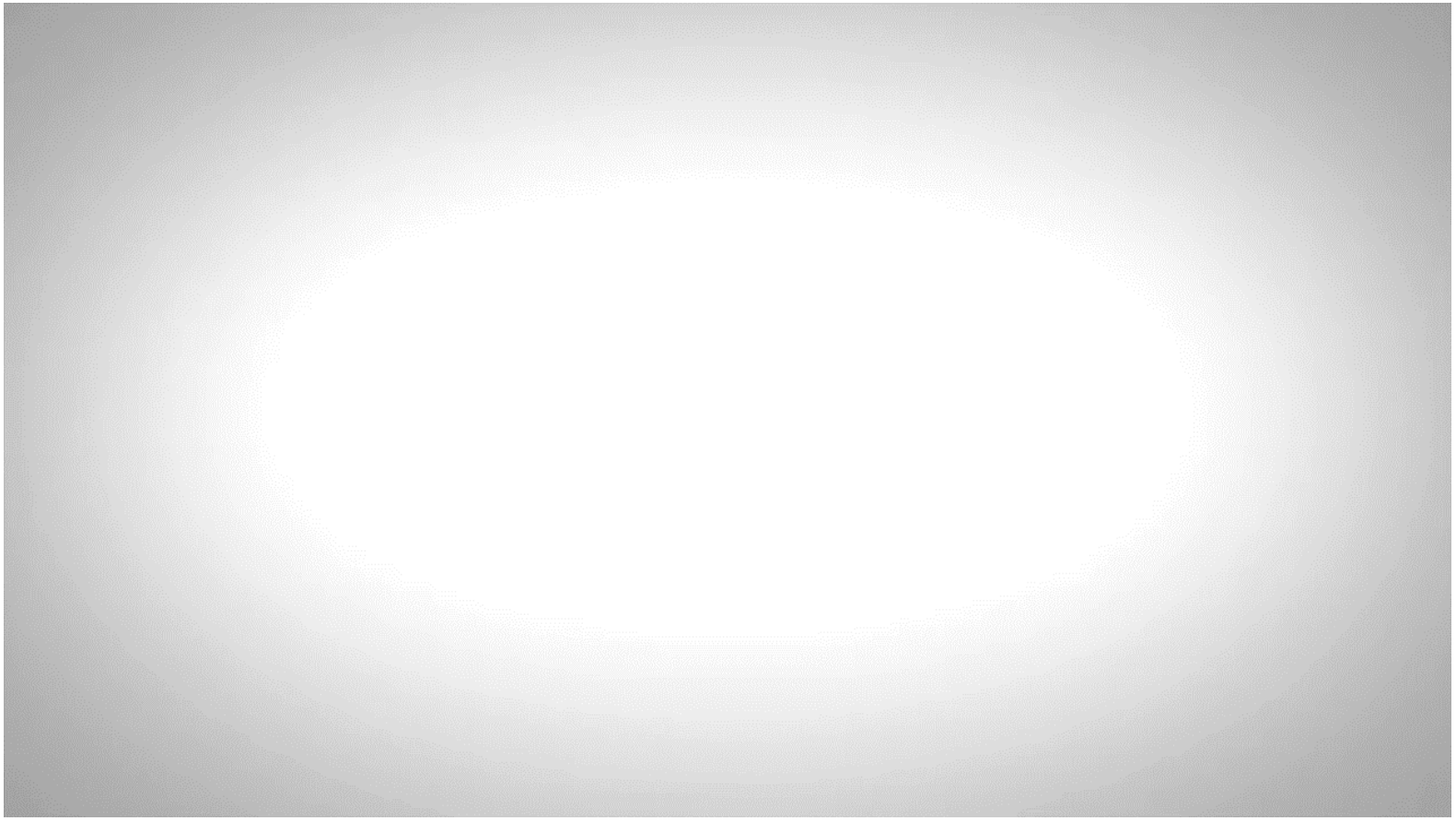
[Giannopoulos, Kiefer, Raubal; MobileHCI 2015]



Conclusions

- Mobility & mobile decision-making: Large challenges and opportunities
- Data, Methods, Technology for decision support
- Mobile eye-tracking offers novel ways to investigate individual behavior and provide support.
  - Analysis: Human wayfinding behavior
  - Interaction: Gaze-based decision support
- Watch out for new fields such as GeoHCI!

Do we even need cognition-aware wayfinding assistants?



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Eye Tracking for Spatial Research

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