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Association Cartographique Internationale

Augmented reality (AR) display and spatial learning in autonomous vehicle: A cartographic and cognitive perspective

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Keywords: augmented reality, spatial knowledge, eye-tracking, autonomous vehicle

Abstract:

Like in-vehicle navigation systems (aka. GPS), autonomous vehicles have raised researchers' concern as the attention of travelers to the environment in such vehicles would further decline (McKerral et al., 2023), which substantially impacts travelers' spatial awareness of the surroundings. Studies investigating the impact of following GPS on spatial learning show that drivers acquire very limited spatial knowledge (see Ishikawa, 2019; Parush et al., 2007). The acquisition of spatial knowledge can worsen in autonomous vehicles as travelers no longer have to pay attention to the environment or directions at all. To address this program and facilitate traveler's spatial awareness, researchers adapt augmented reality (AR) to display landmarks or information on head-mounted displays during navigation (see Liu et al., 2021; Keil et al., 2020). This study investigates the theory of displaying AR landmarks on vehicle windshield to facilitate incidental spatial learning. At current state, this study focuses on testing the theory of how AR landmarks and road condition contribute to acquiring different levels of spatial knowledge.

This study adapts the theories of visualizing distant objects in the environment as distant landmarks on smartphones (see Baudisch and Rosenholtz 2003, Gustafson et al. 2008, Gollenstede and Weisensee 2014, & Li, 2020) and introduces the visualization strategies for windshield. The windshield visualization strategies involve portioning the windshield into three function areas based on types of spatial information. The top 20% portion of windshield is for displaying unseen distant landmarks. The mid 50% portion is for displaying visible landmarks and street names in the immediate surroundings. The lower 30% portion is for displaying auxiliary information such as street names and speed. The partition of the screen into three portions for displaying different types of information is based on the finding of traveler's attention in autonomous vehicles (Riegler et al. 2019). Based on the distance to traveler, the AR landmarks would appear or disappear on screen to represent their relative distance to travelers. Figure 1 shows the design of the display on the windshield in the simulation and the actual simulation seen by each participant on a large screen.

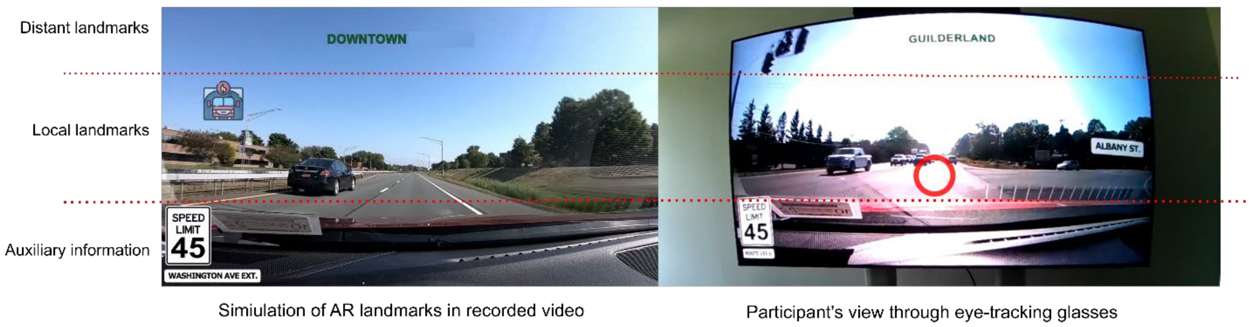

Figure 1: Simulation of AR landmarks on windshield (left) and participant's view of simulation on screen through eye-tracking device (right). The red circle indicates the current gaze of a participant on the windshield.

The in-person experiment uses the same video simulations as in the author' previous online study (Li, 2023). Earlier results show that designed AR landmarks on the windshield support acquiring spatial knowledge through incidental learning. However, the previous study took place fully online with participants all over the world due to the pandemic.

Abstracts of the International Cartographic Association, 10, 170, 2025
32nd International Cartographic Conference (ICC 2025), 17–22 August 2025, Vancouver, Canada.
https://doi.org/10.5194/ica-abs-10-170-2025

Participants used their own computer screens varying in sizes. In addition, it was unclear how participants engaged with the information display on the windshield. Therefore, this study aims to address two aspects. The first aspect is to carry out an in-person experiment which makes the experimental setup identical and controllable. The second aspect is to employ eye-tracking to investigate participant's attentions to the design and their association with spatial learning.

The in-person experiment took place in the summer of 2024. In total 17 participants (nine male and eight female) volunteered. All participants have never been to the city where the driving simulations represent. Participants were recruited through department listserv and flyers on the campus of University of Augsburg. Using a repeated measure, each participant can only take part in one of two conditions: 1) highway without AR landmark and local road with AR landmark; or 2) local road without AR landmark and highway with AR landmark. Each simulation is shorter than eight minutes which starts with the scenario without AR landmarks. Each participant was randomly assigned to a condition.

Participants watched each simulation at least twice while wearing a pair of Pupil Neon[1] eye-tracking glasses and then completed three tasks afterwards. Powered by a deep learning-based gaze estimation pipeline, Neon provides high-accuracy, research-grade data without calibration, enabling effortless use across various environments and populations. Measurement such as gaze, and fixation based on the relative coordinates of the screen. The measurement provides insight into the participant's attention while watching the driving simulations. For example, heat maps can show participants' gaze patterns on a car windshield. After watching the simulations on an 85" screen with the Neon glasses, participants completed a task assessing the route knowledge by recalling the sequence of landmarks along their travelled route. They then were asked to identify the correct direction between two distant locations, which were indicated either by AR landmarks or signs in the environment, depending on the experimental condition. The next task asked them to choose the correct configuration of the route from three similar maps. At the end of the experiment, participants completed a self-assessment of spatial skills developed by Münzer and Hölscher (2011), which assessed their strategies used in wayfinding, including egocentric, survey, and cardinal strategies.

The analysis of all collected data is ongoing. The results present participants' performance in three types of their acquired spatial knowledge: route knowledge, directional knowledge, and configurational knowledge which play an important role in developing spatial awareness. In addition, eye-tracked data such as gaze and fixation shed light on how AR landmarks engage participants to provide further insights on the relationship between participant's attention and their spatial learning.

Acknowledgements

The authors greatly appreciate the guest professorship from University of Augsburg, without which this collaboration of this study would not be possible.

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[1] For more information about Neon, visit https://pupil-labs.com/products/neon/technology.

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https://doi.org/10.5194/ica-abs-10-170-2025