The Impact of Simulation Modes on Acquiring Spatial Knowledge through Augmented Reality Landmarks on Windshield

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Abstract. Augmented Reality (AR) has emerged as a promising means to visualize landmarks for wayfinding or spatial learning. The work presented at the last symposium shows that displaying AR landmarks on windshield can be an effective way to support traveler's spatial learning in autonomous vehicles, using simulation consisting of recorded real-life driving video and added AR landmarks in an experimental setup. As the previous experiment setup was completely online, this current study intends to investigate the effects of different modes of simulation on the outcome of spatial learning. This study carries out two additional experiments, one of which is an in-person experiment using the same video-based simulation. The other experiment adopts a different simulation which is completely virtual using the head-mounted display. This study intends to compare the acquired spatial knowledge and eye-tracking measures through all three experimental setups and participant's interactions. As these three experiments represent the commonly used modes of driving simulation, an additional contribution of this study is to compare the effectiveness of different modes of simulations for experiments involving simulations of AR displays on windshield.

Keywords. Augmented Reality, Virtual Reality, Spatial knowledge, Landmarks, autonomous vehicles

1. Introduction

Many studies have pointed out the increasing popularity of using AR to visualize and superimpose additional spatial information into the physical surroundings for supporting wayfinding and navigation (see Liu et al., 2021; Keil et al., 2020). Using platforms for AR landmarks like head-mounted devices

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or smartphones, these studies assess the roles of AR landmarks on spatial learning in the indoor environment. Researchers have also suggested the use of AR landmarks on the windshield of vehicle to enhance traveler's experiences in autonomous vehicles (see Riegler et al. 2021). One main reason of using AR landmarks on windshield is to further engage travelers, as attention of travelers to surroundings in autonomous vehicles decreases significantly.

This research follows up the authors' previous work concerning the degraded spatial knowledge acquired by travelers in autonomous vehicles. Evidenced in studies investigating the acquisition of spatial knowledge using Satellite Navigation Systems (aka. GPS), driver's acquired spatial knowledge become very limited (Ishikawa, 2019; Parush et al., 2007). This situation can worsen in autonomous vehicles as travelers do not need to pay attention to the surroundings or directions at all. The previous work of the authors showed the potentials of using AR landmarks on windshield for supporting spatial learning through incidental learning (Li, 2023). The design of the landmark display builds on earlier research of visualizing unseen distant objects on smartphones (See Baudisch and Rosenholtz 2003, Gustafson et al. 2008, Gollenstede and Weisensee 2014, & Li, 2020) and on windshield through AR (Li, 2023).

The previous study, however, utilizes an online crowdsourcing platform for carrying out the experiments. Additionally, the previous study uses a real-life driving video to simulate the autonomous driving experience. Participants' computer screen can differ in size and interaction can be limited. More importantly, the experimental procedure is unsupervised. Therefore, this study intends to carry out two more experiments: one in-person experiment with the same simulation but on a large flat display and one in-person experiment with a simulation in a fully immersive virtual environment. The results can verify the effectiveness of each testing environment and inform the suitable choice of experiment setup for future studies.

2. Design

The AR landmark display used in this study employed the same design as in the previous study (Li, 2023), which adapts the suggestion of traveler's attention areas of the windshield display in autonomous vehicles (Riegler et al. 2019). Different from the visualization strategies for distant landmarks on smartphone that all edges of the screen are used for visualizing distant landmarks (Li, 2020). The windshield is divided into three portions. As shown in Figure 1, the top portion (20%) of windshield is for displaying unseen distant landmarks. The mid portion (50%) of windshield is for displaying labels for visible local landmarks. The lower portion (30%) of the windshield is for displaying auxiliary information such as street names and speed. Depending on the distance of a landmark in the environment to the traveler's location, the transparency of the landmark will gradually decrease or increase. If the distance is greater than one kilometer, a local landmark becomes transparent and not visible to the traveler. If the distance is shorter than one kilometer and a distant landmark enters the portion of windshield for local landmark display, this distant landmark becomes a local landmark.

Experiment 1 uses the same simulation from the author's study presented at previous symposium of location-based services, that is, a recorded real-world driving video with landmark graphics displayed on the windshield. In comparison, experiment 2 will develop driving simulations in an immersive virtual environment, where 3D models are being used. Participants use a head-mounted display (HMD) to get a stereoscopic view and can physically look around their virtual surroundings. The virtual simulation follows similar experience time and route characteries as in experiment 1. Each experiment consists of four simulated autonomous driving scenarios: on highway with AR landmarks; on local roads with AR landmarks; on highway without AR landmarks; and on local roads without AR landmarks. The last two scenarios serve as controlled conditions in each experiment.

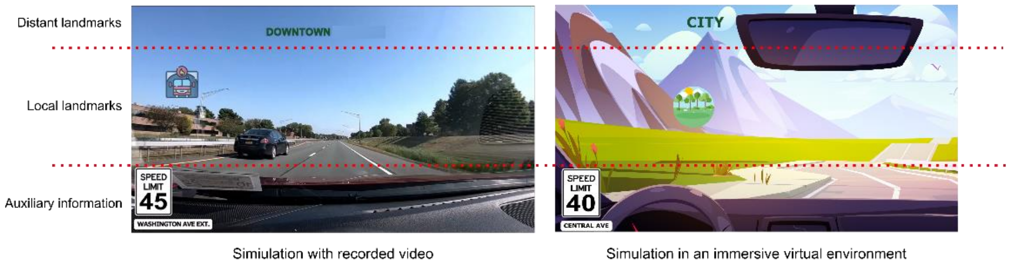

Figure 1: Illustrations of visualized AR landmarks and auxiliary information on windshield in both experiments' simulations. This example of simulation in virutal environment is designed and edited using assest from upklyak from Freekpik.com.

3. Experiment

Instead of using a crowdsourcing online platform with recruited participants from all over the world, this study is performed in a laboratory environment with participants recruited from the authors' university. Experiment 1 uses the same simulations from the previous study in an online environment to make the studies comparable. This time it adapts the same setup of Riegler and colleagues (2019) with which uses a 55 inch flat screen TV for playing the simulation. Like in the previous study, the simulation integrates recorded driving videos in real world and rendered AR landmarks using Adobe After Effects. Experiment 2 uses fully immersive virtual environments as the stimuli with participants wearing the HMD to simulate autonomous driving experiences. The experiments have been approved by the institute review board of the corresponding author's university.

Each participant will complete two scenarios (one with AR landmarks and one without) in a counter-balance order. The order of road types in each condition is counter balanced to avoid the order effect of road type. Each participant can only take part in one of two conditions: 1) highway without AR landmark (H) and local road with AR landmark (LAR); or 2) local road without AR landmark (L) and highway with AR landmark (HAR). Each simulated driving experience is approximately eight minute long which starts with the scenario without AR landmarks. Participants are randomly assigned to one condition. Participants are from the authors' universities with an expected number of 40 in each experiment. In the scenario without AR landmarks in each condition, participants simply watch the video (experiment 1) or experience the immersive virtual environment (experiment 2) as they sit in the driver's seat. In the scenario of AR landmarks, participants will first watch an example to help them understand the design before the experiment. Each participant is asked to view the driving simulation at least three times. They can view it for more times as they could not view it again once experimental tasks start in the laboratory. Eye-tracking data are collected for all participants during these scenarios to investigate the cognitive processing involved in the observation of spatial information. In the testing phase, the first task addresses route knowledge by asking participants to recall the order of landmarks along the traveled route. The second task addresses directional knowledge by asking participant to select two distant locations in the correct directions. Depending on the condition, the distant locations are indicated either by AR landmarks or signs in the environment. The third task addresses the configurational knowledge by asking participants to select the correct route configuration out of three options with the same topology. At the end of the experiment, participants complete a self-rated measure of spatial skills (Münzer and Hölscher 2011) which provides assessment of strategies used in wayfinding including: egocentric strategy, survey strategy, and cardinal strategy. Data collection will be done in the following two months to update the results.

4. Expected Results

While the in-person experiment is still ongoing and the immersive driving simulation is being finalized, it is expected that participant's performance would be different among these experimental setups. The results of both experiments will be compared with the author's previous study using a fully online testing platform with videos on participant's own computers. Participant's performance can be more accurate in the in-person laboratory setting as the screen is much larger than a home computer screen, which brings a more realistic experience to participants. It is also important to compare the effectiveness, as measured in spatial learning tasks and eye tracking, between using recorded driving video and using fully virtual simulation, as the latter condition is more flexible and controllable in experimental design.

5. Conclusion

This study compares the acquisition of spatial knowledge in autonomous vehicles by using two different experimental setups. The first one is using the same simulation as in our previous study which is created by recorded driving videos with rendered landmarks. But different from carrying it out on a fully online platform, this experiment employs in-person experiment with a large display. The second experiment also carries out in person but utilizes a fully immersive and controllable virtual environment to simulate autonomous driving scenarios. The study evaluates the effectiveness of all three setups by comparing online versus in-person experimentations and video-based verses immersive virtual simulations. The results will suggest the suitable testing environment for future studies with experiments addressing different aspects of spatial learning in autonomous vehicles.

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