Augmented reality head-up displays effect on drivers' spatial knowledge acquisition

Nayara de Oliveira Faria, Dina Kandil and Joseph L. Gabbard
nfaria@vt.edu, dinak@vt.edu and jgabbard@vt.edu
Virginia Polytechnic Institute and State University

ABSTRACT

Background: Drivers gather most of the information they need to drive by looking at the world around them and at visual displays within the vehicle. Navigation systems automate the way drivers navigate. In using these systems, drivers offload both tactical (route following) and strategic aspects (route planning) of navigational tasks to the automated SatNav system, freeing up cognitive and attentional resources that can be used in other tasks (Burnett**,** 2009). Despite the potential benefits and opportunities that navigation systems provide, their use can also be problematic. For example, research suggests that drivers using SatNav do not develop as much environmental spatial knowledge as drivers using paper maps (Waters & Winter, 2011; Parush, Ahuvia, & Erev, 2007). With recent growth and advances of augmented reality (AR) head-up displays (HUDs), there are new opportunities to display navigation information directly within a driver's forward field of view, allowing them to gather information needed to navigate without looking away from the road. While the technology is promising, the nuances of interface design and its impacts on drivers must be further understood before AR can be widely and safely incorporated into vehicles. Specifically, an impact that warrants investigation is the role of AR HUDS in spatial knowledge acquisition while driving. Acquiring high levels of spatial knowledge is crucial for navigation tasks because individuals who have greater levels of spatial knowledge acquisition are more capable of navigating based on their own internal knowledge (Bolton, Burnett, & Large, 2015). Moreover, the ability to develop an accurate and comprehensive cognitive map acts as a social function in which individuals are able to navigate for others, provide verbal directions and sketch direction maps (Hill, 1987). Given these points, the relationship between spatial knowledge acquisition and novel technologies such as AR HUDs in driving is a relevant topic for investigation.

Objectives: This work explored whether providing conformal AR navigational cues improves spatial knowledge acquisition (as compared to traditional HUD visual cues) to assess the plausibility and justification for investment in generating larger FOV AR HUDs with potentially multiple focal planes.

Methods: This study employed a 2x2 between-subjects design in which twenty-four participants were counterbalanced by gender. We used a fixed base, medium fidelity driving simulator for where participants drove while navigating with one of two possible HUD interface designs: a world-relative arrow post sign and a screen-relative traditional arrow. During the 10-15 minute drive, participants drove the route and were encouraged to verbally share feedback as they proceeded. After the drive, participants completed a NASA-TLX questionnaire to record their perceived workload. We measured spatial knowledge at two levels: landmark and route knowledge. Landmark knowledge was assessed using an iconic recognition task, while route knowledge was assessed using a scene ordering task. After completion of the study, individuals signed a post-trial consent form and were compensated $10 for their time.

Results: NASA-TLX performance subscale ratings revealed that participants felt that they performed better during the world-relative condition but at a higher rate of perceived workload. However, in terms of perceived workload, results suggest there is no significant difference between interface design conditions. Landmark knowledge results suggest that the mean number of remembered scenes among both conditions is statistically similar, indicating participants using both interface designs remembered the same proportion of on-route scenes. Deviance analysis show that only maneuver direction had an influence on landmark knowledge testing performance. Route knowledge results suggest that the proportion of scenes on-route which were correctly sequenced by participants is similar under both conditions. Finally, participants exhibited poorer performance in the route knowledge task as compared to landmark knowledge task (independent of HUD interface design).

Conclusions: This study described a driving simulator study which evaluated the head-up provision of two types of AR navigation interface designs. The world-relative condition placed an artificial post sign at the corner of an approaching intersection containing a real landmark. The screen-relative condition displayed turn directions using a screen-fixed traditional arrow located directly ahead of the participant on the right or left side on the HUD. Overall results of this initial study provide evidence that the use of both screen-relative and world-relative AR head-up display interfaces have similar impact on spatial knowledge acquisition and perceived workload while driving. These results contrast a common perspective in the AR community that conformal, world-relative graphics are inherently more effective. This study instead suggests that simple, screen-fixed designs may indeed be effective in certain contexts.

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