I Am The Passenger: How Visual Motion Cues Can Influence Sickness For In-Car VR

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ABSTRACT

This paper explores the use of VR Head Mounted Displays (HMDs) in-car and in-motion for the first time. Immersive HMDs are becoming everyday consumer items and, as they offer new possibilities for entertainment and productivity, people will want to use them during travel in, for example, autonomous cars. However, their use is confounded by motion sickness caused in-part by the restricted visual perception of motion conflicting with physically perceived vehicle motion (accelerations/rotations detected by the vestibular system). Whilst VR HMDs restrict visual perception of motion, they could also render it virtually, potentially alleviating sensory conflict. To study this problem, we conducted the first on-road and in motion study to systematically investigate the effects of various visual presentations of the real-world motion of a car on the sickness and immersion of VR HMD wearing passengers. We established new baselines for VR in-car motion sickness, and found that there is no one best presentation with respect to balancing sickness and immersion. Instead, user preferences suggest different solutions are required for differently susceptible users to provide usable VR in-car. This work provides formative insights for VR designers and an entry point for further research into enabling use of VR HMDs, and the rich experiences they offer, when travelling.

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

Author Keywords

In-motion; In-car; Automobile; Autonomous Car; Passenger; Virtual Reality; Mixed Reality; Motion Sickness; HMD;

INTRODUCTION

For many travellers, a long journey is not to be relished. Journeys can last for significant durations, for example car journeys in UK last on average 22 minutes [17], with commutes lasting 55 minutes [58]; in the USA, drivers spend 56 minutes a day on average in-transit [76]. These journeys can be repetitive (e.g. the commute to work), with travellers frequently noting that such trips are wasted time [24, 80]. Whilst collocated social interaction can offer some respite [33], journeys are often conducted without the physical presence of friends or family, with the car providing solitary personal space [24]. Entertainment and productivity options are limited to displays significantly smaller than those in the home or office (e.g. phones, tablets, laptops, dashboards and rear-seat systems [81]). In the specific case of car journeys, these issues will gain increasing prevalence given the arrival of fully autonomous cars, which would free drivers from the driving task, and consequently increase the occurrence of passenger experiences.

While autonomous cars will allow for radical redesign of the car interior (e.g. seating locations and internal display configurations [20]), passengers will still perceive themselves as being in a constrained space, with the physical limitations of the interior dictating what is possible to be rendered and displayed. Moreover, the passenger's visual perception of motion may be compromised by use of these displays, through changes in gaze angle (e.g. looking down/away from windows) and occlusion (presenting content over windows, or occluding windows to enhance immersion [43]). This has implications for motion sickness, which in-part arises from the sensory mismatch of visually and physically perceived motion [59, 85].

Many people become travel sick when watching TV, reading or working in vehicles, meaning that they cannot use the time productively. These problems will grow in number with the arrival of autonomous cars [20, 19, 71]; the act of driving stops many people from feeling sick due to the anticipatory cues of being the driver [75] and without these cues people who did not get sick will now do so. Consideration needs to be given to how entertainment and productivity can be supported whilst minimizing motion sickness. Virtual Reality (VR) and Augmented Reality (AR) Head Mounted Displays (HMDs) have the potential to significantly expand the display space, enabling immersive entertainment and workspaces that go beyond the physical limitations of the car interior. Problematically, VR HMDs also occlude visual perception of reality [44, 6] and thus the car's motion, and are likely to lead to sensory mismatch and, consequently, motion sickness. However, assuming the orientation and velocity of the vehicle can be tracked at low latency, HMDs have the potential to portray the vehicle motion virtually. Accordingly, for both VR HMDs, and passengers more generally, the problem of occluding the visual perception of motion, and the resultant sensory mismatch this causes, can be solved (as demonstrated in consumer VR rollercoasters which run over a known and precisely controlled route [77]). VR and AR HMDs are capable of conveying the motion of the vehicle at all times, from all viewing angles. Consequently, the problem is then: how should these

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