Virtual Reality Passenger Experiences

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Figure 1: Examples of our work on VR passenger experiences in car [33, 32] and in flight [42]

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Abstract
Our research aims to improve passenger journeys across both public and private transport, in cars, buses, planes and trains by utilizing Mixed Reality head-mounted (e.g. visual/auditory augmented and virtual reality) displays. This paper discusses our initial motivations and formative work in this area, both for in-car VR [33, 32] and for in-flight VR [42], and outlines some of the key challenges we anticipate in enabling mixed reality passenger experiences.

Author Keywords
Virtual reality; augmented reality; passengers; transportation; in-transit; mixed reality;

CCS Concepts
•Human-centered computing → **Virtual reality; •Applied computing** → **Transportation;** Consumer health;

Introduction
ViAjeRo (http://viajero-project.org/) is a new Horizon 2020 ERC project aiming to improve passenger journeys through the use of immersive Virtual and Augmented Reality (VR and AR, referred to in combination as Mixed Reality [41]) to support entertainment, work and collaboration when on the move. In Europe, people travel an average of 12,000km per year on private and public transport, in cars, buses, planes and trains, with a total of 700 billion passenger km per year

Figure 2: Examples of VR passenger experiences: 1) *COMS-VR* [25]; 2) *VR-OOOM* [14]; 3) *VR HYPERSPACE* [40]; 4) *CarVR* [20].

in the UK alone [1]. These journeys are often repetitive, with travellers frequently noting that such trips are wasted time [13]. This total is expected to increase thanks to the arrival of fully autonomous cars. Consequently, more people will be passengers wanting to fill their travel time usefully and improve their work/life balance [28].

As Groening [16] notes, *"since the 1970s, passengers have sought more forms of separation between themselves"*, with seatback displays, phones, tablets and laptops all used as a *"sensory filter ...crucial for sensory privacy and exertion of control"*. However, these displays are imperfect; they are limited in size, immersion [7], and privacy. Certain display positions induce motion sickness [15], while passengers still perceive themselves as being trapped in the constrained and repetitive space of the vehicle. We suggest that the potential for technology to help passengers reclaim this lost travel time is impeded by 3 significant challenges:

Confined spaces: These limit our interactions and force us to use small displays such as phones, tablets, dashboards, and seat-back/rear-seat systems;

Social acceptability: We may be sharing the space with others, whom we may or may not know, inducing a pressure to conform which inhibits technology usage;

Motion sickness: Many people get sick when they read or play games when in motion - it can take hours for symptoms to resolve and productive time is lost.

VR/AR headsets have the unique possibility to overcome these challenges in ways no other technology can. In this paper, we discuss the motivations behind *ViAjeRo*, highlighting key prior research and industry advancements, as well as our own contributions in identifying the challenges in facilitating passenger MR experiences.

Background and Motivation

MR HMDs can overcome many of the problems suffered by existing displays used in transit. They are unrivalled in terms of immersion/presence [7], with privacy dictated by software constraints rather than physical visibility. Occlusion issues are no longer relevant as any view can be presented in the headset, whilst interactions can move with the user. Healthy, comfortable gaze angles are possible as content can be displayed anywhere around the user and moved at any time. New possibilities for interaction can be supported via gaze [3] or direct touch [5]. Communication and social settings can be created, e.g. telepresence where those you are addressing appear mapped into your local environment [10, 34]. The VR Hyperspace project, which finished prior to the advent of new, cheap, consumer VR headsets such as the Oculus Rift, did the first work on the benefits of VR in transit, with their stated aim being to *"enhance the passenger comfort through... (the) adoption of Virtual and Mixed Reality technologies in the future air cabin"* [4]. Soyka *et al.* simulated a flight experience on a virtual magic carpet ride, so that airline passengers would experience their journey across a VR landscape with unrestricted views [40].

Research into MR HMDs in transit has focused on initial attempts at exploiting vehicle motion and context for presence and immersion, rather than general purpose applications and content consumption (see Figure 2). Kodama *et al.* [25] discussed the use of cars as motion platforms for VR games, where the content was in synchrony with the car motion along one axis (acceleration forward). The VR content was effectively a rollercoaster and induced a significant sensation of falling, despite there being no physical vertical motion experienced. This concept of having VR users control a vehicle was extended by Goedicke *et al.* [14]. They adopted a 'fused reality' approach where passenger driving actions could be simulated by a real driver to create more realistic driving simulators for automotive research. Hock *et al.* gamified car journeys by using the physical movements of a car mapped as inputs to a first-person virtual helicopter flying over a pre-generated virtual landscape [20], as have others [19]. As the car turned, this turned the helicopter in the VR display. Similarly, there exists a number of consumer rollercoaster rides where the virtual experience is tightly linked to the physical motion perceived, to varying degrees of success [23].

Figure 3: From top: 1) Holoride passenger VR [22], 2) Symbioz passenger VR [8]

There is increasing recognition of the importance of the potential of the VR in transit market across a number of international companies, which have investigated prototype VR experiences, e.g. journeys down virtual rivers and roads (as discussed by Renault in their 'Symbioz' demonstration [8], Audi and Holoride [22] and Apple [37]), rollercoasters or through the sky [20, 40], and the short trial Qantas ran giving VR HMDs to first-class passengers [35]. Other airlines have also tested VR headsets for use in-flight [6, 2]. There have also recently been instances in the popular press of VR head-set usage in planes [18, 21, 27]. As a blogger for The Economist noted: *"VR headsets on planes mean we can isolate ourselves from irritating cabin-mates"* [18]. Lewis *et al.* suggest: *"Virtual environments can fully or partially distract people from sources of discomfort, becoming more effective when they are interesting."* [29].

Challenges to Adoption

Motion Sickness

Motion sickness directly affects more than one third of travellers [26] and can be induced in many more by bad design choices. The causes are not fully understood but the general view is sensory mis-match: the eyes see the inside of the car which is not moving relative to the occupant, but the vestibular system perceives all the motions of the vehicle [36]. Symptoms including nausea, vomiting, dizziness, headaches and fatigue. Many become motion sick when watching screens, reading or working in vehicles, and recovery time is slow (often hours), so they cannot use travel time productively. This problem will grow with the arrival of autonomous cars [9, 39, 28, 24]; the act of driving stops many people from feeling sick [38], therefore people who did not get sick will in the future do so.

Our starting point in this domain was in examining the use of VR in-car [33, 32], building upon insights from previous projects such as VR Hyperspace. We evaluated initial prototype solutions using peripheral visual cues, visually integrating car motion into generic VR content to resolve sensory mis-match. Our study took place in a car being driven around a city environment with passengers experiencing different VR presentations to establish baselines. Overall, VR caused significant motion sickness, however, peripheral visual motion cues were generally preferred by those with the most susceptibility. This research gives confidence that VR passenger experiences could become a reality in the near future, and opens the door to other approaches for achieving sensory alignment [30] or manipulating the perception of vehicle motion as done previously in VR [43].

Social Acceptability

Alongside our research into motion sickness and perception, we also looked at passenger UX issues, specifically examining VR experiences in-flight [42]. HMDs partially occlude (AR) or entirely immerse (VR) the user in a virtual space. When interacting with technology that is highly visible, the sustained spectatorship of other passengers creates a potentially uncomfortable situation. Loss of awareness means that MR users may accidentally disrupt others or physically invade their space. Other passengers may not know if they are visible to an HMD wearer and be unsure how or if they can interact with them. Interaction with other

Figure 4: An example of a prototype mid-air interaction being tested in-car.

Figure 5: Shared telepresent VR experiences [34] could be facilitated in-transit

passengers is often unavoidable: to ask for directions or to move out of the way. Safety is an issue if HMD wearing passengers are unaware of dangerous situations or the actions of others. There are also practical reasons to need awareness of surroundings, e.g. to protect your belongings or to know when to get off a bus [17].

In PlaneVR [42] we explored these issues for the first time. Via a survey, we identified the current shortfalls of entertainment devices and attitudes towards VR usage in an aeroplane setting. The survey gave us three design directions for an in-flight entertainment application: to reduce movement required to interact in VR, to give users in VR peripheral awareness of their physical environment, and to enable interruption without requiring any physical contact. We created a prototype with features based on these ideas and evaluated this in a focus group study, finding issues regarding isolation from known intimacy groups (e.g. friends/family also travelling) and facilitating necessary interruptions by fellow passengers and staff. More broadly, the results provided insights into designing experiences that bridge the gap between reality and VR/AR, and ways of supporting interruption and spectator experience for passengers.

Interaction in Confined Spaces

PC users are accustomed to high-throughput, accurate, rested, low-effort interactions with content. MR HMDs are more limited, currently employing hand and gesture-based interactions using controllers or free hand interactions. These are mostly for simple pointing, movement and button pushing. High-throughput interactions, such as text entry, have not been solved for desktop MR, whilst accurate rested inputs can be difficult in a moving environment. Our own work has begun to investigate this by bringing more sophisticated controllers and keyboards into virtual scenes [31], whilst concepts such as rhythmic gestures [12] combined with multimodal feedback [11] could help users to perform casual mid-air interactions. However, fundamentally current MR interaction techniques do not consider the physical constraints of seated passengers: the moving physical environment reduces fine motor control, seat belts restrict body movement and the proximity of others means that smaller, robust and more discreet interactions are needed. There is much work on interaction for car drivers, but these are designed to be low attention and low bandwidth so that they do not interfere with driving. If we can arrive at a point where headsets do not provoke motion sickness and are felt to be acceptable/safe to wear, then the question becomes: how can we support productivity and interactive entertainment in constrained passenger seating?

Conclusions

This paper has provided a brief overview of the motivations behind our current research examining mixed reality passenger experiences in *ViAjeRo* (https://viajero-project.org/). Whilst it is impossible to predict eventual consumer adoption of such technologies, we believe the AutoUI and HCI communities can play an important role in enabling MR headset adoption by addressing some of key challenges in facilitating these new passenger experiences, namely: overcoming motion sickness, facilitating experiences that take into account their shared and social surroundings, and providing new interaction techniques to better enable productivity and entertainment in confined and constrained surroundings such as a car or plane interior. In this way, we can make travel more enjoyable and productive, helping passengers reclaim lost time in-transit.

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