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Analysis of Interaction Spaces for VR in Public Transport Systems

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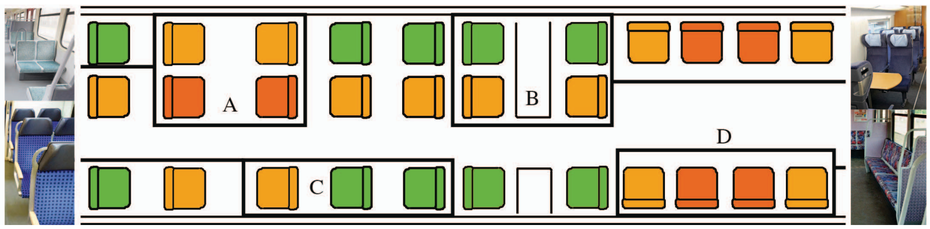

Figure 1: Possible seating scenarios in public transportation systems. Colors represent how a user on this seat could be constrained or interrupted by the environment. Green to red: less interruption to higher interruption level.

Index Terms: Human-centered computing—Human-computer interaction (HCI)—Interaction Paradigms—virtual reality;

1 Introduction

Virtual reality (VR) is becoming increasingly integrated into people's lives. However, current applications are usually limited to a certain fixed location. With the introduction of wireless and mobile head mounted displays (HMD) there is no longer a need for a workstation. In this way it is possible to introduce VR experiences in public spaces. Some airlines have already started to use VR as an alternative entertainment system on flights. The company *Inflight VR* offers a complete system with various applications approved for in flight VR [2]. However, VR in an aircraft is a controlled space compared to other public transport systems. Flixbus in the US also offers FlixVR, a long distance bus experience, where passengers can experience different games and cinematic experiences [1]. It seems that VR is on the rise in the transportation system. The use of VR in any kind of transport brings new challenges. Especially in comparison to a controlled environment of a laboratory or living room. In this work we are focusing our evaluation on VR scenarios in public transport systems: planes, train, metro, tram or as a co-driver in a car. We analyse different seating situations for each type of transportation and its implications to VR applications. We present an analysis of possible scenarios including their challenges and constraints for interaction, space and navigation for public seated VR.

2 Related Work

Driving the advances of VR in everyday life situations is a vast and current field. We provide only a partial overview of relevant research to interaction in mobile scenarios and motion sickness due to the influence of a continuously accelerating and moving environment.

Interaction in public transport: Most research focuses on VR in cars instead of other public transportation vehicles. Multiple applications were developed to experience VR in a car, where its movements were mapped to the virtual world [4, 6]. The goal was to evaluate the applicability of VR in a car for entertainment and calming virtual experiences.

Interaction in a confined space in the back of cars is also a researched topic to allow children in a backseat to interact with a tablet [8]. The focus was on safe interaction methods for the available space and healthy sitting of the children. Interactions like balancing something on the head or catching ghosts in a jar were enjoyable for the children and didn't need much space.

Motion sickness in VR and public transport: Motion sickness in VR is a known issue and a recurring topic for VR research. The mismatch of visually perceived and sensory input triggers motion sickness [7]. Each new type of technology or scenario either increases the comfort factor of a VR application or needs to find strategies to reduce motion sickness. The motion sickness effect of vehicle motion in busses [9] showed that 28,4% of passengers reported discomfort throughout the journeys with different kind of drivers and coaches. The driving style of individual drivers affected the illness level significantly, because fore-and-aft and lateral acceleration stimulate nausea. The effect of motion sickness in a car with a HMD was tested in different VR scenarios [5]. The study showed that motion sickness increases in-motion.

3 Scenarios

We evaluated different scenarios summarized in Table 1 and Figure 1. Our focus was the possible interaction space, a level and frequency of interruption and interaction metaphors possible in each configuration. It needs to be pointed out that all seats, no matter the scenario, could possibly be facing against the moving direction, which can cause more motion sickness. All seating configurations in public transport systems can be reduced to one of the following scenarios:

A - Row seats with view to the front side of next row: A row facing other seats have the highest neighbor count. Other passengers are sitting to the front and to the side. While people take a seat the interaction area will be compromised.

B - Row seats facing table: Sometimes areas with seats facing each other have a table between them. This reduces the chance to get interupted. Additionally the table could be used as an haptic feedback area for VR.

C - Row seats with view to the backrest of next row: Seats with only the backrest of other seats in front have the lowest interuption level. Only the people from the same row can interupt the VR experience or could be influenced by the user. Additionally the backrest allows for a realworld boundary and could be used for haptic interaction. The interaction area to the front could be smaller in comparison to other seats, but will not change unexpectedly.

D - Row seats with view to aisle and neighboring seats: Another szenario are seats, which are directly facing the aisle. In most cases there are multiple seats next to each other to offer a lot of space in front of the sitting area for bigger objects, bycicles or

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standing space. In a empty vehicle these seats offer the biggest interaction area to the front. But as middle seats between the ends are less wide, the interaction area width is also smaller.

One special case is standing: Due to the acceleration and moving direction, standing while using VR can be really dangerous for the user and other passenger.

Table 1: Scenarios - rows match the seating configurations in Figure 1, A - Seats frontfacing, B - Seats in front of Table, C - Seats facing backrests, D - Seats left and right, Aisle in Front. Each row in a cell describes the maximum number of possible neighbors (next to and opposite), width/depth of interaction space, interruptions (no/neighbors/aisle), interaction possibilities (haptic with backrest or window, free interaction, limited interaction)

	Window Seat	Middle Seat	Aisle Seat
A ↑↓	two neighbors 0.6/0.8m no haptic + limited	three neighbors 0.5/0.7m neighbor limited	two neighbors 0.6/0.8m neighbor + aisle limited
B ↑↓	one neighbor 0.6/0.8m no haptic + free	two neighbors 0.5/0.7m neighbor haptic + free	one neighbor 0.6/0.8m neighbor + aisle haptic + free
C ↑↓	one neighbor 0.6/0.8m no haptic + free	two neighbors 0.5/0.7m neighbor haptic + free	one neighbor 0.6/0.8m neighbor + aisle haptic + free
D ↔	one neighbor 0.6/0.8m aisle haptic + limited	two neighbors 0.5/0.7m aisle limited	one neighbor 0./0.8m neighbor + aisle limited

4 Design Aspects for VR in public transportation

To evaluate the scenarios in section 3, we developed user stories for the different seating positions. The user stories included playing popular VR games or using the public transportation system (see Figure 2). By playing through and reenacting the scenarios, we were able to identify several design aspects that need to be considered or resolved to create a compelling VR experience in public transport.

Motion Sickness: Seated VR in moving vehicles poses a specific problem for simulator sickness, as the introduction of external movements increases the problem. While vehicles travelling with large speed such as airplanes and long distance trains and cars rides will not be affected as much. Public transport or cars in a city are influenced even more. Matching the external motion to the virtual world will improve the comfort level of users.

Safety: For motion tracking in a living room or laboratory the user calibrates the area in which he can move around safely. For confined spaces with obstacles we would need a calibrated interaction area. This area could either be defined by the user, similar to the boundary calibration of current HMDs, or cameras can be used to map the surrounding. With depth information and object detection a safe place for interactions could be visualised to give the user feedback or warnings. It should always be an option for the user to visualise the real world in VR. Without having this option the user will most likely feel very observed and vulnerable. In close-range city rides the possibility to orientate is crucial - for example current location. Audio announcements can be used as voice commands into applications and forward the information to the user. Acceleration, moving direction, interruption level and other status informations could either be displayed or influencing the vision in the HMD.

Input: Current HMDs have either controller or handtracking available. Pointing around with a controller will very likely result in conflicting with other passengers and requires to handle additional hardware. Using VR in public spaces will be impractical, if the user has a complex setup process. The faster the setup can be done, the more likely people will want to use it. Hand tracking on the other side fits perfectly in the available space as the tracking area for hands is close to the HMDs. Fortunately there has been research in the past years to improve the hand tracking quality. Furthermore the available surrounding can be integrated into VR. Backrests or tables could be detected by a camera system to allow haptic input.

Figure 2: We evaluated the scenarios A, C and D in a metropolitan railway system and measured interaction space and possible interruptions by other passengers.

5 Conclusion

With this analysis we want to start the discussion of seated VR in public transportation. By taking a deeper look at various seating setups apart from a safer tracking area, we addressed different design aspects which are important. The most important issues are motion sickness, safety to users and passengers and input and interaction metaphors. VR applications need to be designed for comfort and security while interaction concepts for confined spaces should allow for an enjoyable experience. Environment-aware HMD applications as demonstrated by Gugenheimer et al. [3] can help to notify users in case of changing scenarios and interaction conflicts. Using the available tables, backrests or windows one can also allow for interactions with haptic feedback. This would allow for more sophisticated input and additionally increase VR experiences.

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