Multi-Modal Transition and Traces in Everyday Mobile Virtual Reality

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In everyday transport, virtual reality (VR) users are challenged to quickly transition between realities for a variety of reasons, such as onboarding other passengers into the shared space or making a phone call. To facilitate this in-car transition, we interviewed nine automotive experts about the feasibility of interactive multi-modalities supporting this process, e.g., using car-interior-based passive haptics. We discussed different solutions for ten real-world incidents occurring on the road and triggered by the user, the VR system, or continuous communication between both. The results showed the consensus on using visual and auditory modalities but diverged in using haptic stimuli due to its relevance to emergencies in the automotive context. Our position paper explores multi-modal traces as anchor points to support a quick transition from the real environment back to VR. Finally, we discuss the potential for multi-modal transition in everyday mobile VR to facilitate simultaneous activities in both realities.

CCS Concepts: • **Human-centered computing** → **Virtual reality**.

Additional Key Words and Phrases: everyday mobile VR, haptic display, interruption recovery, HMD, passenger well-being

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1 INTRODUCTION

Everyday Virtual Reality (VR) deals with environments such as homes or transportation [2]. Specifically, people start to use head-mounted displays (HMDs) in a range of transportation means from airplanes [13] to passenger cars [4, 6–9]. Researchers expect future passengers to bring their own HMDs to spend their travel time effectively in various ways. Potential passenger activities comprise, e.g., working in a virtual open office [6] or relaxing at a virtual beach [7]. However, interruptions, or breaks [1], from the ever-changing real environment (RE) challenge the users' sense of presence in VR. For example, while relaxing in a beach scenario, the passenger receives an incoming phone call or another passenger on-boards the shared space. Such interruptions make it harder for HMD users to resume their previous state, which might cause them to completely drop out of their VR experience. In our work, we approach the problem by interviewing nine automotive experts about the feasibility of interactive multi-modalities to facilitate the transition from VR to RE and vice versa. Accordingly, we focus on: *How can we support future HMD users through different interaction modalities to recover from interruptions along the way and restore their feeling of presence in passenger activities?* We develop a systematic overview of transition triggers (system, user, and a continuous trigger by both) and present interaction modalities per system cluster. Based on our findings, we derive a design concept of transitional interfaces that aims at facilitating the recovery through personal traces of use as memory anchor points.

2 BACKGROUND

VR technology is pervading our everyday life [2]. Prior work anticipated the passenger use of HMDs in future mobility to spend travel time in a diverse way such as relaxation [7, 9], productivity [6], and entertainment [4, 8]. Facing less controllable environments in such mobile VR, users can easily get interrupted in their feeling of presence by an onboarding passenger or an incoming phone call. Moreover, the awareness of the reality (e.g., changes of vehicle states or traffic situations) is essential throughout the entire passenger VR experience [5]. To approach this, Li et al. [7] proposed transferable ambient information using artifacts integrated into the virtual environment e.g., a ship and seagulls embedded in a virtual beach as metaphors of travel information like vehicle speed and journey duration. In a VR study, George et al. [3] explored a seamless transition (SeaT) concept by deploying multi-modalities like visual and auditory cues to support simultaneous engagements in both realities. However limited research studied the use of the haptic modality. Referring to the design research, prior work applies traces of use as memory anchors that connect an object with a certain situation and support users in remembering [11, 12]. Such traces often relate to a change in the material texture caused by prior interaction that can be sensed through tangible interaction or visual indication [10]. In this position paper, we focus on in-car transition interfaces based on a multi-modal approach like haptic, visual, and auditory cues across realities.

3 AUTOMOTIVE EXPERT INTERVIEW

To understand the motivation for transitions on the go, we interviewed nine automotive experts recruited from the ACM AutomotiveUI community. In one-to-one interviews, we showed a video clip of an exemplary application Nature Treks VR[1] to demonstrate passenger use of HMDs for relaxation on a virtual beach scenario. Inspired by the SeaT design space [3], we prepared ten incidents that were triggered by the user, the system, or the continuous communication between both. Making a Phone Call, for example, is triggered by the user, while answering a Phone Call is triggered by an external source and notified through the VR system. In addition, we ideated corresponding transition concepts using the multi-modal approach. Figure 1 presents an overview of all ten incidents and transition concepts using different modalities. For example, when encountering onboarding passengers, the user receives notifications from the VR system displaying their avatars, location information, and surrounding real environments on top of the virtual beach scenario. After real-world interruptions, a shape-changing armrest could enable the user to leave physical and tangible markers (e.g., mapped to visual changes in the virtual beach) and, thus, facilitate their recovery of presence in relaxation by recalling their previous state visually and tangibly (see Figure 2). During the interview, we asked the experts: 1) how the VR system can notify the passenger with the least interruption in relaxation especially considering the use of multi-modalities, 2) how the system can help the passenger transition from real-world incidents back to relaxation in VE, and 3) their comments on our concept of traces of use by creating a tangible, visual, and/or auditory anchor point cross VE and RE. We recorded the interviews of which each took about one hour in total.

4 RESULTS AND INSIGHTS

Table 1 shows an overview of the interview results. After clustering mentioned modalities for notification in VR, we found that our experts favor using visual modality across incidents (n=77/90), followed by auditory cues (n=48/90), and haptic stimuli (n=11/90). Our experts agreed in using visual and auditory stimuli to notify passengers of interruptions.

[1] https://naturetreksvr.com/, last visited November 10, 2021

However, their opinions diverged in active haptic stimuli (e.g., vibration) because these were considered relevant to emergencies in the car context, which *"might interrupt the relaxation experience in VR"*.

Regarding the transition phase back to VE, we found three categories: i) the majority questioned the necessity of seeing the real environment and demanded a transition within VR (VE–VE; n=60/90). For example, they can quickly complete the interruption task in another corresponding application in VR like video call and switch back to the relaxation application; ii) some considered the possibility that the user wants to stay in the real environment without getting back to relax when the incident is crucial such as the onboarding passenger and the point of interest (VE–RE; n=15/90); and iii) others found the concept of anchor points a novel and valid strategy but hard to evaluate its feasibility without experiencing a working prototype (VE–RE–VE; n=8/90). They envisioned keeping visual reference in virtual environments such as vehicle motion and the steering wheel, fading in and out the real environment for a smooth transition, and consistent prompt sounds for reminding the transition mode.

User-triggered	***Re-navigate for Food*** While relaxing, you suddenly want to stop by your favorite restaurant on the way. *Transition Concept:* Pop-up current position and alternative routes; 2D map or the 3D rendering of the street view; mid-air gesture interaction for rerouting; fadeout street view; back to relaxation; haptic patterns on the seat guiding the user to continue the meditation process.	***Adjust Temperature*** While relaxing, you want to adjust the air conditioner and lower the in-vehicle temperature. *Transition Concept:* Mid-air gesture interaction for changing temperature; metaphor feedback via the weather system in the virtual environment.	***Point of Interest (PoI)*** While relaxing, the system notifies you of passing by a place that you liked on the map. *Transition Concept:* Prompt sounds; semi-transparent street-view blend into the virtual scene; voice interaction to mark the PoI and download its media library; revisit this place in a 360-degree video; back to relaxation.	***Make Phone Call*** While relaxing, the system reminds you to call your friends. *Transition Concept:* A menu for making a call with the dialing screen and a list of contacts; switch to other VR Apps; back to relaxation by feeling the haptic markers left on the shape-changing armrest.
System-triggered	***Re-navigate for Quickest Route*** While relaxing, the system suggests a faster route to avoid traffic jams ahead. *Transition Concept:* Pop-up current position and alternative routes; 2D map or the 3D rendering of the street view; mid-air gesture interaction for rerouting; fadeout street view; back to relaxation; haptic patterns on the seat guiding the user to continue the meditation process.	***Low Fuel Warning*** While relaxing, the system informs you the fuel level is under 20% and suggests you visit a gas station. *Transition Concept:* Blinking gas tank icon and warning sounds; default system decision is a detour to the closest gas station; on-demand full-screen 2D map for entering a specific gas station the user preferred; the user stays in the virtual environment throughout the incident without seeing much of the reality.	***On-boarding Passenger*** While relaxing, the system notifies you of an on-boarding passenger. *Transition Concept:* Display a passenger icon and haptic hints on the seat; render an avatar of the onboarding passengers, their location, and the real environments; shape-changing armrest that the user can leave haptic markers to recall the previous relaxation; auditory stimuli using the same background music; visualization to guide the user rebuilt prior breath pattern.	***Answer Phone Call*** While relaxing, the system notifies a call from your friends. *Transition Concept:* An incoming call interface showing the avatar and name of the caller; pick up the call by switching to other VR Apps; back to relaxation by feeling the haptic markers left on the shape-changing armrest.
Continuous	***Road Priority*** While relaxing, the system asks your decision when in conflict with the facing car. *Transition Concept*: on-demand real-time external camera view displayed in the user's peripheral field of view; cooperate driving with the car system via text or voice interaction to make a decision.	***Invite to VR*** While relaxing, you want to share the view with your friends. *Transition Concept:* the system plays the video and audio via the integrated infotainment system; the user sees the avatar of the non-VR passenger.		

Fig. 1. Ten incidents and relevant multi-modal transition concepts asked in the automotive expert interview.

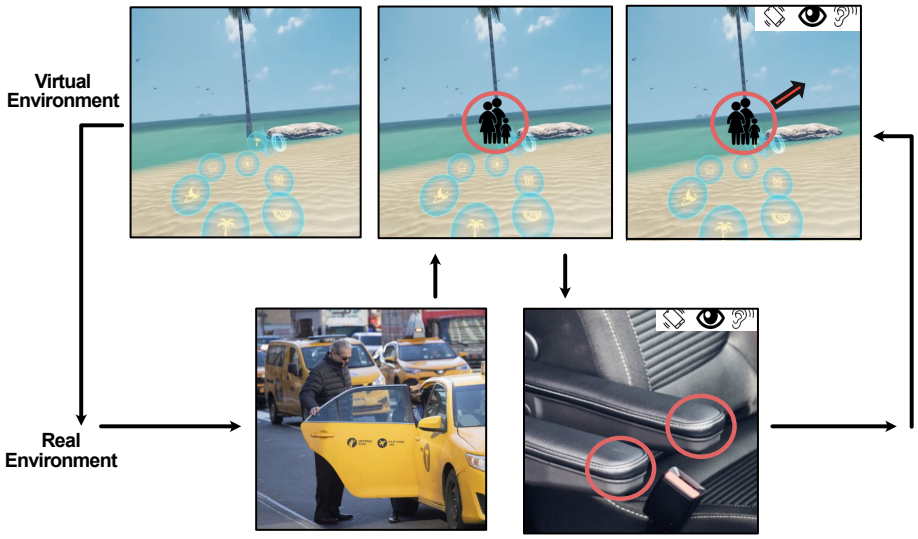

Fig. 2. The in-car multi-modal transition across virtual and real environments when the passenger wearing the HMD for relaxation on a virtual beach and having other onboarding passengers at some point in time.

Table 1. Count of experts who mentioned modalities for transition notification in VR and chose different transition-back concepts.

		User-triggered				System-triggered				Continuous		
		Re-navigate for Food	Adjust Temperature	Point of Interest	Make Phone Call	Re-navigate for Quickest Route	Low Fuel Warning	On-boarding Passenger	Answer Phone Call	Road Priority	Invite to VR	Total Count
Mentioned notification modality(s)	Visual	9	6	5	7	8	9	8	9	8	8	77
	Auditory	6	4	3	7	7	8	4	4	3	2	48
	Haptic	4	1	0	0	1	3	0	2	0	0	11
Transition-back concept	VE-VE	9	8	1	8	7	8	2	7	7	3	60
	VE-RE(-VE)	0	0	5	0	0	1	5	0	0	4	15
	VE-RE-VE	0	0	2	0	2	0	2	0	2	0	8

5 SUMMARY AND OUTLOOK

In everyday mobile VR, less controllable real environments challenge the pursuit of full presence in virtual environments during the passenger use of HMDs. However, limited work in this interdisciplinary area, i.e., automotive and VR research, explored contextual simultaneous engagements in both realities. In this position paper, we interviewed nine automotive experts to understand the possible contextual interruptions and corresponding transition strategies. The results showed that the multi-modal notification in VR (e.g., visual, auditory, and haptic cues) has the potential to enable the user or the system to trigger the transition according to the emergency level of the real-world incident. Moreover, if the incident is urgent, the transition should offer a quick solution within VR across different application and consider the possibility that the user may completely abort the experience in HMD. Based on the insights, we advocate future studies to design and measure the degree of multi-modal, personal traces of use as anchor points for different levels of transition demanded by the passenger using VR headsets.

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