Evaluating 6DOF monoscopic tablet devices for an inclusive, immersive, and social virtual environment

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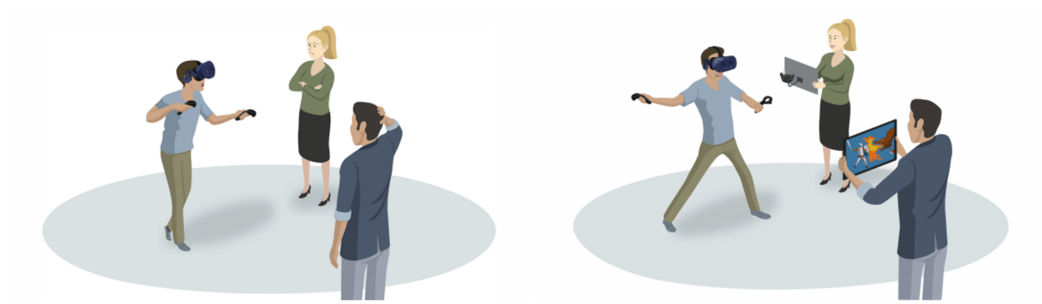

Fig. 1. (Left) those who are not willing to wear HMD device cannot experience VR with HMD users. (Right) Researchers have suggested novel interaction scheme where non-HMD users view VR world and HMD users using 6 DOF tablet device .

Virtual reality (VR) is an emerging technology that enables a live, immersive experience. However, not everyone is comfortable using VR headsets to interact with the virtual environment. Many people are unable to wear VR head-mounted devices (HMD) due to various reasons: glasses, make-up, hairstyle, discomfort, etc. Recently, researchers have proposed systems to include more people to be able to interact with the virtual environment using a non-HMD medium such as tablets or smartphones. In this workshop paper, we propose an experimental study on the non-HMD interaction with the virtual environment through monoscopic 6 degree-of-freedom (6DOF) tablet devices, measuring the usability, presence, social presence, and situational awareness of non-HMD users' interaction through such devices. We anticipate that the use of non-HMD VR devices will lead to more inclusive interaction in a virtual environment.

CCS Concepts: • **Computer systems organization** → **Embedded systems**; *Redundancy*; Robotics; • **Networks** → Network reliability.

Additional Key Words and Phrases: datasets, neural networks, gaze detection, text tagging

ACM Reference Format:
MD Tahsin Tausif, Soumya Khanna, Dana Sooyoung Ryu, Shane R Bennett, Hye Sung Moon, Sang Won Lee, and Myounghoon Jeon. 2018. Evaluating 6DOF monoscopic tablet devices for an inclusive, immersive, and social virtual environment. In *Woodstock '18: ACM Symposium on Neural Gaze Detection, June 03–05, 2018, Woodstock, NY*. ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/1122445.1122456

1 INTRODUCTION

Virtual Reality (VR) has been shown to be beneficial in many fields; from interactive games to educational tools to an artistic medium [1, 5, 23]. However, sharing VR creations and experiences in a social or collaborative setting - e.g., exhibitions, public demos, social gathering - becomes an essential and challenging concern [7, 17]. Bystanders - people who are not wearing VR head-mounted device(HMD) in the physical reality - will neither be able to partake nor understand what a VR user is experiencing. Therefore, VR-based interactivity is often a solitary experience, cutting the users off from their physical surroundings, preventing them from interacting with people in the physical world, and keeping bystanders from sharing the VR content. One of the potential solution is to allow all the bystanders to wear VR headsets. But VR headsets are still not inclusive, as many people are not able to wear them. For example, VR headsets tend to create cybersickness [10, 12], which discourages many users from wearing them. Also, the use of VR headsets for children has elicited concern that exposure may damage their vision [13]. Lastly, there exists a certain population for whom wearing a headset is not convenient; those who have thick hair texture, are afraid of messing up their hairstyle or make-up and wear prescription glasses [8, 11, 20].

As an alternative, a secondary computer monitor is often used to mirror what the VR user sees at the moment, mirroring the VR head-mounted device(HMD) user's egocentric view. However, the lack of agency and controllability of POV for bystanders makes it challenging to understand what is happening in virtual reality. In addition, POV on a secondary display is often limited for peripheral visions, making the 2D screen viewers have a less immersive experience [3]. Furthermore, the first-person perspective of the 3D environment on a 2D screen may cause motion sickness [14].

Research has been done to introduce more inclusive collective VR experience. In the work by Gugenheimer et al. [7], they use a motion-tracked secondary monitor to allow non-HMD users to see monoscopic VR, shared with the HMD users. Their work shows the potential of non-HMD mobile devices as a more inclusive medium towards immersion. In our workshop paper, we propose an experimental study, that will focus on the use of non-HMD mobile devices for sharing VR experience with HMD users.. We propose studies that evaluate the spectatorship of such approaches. We aim to measure usability, presence, social presence, and situation awareness to show that the inclusive VR experience can still be effective for immersive experiences for non-HMD users.

We hypothesize that, it is possible to provide usable, immersive experience to non-HMD users with tablet devices. To that end, we aim to evaluate the social virtual environment. Throughout the entirety of the project, we plan to address the following research questions:

- To what extent does a tablet-based VR viewing device usability to non-HMD users?
- To what extent a non-HMD user can have presence and social presence in the virtual environment?
- To what extent a non-HMD user can be situationally aware of both virtual and physical world through the use of the non-HMD devices?

We anticipate that the use of non-HMD system will make the immersive experience more inclusive for people who are not comfortable using VR headsets.

2 RELATED WORKS

Researchers studied and found that the first POV in a headset feels more realistic compared to virtual content on a 2D display because of head-mounted displays targeting both eyes [15]. However, wearing a headset is a challenge for specific populations. For example, children are not recommended to wear VR headsets as it may impact their vision development [13]. Other factors that prevent people from wanting to wear headsets are cosmetic and hygiene reasons: hairstyle, makeup, hair thickness, not wating to share VR headsets with others for hygiene reasons. For example, VR headsets are not particularly suited for those who have certain hairstyles, excluding certain populations from experiencing it [8, 11, 20].

Supporting a shared VR experience among VR headset users and non-headset users is an emerging topic to support situation awareness for bystanders and support collaboration. ShareVR exemplifies researchers efforts to engage non-HMD users and to allow them to collaborate with VR headset users [7]. HMD Light is another example, in which a wearable projector mounted on a VR headset user's head can display VR surrounding, typically on the floor, to let bystanders know VR content and collaborate with the users [22]. Another work of the authors presents a technique for a VR headset user to switch between two virtual worlds, which share the same physical space [21]. Although it still mirrors First-person POV, TransceiVR takes a similar approach of using a handheld device, mirroring a VR headset user's egocentric view on a tablet and allowing an external user to navigate FPOV temporally and to annotate on top of VR scenes [17]. We see the usage of mobile devices as "virtual phone", where it is used as a seamless transition from VR world to real world [6]. It shows the potential of using mobile devices as a feasible medium to interact with the virtual environment. Silhouette Games used the metaphor of mirror for viewing the VR world, visualizing VR content on a wall-mounted large display with the VR headset user overlaid on top of it [9]. It is undoubtedly an increasingly important topic to support spectatorship in VR for scaling the viewing experience and supporting collaboration across realities. Espeiclaly, with each individual's control afforded with 6DOF mobile devices, we expect non-HMD bystanders to have more agnecy in sharinv VR experience, compared to watching VR through mirrored display [16].

Our study focuses on studying the effects of bystanders' spectatorship on their immersiveness and situation awareness. Our approach can be practical in informal settings (museums, exhibitions, public demo booths) to involve bystanders in an accessible way.

3 EXPERIMENTAL DESIGN

In this section, we talk about our experiment's setup and planned study. We are planning to focus on usability, presence, social presence, and situation awareness to show the potential of non-HMD towards an immersive, inclusive, and social virtual environment.

3.1 Experimental Setup

For our experiment, we are going to use a similar non-HMD setup mentioned in the paper by Gugenheimer et al. [7]. Our non-HMD mobile device is going to be an iPad, that is being tracked by a vive-tracker. We use iDisplay to extend the display of the desktop to the iPad. The iPad's location, orientation is going to be tracked by the vive-tracker. We are using 4 Basestation 2.0's to track a 10m x 10m room where the tablet device and VR headset users will be interacting with each other. In the virtual environment, the VR headset user and the tablet device user will be represented with virtual avatar.

In the space, the VR headset user will experience various VR media and the non-HMD user will be asked to see the VR user's experience through the tablet.

3.2 Proposed Study

We divide our work into 3 tasks to measure (1) usability, (2) presence and social presence, and (3) situation awareness.

- **[Task 1: Usability] Tracking objects in virtual environment using 6DOF monoscopic VR devices**
  In this task, we are going to ask a non-HMD user to find a virtual object - ball-shaped objects - using a 6DOF tablet device. A ball will be appearing in a random position, and the users will be asked to find it, and approach to the object. Once, the tablet device is close enough to the ball and the ball is visible on screen, the ball will disappear and the system spawns another new ball in a random location. We repeat this task for 20 times in total. We will be measuring the time it takes for the users to find all the balls. This task is for participants not only to get used to the system for further study but also to provide an evidence that the system provides a usable and intuitive interface for general users to locate virtual objects and view a VR world. After they complete the task, the users will be asked to fill up system usability scale (SUS) questionnaire [2] to measure the usability of the system.
- **[Task 2: Presence/Social Presence] Observing VR users interacting with virtual environment**
  In this task, the non-HMD user will be spectating a VR user interacting with a virtual environment. Their task is to observe the HMD user in an VR space where their position is tracked. After the observation ends, the non-HMD user will be asked to fulfil a presence questionnaire[19] and a social-presence questionnaire, adapted after an existing questionnaire developed for computer-mediated communication [18]. Using the questionnaires, we plan to measure a non-HMD user's presence and social presence in the virtual environment. We compare this result with a baseline condition where a user will be asked to watch a mirrored egocentric view on a computer screen, evaluating their experience with identical questionnaires. The order of condition will be randomized.
- **[Task 3: Situation Awareness] Playing pictionary with a VR headset user** In this task, we measure situation awareness of the non-HMD user, both physically and virtually. For the final task, the non-HMD user will be asked to play pictionary with the VR headset user. The VR headset user will be drawing, and the non-HMD user will have to predict what they are drawing. We will be using SAGAT to measure situation awareness[4]. In the virtual environment, the users will be asked about the objects and the system (e.g., "How does a VR headset user change a color?") that are available in the virtual environment for perception and comprehension, and predict what the VR user is drawing for prediction to measure situation awareness. Similarly, the same task will be repeated for comparision, using a computer screen which mirrors an egocentric view of the VR headset user.

Based on our measurements in the 3 tasks, we will be able to see the potential of non-HMD mobile devices to make virtual environment more inclusive.

4 CONCLUSION

In this workshop paper, we talked about non-HMD devices to be a more inclusive medium for virtual environment. We are planning to look into the potential of non-HMD devices by measuring usability, presence, and situation awareness. We anticipate that, using non-HMD user is going to lower the barrier of interaction in virtual environment.

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