AN EXPERIMENT DESIGN: INVESTIGATING VR LOCOMOTION & VIRTUAL OBJECT INTERACTION MECHANICS

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ABSTRACT

In this paper, we describe an experiment outline on investigating design and user experience related aspects of several virtual reality locomotion and virtual object interaction mechanics. These mechanics will be based on consumer hardware like a common game controllers, an infrared hand and finger tracking device, VR hand controllers and an omnidirectional treadmill. Corresponding related work will contextualize and motivate this research. The projected experimental study will be based on user test sessions with a specifically developed 1st person VR puzzle horror game, called Gooze. A hybrid approach of self-assessment, in-game parameter tracking and session observations will be proposed for the investigation. Statistical analysis methods will be suggested to evaluate results. Furthermore, this paper will give an overview of the game and elaborate on design, gameplay and user experience related insights of already conducted informal pre-studies with it.

INTRODUCTION

Merging previously established game types, e.g. like 1st person shooters, with the capabilities of modern virtual reality (VR) is not a trivial task. Various aspects of game design and development like high rendering performance, attractive gameplay, sophisticated user experience (UX), usable design and diverse hardware setups are among the challenging areas. Related to several of these areas are two outstanding challenges: controlling locomotion and interacting with virtual objects in VR. 1st person locomotion in VR is problematic, as previously established paradigms of controlling movement in games often leads to simulator sickness in VR players, "when visual cues do not match other sensory modalities" (Jerald 2016). E.g. the common mechanic of using two analogue sticks on a common game controller to turn and move, directly ported to VR, likely leads to nausea in a lot of users (Riecke and Feuereissen 2012 and Yao 2014). On the other hand, interacting in VR with virtual objects can lead to exciting experiences and open up lots of new gameplay possibilities, but is also confronted with a variety of fundamentally different hardware setups. To deliver an as good as possible experience for players, it seems essential to offer several virtual object interaction mechanics. In the following, this paper will outline some possible combinations of consumer technology based VR locomotion and virtual object interaction mechanics and in which way they will be evaluated in a projected experimental study.

RELATED WORK

The following will inform on related works regarding VR locomotion and virtual object interaction, as well as the chosen platform of the proposed experiment, the specifically developed game Gooze.

Locomotion

Reddit lists 24 different VR locomotion mechanics, categorized into teleportation, motion, roomscale and artificially based ones (2016). These different approaches lead to the assumption, that providing an attractive gameplay, while solving simulator sickness caused by locomotion is not only a technical issue, but rather a challenge in design. Our experiment will investigate the most prominent mechanics, develop individual integrations, compare them and eventually provide case based recommendations for developers and designers.

On the basis of "travel time, collisions (a measure of accuracy), and the speed profile" through a virtual environment (VE) consisting of orthogonally arranged corridors, Ruddle et al. (2013) evaluated different locomotion mechanics like using a joystick, actual walking in VR and using industrial linear and omnidirectional treadmills. Their study "illustrates the ease with which participants could maneuver in a confined space when using an interface that was 'natural'" like using an omnidirectional treadmill or walking completely freely (Ruddle et al. 2013). Furthermore, user issues with translational movements seem to be inherent in abstract interfaces "(e.g., a joystick, keyboard or mouse) … irrespective of whether or not an immersive display is used" (Ruddle et al. 2013). By comparing these previous findings with the corresponding UXs of our projected experiment, prospective outcomes will be contextualized on a different level.

More concerned with UX of locomotion mechanics, Bozgeyikli et al. conducted an experiment comparing point and teleport, walk-in-place and joystick locomotion mechanics (2016). Their findings indicated, that their implementation of a point and teleport mechanic is "an intuitive, easy to use and fun locomotion technique", while reducing simulator sickness to minimum (Bozgeyikli et al. 2016). Although closely related to our projected experiment, using the almost consumer ready game Gooze as a testing platform, instead of an experiment application, and additionally comparing locomotion via omnidirectional treadmill, will differentiate our experiment.

Relating to testing consumer ready omnidirectional treadmills, Cakmak et al. have introduced the "Cyberith Virtualizer" (2014). This device consists of a low friction base plate and a pillar structure holding a vertically movable harness for the user. Strapped into the harness a user then walks over the low friction surface on the spot. Sensors provide data on the user's orientation, current height and movement speed, to be interpreted into locomotion commands (Cakmak et al. 2014). Though the Virtualizer is a very sophisticated omnidirectional treadmill, we will use a slightly inferior, but nevertheless similar treadmill called ROVR (Wizdish 2017) instead, because of availability issues.

Virtual Object Interaction

There seems to be a lack of literature investigating solutions for complete virtual object interaction mechanics, instead of dedicated sub tasks like virtual object selection or transport.

E.g., the literature survey by Argelaguet et al. is concerned with a plethora of virtual object selection mechanics using mostly industry and research based hardware (2013). They come to the conclusion that, "Although 3D interaction techniques for target selection have been used for many years, they still exhibit major limitations regarding effective, accurate selection of targets in real-world applications" (Argelaguet et al. 2013). They argue, that current limitations arise through a combination of "visual feedback issues" (e.g. occlusion and depth perception in stereoscopic 3D) and "inherent features of the human motor system" (e.g. neuromotor noise, Argelaguet et al. 2013). Argelaguet et al. propose that designing 3D interaction mechanics with improved efficiency, would involve developing novel "strategies for controlling the selection tool" and enhancing provided visual feedback (2013). We further agree with Argelaguet et al., that "in the real world selection tasks are mixed with other primary tasks such as manipulation and navigation" and should in turn be evaluated not only in isolation, but in a more holistic manner. This will be the case with our proposed experiment.

Kim et al. investigated virtual object interaction (grabbing and transporting) with a hand and finger tracking device in the context of causing "awkwardness and manipulation difficulties" in users, which they named "VR interaction-induced fatigue symptom" (2014). Their study inferred e.g. duration time, maximum grip aperture and the number of trials and errors to induce "fatigue and difficulties in manipulation" (Kim et al. 2014). Their design guidelines include enhancing object "contact cues" through sensory user feedback and adjusting the "input action strategy" and the viewpoint (Kim et al. 2014). The latter aspect will likely not be feasible to control in a completely dynamic VR application and although the input action strategy might be optimized to some degree, the game's gameplay for the projected experiment will still require certain durations of grabbing and interacting with objects. Nevertheless, it seems reasonable to take Kim et al. 's "Conceptual interaction model for grasping control" (2014) into account in the further design process of the game Gooze.

Gooze

Gooze is a singleplayer 1st person horror VR game (see Figure 1), based on a real derelict sanatorium. The user needs to solve puzzles, by interacting with objects to flee from scary creatures from room to room, e.g. like using a loose bedpost as a lever to break open a padlock on a door. For that, the player needs to explore the surrounding by walking around and to grab, carry and use interactive objects with each other. He or she will be supported by subtitles, visualizing thoughts of the player character and giving subtle hints regarding the puzzles.

Figure 1: Stereoscopic Screenshot of Gooze, showing the player's hands, tracked with a Leap Motion controller

While living through a horrifying atmosphere of decay and surreal entities, the player will not be provided with any weaponry. To create this atmosphere, Gooze subtly creates pressure in players, by playing with different room settings and limiting light sources. E.g. the ceiling light in Figure 1 can be grabbed and turned to temporarily light up a corner of the room. Once you have done that, you need to explore that corner more thoroughly in semi-darkness though, as you cannot take the light with you. Inspiration for puzzles, rooms and textures was gathered during a two-day expedition to the derelict Grabowsee sanatorium near Berlin (Jüttemann n.d.). Built on the Unity 3D game engine (Unity Technologies 2017), Gooze uses the Oculus SDK (Oculus VR 2017a) for VR. Though some features are already implemented, in its next iteration, it will provide several input options. Eventually, these will include support for common game controllers, the Leap Motion controller (Leap Motion 2017), the Oculus Touch hand controllers (Oculus VR 2017b) and the Wizdish ROVR (Wizdish 2017) omnidirectional treadmill.

Insights of informal Pre-Studies

Figure 2: Photograph of one informal Pre-Study

A simple evaluation of simulator sickness has been performed during one pre-study with the game (see Figure 2). After each of the 40 sessions, ranging between 5 to 15 minutes, the current user was asked to assess any present nausea on a scale from 0 to 10 (10 relating to feeling extremely sick). Although, not creating scientifically exploitable results, this method led to an estimation of how well this previous iteration of Gooze was accepted in terms of simulator sickness, which was really well when looking at 90% of users placing themselves in the lower third, of which the majority did not feel any nausea at all (65%). The nausea level score's mean and standard deviation were 0.825 ± 1.466 (see Figure 3 and Table 1).

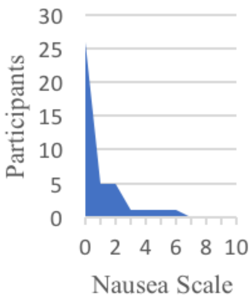

Figure 3: Diagram of Nausea Ratings

Nausea levels on a scale from 0 to 10	Participants
0	65% (26)
1-2	25% (10)
3-4	5% (2)
5	2.5% (1)
6	2.5% (1)
7-10	0% (0)

Table 1: Nausea Ratings

Further pre-studies also uncovered several relevant insights regarding the game's design, gameplay and UX. E.g., in an earlier iteration of the game a gaze based virtual object selection and a controller button based interaction mechanic with the selected virtual object was offered. Switching from this, to a more natural mechanic of tracking player hands with a mounted Leap Motion controller (see Figure 2) and using these hand representations for object selection and interaction hugely effected the feel of the game and its UX. Seeing one's relatively accurately tracked hands and fingers much improved the game's chance to induce presence (International Society of Presence Research 2000) in a player. On the other hand, these studies and the prior development phases also uncovered the need for a robust grabbing mechanic. However, this could not be solved by simply making use of physics colliders attached to the hand representations, as without actual haptic feedback and the underlying imprecisions of Unity's physics engine, virtual objects would just be pressed through the virtual hands. Instead, a semi-automated grab mechanic seemed more reliable. With this, a grab parameter of a virtual hand, defined through its pose, would be checked and if in a certain range of an interactive object, the object would be snapped into this hand in a predefined pose, most likely for the object. E.g. a polaroid is more likely to be held with 2-3 fingers at one of the corners, instead of holding it like an apple in the palm of a hand. Though not being a perfect solution, this mechanic was accepted and understood well by users.

Another important finding was, that using a combination of a common game controller for locomotion, and a Leap Motion controller for virtual object interaction, does not work well together. Gazing at your hands on the common controller when walking around the VE unwantedly created possibly obstructing virtual hand representations. Additionally, needing to push buttons and analogue sticks on a common game controller while carrying a virtual object, by holding your physical hand in front of you, seemed very awkward for players.

Finally, the play sessions approved the game's general gameplay mechanic and its look and feel was supported well by players with a liking for the horror genre.

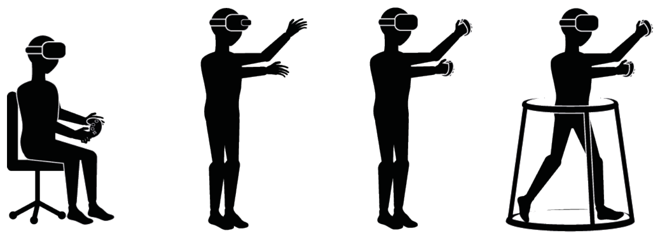

Figure 4: Interaction Setups to test a) Common Controller for Locomotion and Object Interaction, b) Leap Motion Controller for Point and Teleport Locomotion and Object Interaction, c) Oculus Touch Controllers for Point and Teleport Locomotion and Object Interaction and d) ROVR Omnidirectional Treadmill for Locomotion and Oculus Touch Controllers for Object Interaction

EXPERIMENT DESIGN

Locomotion & Virtual Object Interaction Mechanics

The following combinations of mechanics do not have to be discrete, but can also be recombined, filtered or extended, depending on the design and objective of a game, in which they should be applied. Nevertheless, these combinations have been chosen for evaluation, as they likely correspond to real-world use-cases in terms of VR hardware setups and seemed appropriate for the game Gooze. For stereoscopic 3D VR vision, all of them incorporate an Oculus CV1 head mounted display (HMD) and corresponding tracking equipment.

In the hardware setup of Figure 4a, participants will sit on a swivel chair, providing the freedom to physically turn while also simulating a seated gaming situation. A common game controller will be used to perform in-game locomotion and virtual object interaction.

In the setup of Figure 4b the participant will be standing and a Leap Motion controller, mounted to the HMD, will track his or her hands and fingers. Locomotion can be performed via a point and teleport mechanic with one hand, while the other hand can be used to interact with virtual objects.

The setup of Figure 4c is almost identical to Figure 4b, except two Oculus Touch hand controllers will be used to point and teleport and interact with virtual objects instead.

Finally, in the setup of Figure 4d, the participant will use a Wizdish ROVR omnidirectional treadmill for locomotion and two Oculus Touch controllers for virtual object interaction.

Experiment Methodology

All participants will be introduced to the experiment's subject and procedure and ethical consent and general gaming and VR related information will be collected from them.

In a within subject experiment design, each participant will be asked to play the game Gooze. While doing so, each one will go through all experiment phases and try out the previously mentioned hardware/mechanics setups (see Figure 5). The order of these setups will be pseudo randomized via the Latin

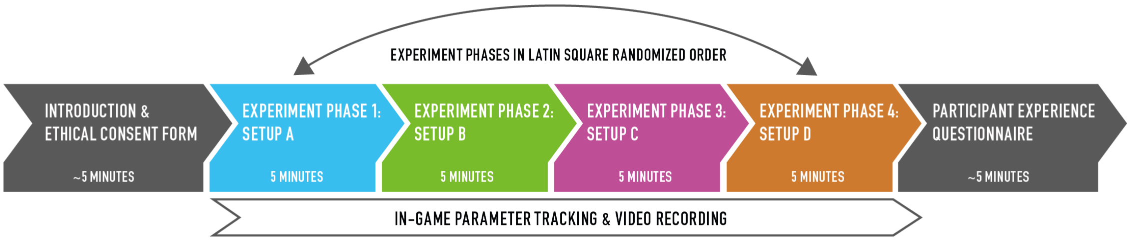

Figure 5: Experiment Phases and Procedure

square method. Each phase will last for 5 minutes. After each phase, the game restarts itself. The whole process will be video recorded to capture any remarks or relevant user behavior, for later analysis. Also, various in-game parameters, e.g. like locomotion and turning speeds, as well as the number of object drops and the individual order of setups will be tracked.

Once all phases have been completed, a self-assessing experience questionnaire will be filled out by the participant. Each setup will be processed in a repeating section: The igroup presence questionnaire (igroup 2016) will establish an individual presence rating, participants will further be asked for a 7 point Likert scale rating of the current setup's ability to support the gameplay of the game and one for their individual enjoyment. Additionally, each setup will be rated for simulator sickness on scale between 0 to 10 (for comparable results with previous data). Finally, participants will be asked to choose a preferred setup and they will be provided with several free text fields to give comments specific to setups and the game in general.

Once all participant and tracking data has been processed into a single database, it will be statistically analyzed for significant mean differences between setups. These results will be analyzed for possible cross correlations and then be interpreted in parallel with the gathered qualitative data. Finally, possible design and development guidelines will be extrapolated.

EXPECTED EXPERIMENT LIMITATIONS

Due to the experiment's projected design and complexity, it may not be able to uncover fine grained insights on sub tasks of virtual object interaction like object selection, grabbing, carrying and using. Though qualitative free text answers of participants may or may not give relevant insights related to specifics of design or implementation of mechanics, the focus of the study will be on openly comparing the UXs of those mechanics. Furthermore, again due to the already complex within subject design of the experiment, it will not be possible to acquire entirely discrete simulator sickness ratings for each locomotion mechanic. Possible bias will be attenuated though, by using a Latin square randomization for the order of setups per participant and by interpreting qualitative participant data in parallel.

CONCLUSION

In this paper, we illustrated the need to investigate two challenging areas of VR gaming, namely locomotion and virtual object interaction. The reduction of simulator sickness to an absolute minimum is essential to deliver a pleasant VR experience and locomotion mechanics are tightly linked to this challenge. Related work suggests needed investigations of different mechanics in the context of design and UX. On the other hand, related work on virtual object interaction seems to be specifically concerned with sub tasks and does not investigate corresponding mechanics in a holistic way.

In turn we proposed to conduct a within subject experiment, to compare four different setups of combined mechanics, by letting participants play the specifically developed game Gooze. Afterwards they will self-asses their individual UXs and the design of the game. After processing and analyzing the gathered data, any findings will be extrapolated to form corresponding design and development guidelines.

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