Head in the Clouds - Floating Locomotion in Virtual Reality

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ABSTRACT

Navigating large virtual spaces within the confines of a small tracked volume in a seated position becomes a serious accessibility issue when users' lower seating position reduces their visibility and makes it uncomfortable to reach for items with ease. Hence, we propose a "floating" accessibility technique, in which a seated VR user experiences the virtual environment from the perspective of a standing eye height. We conducted a user study comparing sitting, standing and floating conditions and observed that the floating technique had no detrimental effect in comparison to the standing technique and had a slight benefit over the sitting technique.

Index Terms: Human-centered computing—Human Computer Interaction (HCI)—Design and Evaluation Methods—User Study; Human-centered computing—Accessibility—Accessibility Systems and Tools; Human-centered computing—Human Computer Interaction (HCI)—Interaction Paradigms—Virtual Reality

1 INTRODUCTION

One of the most important features of immersive virtual reality (VR) is that much of the user input is performed via naturalistic body movements. Hence many VR applications are designed for a standing user who can move around and experience the virtual environment. However, there are many reasons why a user may not want to stand, instead preferring a seated position. While for some users a seated position is mandated by injury or disability, there are also reasons for healthy users to prefer a seated position. Apart from simply providing more comfort, experiencing VR in a seated position also causes less physical strain [2] and is less likely to induce motion sickness [5]

However, with the seated position comes a lower eye height in the virtual world resulting in a poorer visual overview of the world, especially in a cluttered environment. To compensate for this, we propose altering the user's virtual eye height to match the eye height they would have when standing. With this *floating* technique, we aim to combine the advantages of both sitting and standing postures without negatively affecting the user experience.

Manipulations of eye height of VR users has its roots in the findings of psychophysical studies where eye height was observed to influence perceived depth [1,9]. Nguyen-Vo et al [6] compared four locomotion methods in terms of their supported translational cues and control. Two of these methods were seated while the other two were standing. No significant difference was found between sitting and standing for a translation method with embodied cues (leaning) and the authors acknowledged that further work was required to assess the generalisability of their results. Another study by Coomer et al. [3] investigated both standing and seated locomotion in the context of a visual exploration task; they also found no significant difference between user performance in the standing and seated

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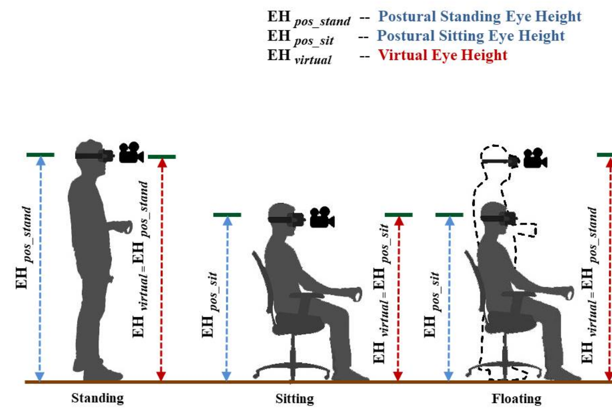

Figure 1: Diagram showing the body posture and virtual eye height for the individual conditions. For standing and sitting, the virtual eye height aligns with the real-world eye height, while the floating technique uses a standing eye height for a sitting user.

interfaces. While these results suggest no detriment to a seated interface compared to a standing one, they all are based in a sparse virtual environment with targets arranged at the same height, within comfortable reach/view of both seated and standing users. The design of our study tests this difference (between seated and standing interface) as well as introducing a further comparison with our floating technique. This study's task is a guided search within a more realistic and cluttered scenario (a supermarket) with items placed at a variety of heights.

2 PROPOSED TECHNIQUE

Most commercial VR applications are designed to facilitate a standing posture. Standing offers more freedom of movement compared to sitting, which offers greater comfort [7]. To harness the benefits of both postures, we propose the *floating* technique. With this technique the user remains in the seated position but a fixed offset is applied that lifts the camera's viewpoint to the height it would have if the user were standing. The same offset is also applied to the hands. To determine the offset for the floating condition, participants are initially asked to stand and then to sit down. In both of these postures, a measurement is taken through the tracking system and the height difference calculated. This difference forms the offset that is then applied at the start of the floating condition. Fig. 1 outlines the participant body posture and virtual eye height for all three experimental conditions.

3 STUDY DESIGN

We designed a user study with a task requiring participants to both locomote and interact within a virtual supermarket, while either seated, standing or floating. The supermarket environment was chosen as it allowed interactions (picking up items) from different heights and navigation through an environment with a range of depth cues. Task performance was assessed by time to complete and number of collisions, while post-experience questionnaires were employed to assess participants' sense of presence, simulator sickness and various subjective preferences. For our study we selected a virtual translation method (via controller joystick) since this is still the most prevalent translation method for VR apps. Both virtual (via controller joystick) and real rotation is supported, with real rotation restricted according to chair type (fixed or swivel).

We used a repeated-measures design to mitigate against the influence of individual differences in overall task performance among participants. To account for potential learning effects, the order of the conditions was randomised. Each participant completed the task for each of the three posture conditions (standing, sitting and floating).

Due to the Covid-19 pandemic, the experiment was initially conducted remotely, with participants (N=18) recruited online who then performed the experiment with their own headset at home. A follow-up lab-based study (N=18) was conducted using identical materials, but under the supervision of an experimenter. Post-hoc statistical analysis showed no significant difference in the data between the two cohorts. All of the participants were older than 18 years, had no motor disability and were not sensitive to photosensitive epilepsy. The experiment took 40-50 minutes for each participant. This included the introduction, pre-questionnaire, instructions, training, performing the tasks and filling out the online questionnaires. They were compensated for their time with a gift voucher in their local currency worth £10.

4 Results

4.1 Total Task Completion Time

We measured the total time participants needed to complete the task from the start position to the last target. The data was found to be normally distributed with the overall mean and SD for total time completion (M= 79.51, SD=29.86) using Levene's test. We analyzed the data by one-way ANOVA with 5% significance level ($F(2,108) = 0.40$, $p = 0.67$). There was no statistically significant difference in total time taken for completion among the Standing, Floating and the Sitting postures.

4.2 Simulator Sickness

The results of the Simulator Sickness Questionnaire (SSQ) [4] was found for all the three postures. We measured mean SSQ scores of Standing (M=26.69,SD=25.58), Floating (M=19.84,SD=19.54) and Sitting (M=21.29 SD=20.71) from all 36 study participants, since all of them experienced the three techniques long enough to be able to evaluate them in the SSQ. A one way ANOVA on total score showed no statistically significant difference ($F(2,108) = 0.96$, $p = 0.38$) among the conditions. A further analysis found no effect of condition order on SSQ scores.

4.3 Presence

The participants filled out the Slater-Usoh-Steed (SUS) presence questionnaire [8] after performing each condition. The SUS questionnaire consisted of eighteen questions with seven-point Likert scales. A Levene's test did not indicate that the assumption of normality had been violated. Therefore, we analyzed the results with an ANOVA at 5% significance level from which we found no statistical significance difference ($F(2, 108) = 2.32$, $p = 0.103$) in presence among the conditions.

5 Discussion

The task in our experiment was to follow the path and pick up items along the way. We did not find any significant difference in the task performance among the conditions. This could indicate that our floating technique has no negative impact on user task performance. To assess user preference, we asked participants to rank the three conditions and pick a preferred technique for six different aspects of the experience (navigating, looking for items, grabbing items, avoiding collisions, comfort, effort). Significant differences were found for navigating, looking for items, and effort required. For navigating, both standing and floating were preferred over sitting, for looking at items standing was preferred over both floating and sitting, for grabbing items standing was preferred over sitting, and for effortlessness floating was preferred over both sitting and standing.

Further, the qualitative data suggested that the sitting condition was more comfortable but participants had difficulties in seeing and reaching for objects.The standing condition was found to be more realistic and natural, but participants also reported nausea and motion sickness. With floating, they praised comfort and the ease of seeing and reaching for objects, but some still reported feeling nausea.

6 Conclusion

We have evaluated a technique that adjusts the seated VR-user's eye height to that of a standing player. In our study, 36 participants performed a search-task while we captured metrics such as task completion time, simulator sickness, presence, and preference. Standing and floating were equally preferred with standing scoring high for looking for items while floating scored high for effortlessness. When compared to sitting, floating was rated higher for navigating the VE and requiring less physical effort than the sitting condition. This can potentially be useful for VR users who need to, or want to, experience VR in a seated position because it does not require any changes to the VR application. It could also allow researchers to include disabled populations in their participant pool for experiments using virtual reality without biasing their outcomes.

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