Please Don't Puke: Early Detection of Severe Motion Sickness in VR

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ABSTRACT

Motion sickness is a potentially debilitating side effect experienced by certain users of virtual reality systems. Unexpected results from a user study on redirected walking suggest that there is a need to quickly identify participants who have an extremely low tolerance for virtual motion manipulations and remove them from the experience. In this poster, we investigate the use of a previously introduced "fast motion sickness" measure to identify potential outliers with heightened levels of sensitivity. This work demonstrates a promising experimental methodology and suggests possible shared characteristics among users in this group.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality; Human-centered computing—Human computer interaction (HCI)—HCI design and evaluation methods—User studies

1 INTRODUCTION

With the emergence of low-cost consumer head-mounted displays, immersive virtual reality (VR) experiences are increasingly common. Exploration of virtual environments by physical walking can be powerful, but the virtual area that can be explored through physical walking is constrained by the size of the tracking space. Solutions to this problem include techniques that manipulate human perception in order to maximize the available physical space. One such technique is redirected walking, which allows users in virtual reality to explore large virtual environments within limited physical spaces by manipulating the mapping between real and virtual motion [3].

An open problem with redirected walking is finding a level of manipulation that is high enough to minimize the necessary physical space, but low enough to remain imperceptible to the user and to avoid motion sickness. Previous research has found general guidelines for perception thresholds, but these guidelines may be insufficient due to the wide variance in thresholds between users [4]. We sought to create a process that would allow quick and accurate calibration of rotation gain redirection thresholds for individual users.

The subtle sensory conflict introduced by redirected walking algorithms is known cause motion sickness [1]. In light of this, a "fast motion sickness score" (FMS score) was incorporated to periodically monitor a participant's level of discomfort throughout the experiment. The FMS score, originally presented by Keshavarz and Hecht, provides a quick method to estimate a user's level of motion sickness without disrupting an experience [2]. This method has been shown to have a high correlation with a participant's simulator sickness questionnaire (SSQ) score, a tool commonly used to measure motion sickness. Thus, the FMS score provides a quantitative means to monitor a participant throughout the course of an experiment.

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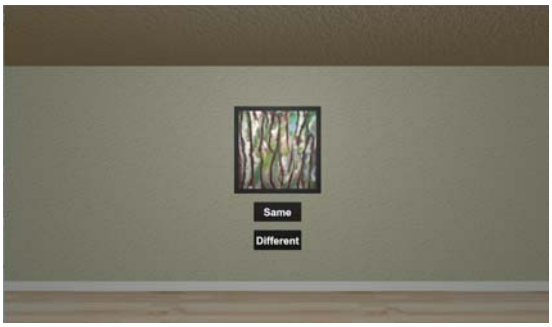

Figure 1: The virtual reality environment used during the study.

We conducted a user study that suggested there is a wide variance in individual tolerance for redirection and indicated that while most users can easily tolerate redirection, a small number may be especially prone to severe motion sickness. While this group is in the minority, the FMS score appears to be a lightweight solution for identifying these participants and removing them from the experience. In additions, protocols are suggested for using the FMS score to prevent participants from experiencing severe motion sickness.

2 METHOD

For the experiment, participants were immersed in an indoor, room-size virtual environment, shown in Figure 1. Participants were instructed to turn in place until they faced a painting on the wall; without redirection, the turn was 270 degrees. The participants were then asked to select one of two buttons: "same" if they felt their virtual rotation matched their physical rotation, or "different" if they felt their virtual rotation was greater than or less than their physical rotation. After a tutorial introducing participants to their environment, redirection, and the turning procedure, redirection was applied at various levels as the participant turned in place to calibrate their threshold. When the participant noticed the gain, the threshold would decrease; if the participant did not notice the gain, the threshold would increase, until an individualized threshold was converged upon. This process was repeated twice, with an optional break offered after each calibration procedure.

Following the calculation of the individual's thresholds, the participant would walk along a short path with a 90-degree turn while redirection was applied at the threshold level. At the end of the path, they were asked if their virtual rotation was the same as or different than their physical rotation. This was repeated eight times, with an optional break offered after the first four turns.

FMS scores were obtained at eleven points throughout the study: at the conclusion of the tutorial, after each calibration procedure, and after each path. The participant provided a rating of their symptoms on a scale from 0 to 20, and was instructed to focus on feelings such as nausea, dizziness, and sweating. If a participant reported an FMS score of 15 or greater, they were required to remove the headset and take a break from the virtual environment. If a participant reported an FMS score of 20, the experiment stopped immediately.

Prior to the experiment, participants were introduced to the HTC Vive headset and a Vive controller. They were given a brief outline

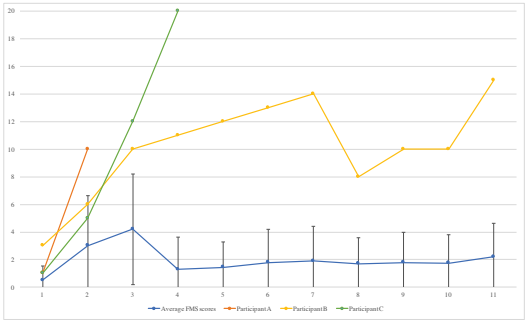

Figure 2: Average FMS scores at checkpoints during the experiment compared to FMS scores from three participants in the MS group.

of the experimental procedure and the chance to ask questions. They were reminded that they were under no obligation to complete the experiment, and could stop or take a break at any time.

All participants were financially compensated for their time. A total of 29 participants (17 male, 11 female, 1 electing to not identify) were recruited via department mailing lists and word-of-mouth. Participants were between 21 and 28 years old with a mean age of 24 years (two elected not to report their age); participants were required to have normal or corrected to normal vision.

3 Results

In total, 20 participants (13 male, 6 female, 1 electing not to identify) successfully completed the experiment. Two participants were unable to complete the experiment because they could not sense redirection. Two participants gave highly inconsistent responses, suggesting that they did not understand the task, and were excluded from analysis.

Notably, five participants were unable to complete the experiment due to motion sickness. Unexpectedly, one participant vomited during the experiment, and one vomited immediately following the experiment. Three of these participants were female and two were male; both participants who vomited were female. The average age among the group was 26 years old. This group of five participants is collectively referred to as the motion sickness group, or "MS group".

Prior to the start of the experiment, participants were asked about their previous experience with gaming and virtual reality systems. They completed the Kennedy-Lane SSQ to provide a initial measurement of motion sickness symptoms. At the end of the experiment, the SSQ was repeated and demographic information was collected from the participants. All participants completed this final step, regardless of whether they were able to complete the experiment.

Among the group that successfully completed the experiment, 65% had prior experience with virtual reality systems. However, only one of the five participants from the MS group had previous experience with virtual reality systems. None of the participants in the MS group had prior experience with natural locomotion in VR.

Participants who were able to complete the experiment exhibited fairly low SSQ scores and low FMS scores. The average exit SSQ was 5 ± 3, and the progression of the FMS scores through the checkpoints can be seen in Figure 2. The spike at the second and third checkpoints is due to the amount of redirection applied prior to those two phases. Among the MS group, the average exit SSQ was 19 ± 4. Figure 2 shows FMS scores for three participants from the MS group. A comparison between the exit SSQ scores for these two groups can be seen in Table 1.

4 Discussion

Clearly, the majority of participants were able to successfully complete the experiment without experiencing significant side effects.

Table 1: SSQ scores for the completion group and motion-sick group

	Initial SSQ	Exit SSQ	Change in SSQ
Completed	0.9 ± 1.3	4.7 ± 3.5	3.8 ± 2.9
MS group	0.8 ± 1.3	19.2 ± 3.4	18.4 ± 4.1

However, the findings from the motion sickness group should not be disregarded. Feedback from participants after the experiment indicates a stark divide: those who successfully completed the experiment felt fine, while those who experienced motion sickness felt *very* sick. The difference in exit SSQ scores supports this binary grouping, as does the drastic difference in the average change in SSQ from the start of the experiment to the end.

The FMS score proved to be a useful screening tool for most participants. In hindsight, implementing a mandatory break at a threshold of 10, rather 15, would have more accurately identified participants that were severely impacted by nausea and motion sickness. Additionally, lowering the threshold for removing a participant from the experience from 20 to 15 may likely have mediated some of the discomfort experienced by the MS group. Implementing the FMS score periodically (such as every 5 or 10 minutes) rather than at pre-determined checkpoints may help identify vulnerable participants, particularly during experiences where perception is manipulated.

While the sample size is too small to draw significant conclusions from the MS group, it is notable that most of the cohort had no experience with virtual reality and little to no experience with immersive 3-D environments. The majority identified as "casual gamers" or "non-gamers". Because of their lack of experience, these participants may have been unaware of how the immersive virtual experience would impact them. In addition, informal verbal feedback from participants suggests that for some, the novelty of the virtual experience may have inhibited their ability to recognize the warning signs of motion sickness.

5 Conclusion

While some may argue that it is the user's responsibility to monitor their body for adverse effects during an immersive virtual experience, the VR community has a responsibility to minimize discomfort for all users. This includes the minority of users that may have a very low tolerance for immersive virtual experiences or manipulation of perception. Steps such as incorporating FMS scores or reminding novice users to take a break from the virtual environment to assess their physical condition could mitigate the chances of experiencing severe motion sickness.

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