# Design and Evaluation of a Visual Acclimation Aid for a Semi-Natural Locomotion Device

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### Abstract

One of the limitations of most virtual reality (VR) systems is that users cannot physically walk through large virtual environments. Many solutions have been proposed to this problem, including locomotion devices such as the Virtusphere. Such devices allow the user to employ moderately natural walking motions without physically moving through space, but may actually be difficult to use at first due to a lack of interaction fidelity. We designed and evaluated a visual aid that shows a virtual representation of the sphere to the user during an acclimation phase, reasoning that this would help users understand the forces they were feeling, plan their movements, and better control their movements. In a user study, we evaluated participants' walking performance both during and after an acclimation phase. Half of the participants used the visual aid during acclimation, while the other half had no visual aid. After acclimation, all participants performed more complex walking assessment tasks without any visual aid. The results demonstrate that use of the visual aid during acclimation was effective for improving task performance and decreasing perceived difficulty in the assessment tasks.

**Keywords**: Locomotion, Virtusphere, interaction fidelity.

**Index Terms**: H.5.2 [User Interfaces]: Training, Help, and Documentation—Input Devices and Strategies; I.3.6 [Methodology and Techniques]: Interaction Techniques

## 1 Introduction

In many virtual reality (VR) systems, it is important to have interactions similar to the real world to promote the sense of presence, to afford realistic user response, or to ensure effective training. However, natural locomotion is challenging due to small tracked spaces, large virtual environments (VEs), and the limitations of user interfaces for locomotion.

Various locomotion interfaces, such as omni-directional treadmills [4], walking-in-place [18], redirected walking [15] and the Virtusphere [7], have been developed to provide a general-purpose infinite walking solution using "natural" walking motions [3]. However, many of these interfaces require users to walk differently and provide cues dissimilar to the real world, such as visual-vestibular cue mismatch. As a result, performance may suffer, mental workload may increase, and users may lose balance, get disoriented or have simulator sickness [8-13,17].

Since such interfaces present themselves as natural, users assume that realistic walking motions will apply to such interfaces, but this is often not the case. Rather, users must acclimate to the interface before they can use it effectively.

Designing quick and effective acclimation procedures for semi-natural locomotion interfaces can make them more usable and provide a better experience to the user [9]. Our hypothesis is that providing an appropriate visual cue during acclimation will help users to better understand their walking in the VE and how it differs from their natural gait. After acclimation, we posit that they will be able to perform more effectively. The visual cue can also increase the match between visual display and proprioceptive cues, which improves presence [14,18].

We designed such a visual acclimation aid for the Virtusphere [7] —a large spherical device similar to a "human hamster ball"— to test this hypothesis with a semi-natural walking interface. We conducted a user study to determine whether we could improve users' walking performance by acclimating them to the interface with the visual cue.

## 2 Related Work

The Virtusphere combined with a tracked head-mounted display (HMD) enables infinite walking in any horizontal direction [7]. The idea of walking inside a sphere was also proposed by Fernandes et al [5], who described fully immersive spherical projection system called the Cybersphere.

Researchers have studied various parameters for locomotion interaction using the Virtusphere. Medina et al. [13], studied Virtusphere walking and found that for motion sickness and balance disturbance a third-person viewpoint was better, while for performance and subjective enjoyment a first-person viewpoint was preferred. Presence, overall involvement/control and sickness were studied for locomotion using the Virtusphere compared to a gamepad technique [17]. Although no significant difference for these metrics were observed, the mean values for the gamepad were better than the Virtusphere.

Some semi-natural locomotion interfaces exhibit poorer performance and usability compared to highly natural or well-designed non-natural interfaces. McMahan et al. [11] compared semi-natural (human joystick) and non-natural (mouse and keyboard) techniques in a first-person 3D game. Their results indicated that the lower fidelity technique had significantly better performance. Similarly, low-fidelity interaction techniques were significantly more effective than semi-natural ones in a 3D racing game [12]. Marsh et al [8] observed that cognitive load of real walking was significantly less than two less natural interfaces for a memory measure.

Training can help users acclimate to the interface and improve performance [1,2,16]. Marsh et al. examined the effectiveness of training on performance and cognitive resource demands in the Virtusphere [9]. They found that using the Virtusphere imposes cognitive demands on users that make this interface less effective than real-world walking. They also showed that training can have a positive effect on movement abilities and performance.

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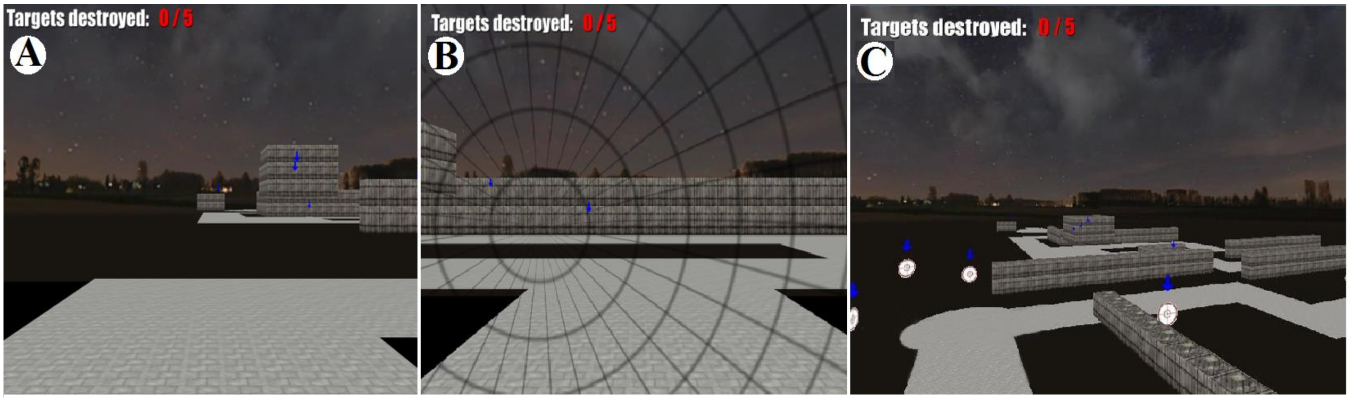


Figure 1: Study environment, A) without visual cue, B) with visual cue, C) overview of one of the assessment courses

While walking in a VE, the user may receive vestibular and proprioceptive cues that are different than the cues that would occur when walking in the real world. Visual cues dominate vestibular or proprioceptive cues in our perceptual system [15]. Considering this fact, we hypothesize that providing appropriate visual feedback can facilitate learning of semi-natural interfaces.

## 3 Visual Cue Design

The Virtusphere affords similar body movements compared to walking in the real world. However, it is quite different from the real world in terms of the direction and magnitude of forces used in walking. Although experienced users might be able to reach an appropriate level of performance, many new users struggle to walk in the Virtusphere. The Virtusphere's inertia and momentum, caused by its significant weight, makes initiating walking, maintaining balance, and terminating walking a challenge. Walking on the curved inner surface of the device also feels different than real-world walking.

To address these problems, we propose to train users *not* to think of themselves as walking through an environment, but rather to think of themselves as rolling a ball through the environment. Thinking this way should allow users to understand better the forces they are feeling, change the way they move, and adapt their actions to be more appropriate for the Virtusphere.

Inspired by the video game Super Monkey Ball, we designed a virtual spherical visual aid that rotates around the camera in sync with the movement of the Virtusphere. Considering the dominance of visual cues in the human perceptual system [15], we hypothesize that showing the virtual sphere will keep users aware of the form factor of the device and make them adjust their walking accordingly and learn the differences between the Virtusphere and real walking more quickly.

We needed to create a texture that would convey the manner of rotation to the user observing it from the inside. We prototyped different transparent visual patterns. We found brightly colored patterns to be distracting, while fine-grained grid patterns occluded the user's vision. A transparent pattern with a mid-size grid (Figure 1B) was not very distracting and induced the feeling of walking inside the Virtusphere. The size of the visual sphere was similar to the actual Virtusphere.

## 4 EXPERIMENT

We designed an experiment to investigate the value of acclimation to the Virtusphere using the visual cue we designed.

### 4.1 Virtual Environment and Tasks

In a large number of real-world applications, locomotion is not the primary task but rather enables the user to perform another primary task. We evaluated our visual cue using a task in which walking is useful but is not the focus of the action. We designed a target practice course, with the targets placed in locations that required the user to move into strategic positions in order to shoot them. Our VEs (figure 1C) featured raised platforms without walls so that users could fall off the platforms if they did not walk accurately.

For each course, we asked the user to shoot the targets while navigating a pathway, without falling off the platform. A (virtual) fall caused the user to be re-spawned at the last location on the pathway to continue the task. We logged the number of virtual falls as a measure of how accurately users could control the navigation. We also measured the total time spent to finish the course, which required the user to shoot all targets.

### 4.2 Experimental design

Our experiment had two independent variables: course type and visual aid. Course type (with levels acclimation and assessment) was varied within subjects, while the presence of the visual aid was varied between subjects.

During the acclimation phase of the study, users completed four courses of relatively low difficulty. These courses averaged 150 feet in length with a few turns and one or two targets. To manipulate the visual aid independent variable, during the acclimation phase we showed the visual aid to half of our participants, while the rest did not use the visual aid.

In the assessment phase, participants completed two complicated courses. These courses averaged 600 feet in length with several turns and eight targets. None of the participants had the visual cue during the assessment phase.

The dependent variables were completion time, number of falls from the virtual platform, number of times the user physically lost balance, and the perceived difficulty for each course.

To assess simulator sickness, we used the Simulator Sickness Questionnaire (SSQ) [6]. In this questionnaire, 16 symptoms of simulator sickness are evaluated on a four-point nominal scale (i.e., none, slight, moderate, severe). We also asked participants about level of fatigue, ease of use and naturalness of walking in the Virtusphere.

### 4.3 Apparatus

We visualized the VE using a Sensics zSight HMD with a 60° field of view, stereoscopic rendering and resolution of 1280x1024. The user wore a backpack containing wireless video equipment and batteries. The user also wore knee and elbow pads, for safety considerations. The participant's head orientation was tracked using the inertial sensors in a Sony Move controller attached to the HMD. Another Sony Move controller was used as a wand to shoot targets. We used the "Move.me" application on a Sony PlayStation 3 to perform orientation tracking for both controllers. The Virtusphere's rotation was tracked with its own custom optical tracker allowing the user's viewpoint to translate in the VE. We used WorldViz's Vizard 4.0 software to interface with the hardware, render the VE, manage the flow of the experiment, and log the users' data.

### 4.4 Participants

We recruited 24 participants (13 females and 11 males) from the university undergraduate and graduate population on a voluntary basis for this study. The participants ranged from 19 to 29 years old. Subjects under the age of 18 and those weighing over 190 lbs. (the weight limit of the Virtusphere) were excluded. None of our participants had prior experience with the Virtusphere.

### 4.5 Procedure

We received approval from our university's Institutional Review Board (IRB). Upon arrival, participants were asked to read and sign the approved consent form. Then, they completed a background questionnaire, asking for their gender, age, occupation and experience of playing video games. After an introduction to our experiment and study procedures, participants were introduced to the Virtusphere and had a chance to use it for about seven minutes without the HMD. Participants were introduced to the VE by wearing the HMD and were asked to start the four acclimation courses. After each course they were asked about the perceived difficulty of the course on a scale of one to ten, with ten being extremely difficult to perform. The twelve participants in the visual cue group received the visual cue during the acclimation courses, while the other group did not.

After the acclimation phase, participants started the assessment phase, in which both groups performed the same tasks without the visual cue. Both Move controllers were calibrated at the beginning of each training or assessment course to eliminate the drift caused by the inertial sensors. Participants were allowed to rest at the end of each course. After finishing the assessment courses, participants filled out an exit questionnaire.

## 5 Results

### 5.1 Virtual Falls

We performed a two-way ANOVA on the visual cue and course type. We found a significant effect of visual cue on number of virtual falls ($F_{3,140}$=9.27; p=0.0017). The group trained with visual cue had significantly fewer virtual falls (mean per course=1.96) than the group trained without visual cue (mean per course=3.04). Comparisons of the number of virtual falls on each course using the Student's t-test (Figure 2) showed that participants trained with the visual cue performed significantly better on the first assessment course ($T_{1,22}$=-2.30; p=0.03). Participants trained with the visual cue also had fewer virtual falls on the second assessment course, but this difference was not significant.

### 5.2 Completion Time

We did not observe any significant interaction between course type and visual cue. Our results indicated a significant effect of course type on normalized completion time (time divided by distance). Users in both groups walked faster in the assessment phase than the acclimation phase ($F_{3,140}$=12.33; p<0.0001). Pairwise comparisons using the Student's t-test did not show any significant differences between the two visual cue groups.

### 5.3 Perceived Difficulty

User's perceived difficulty gives insight about the subjective ease of use and the effect of visual cue on user experience. We found a significant interaction of visual cue and course type on perceived difficulty levels ($F_{3,140}$=12.86; p=0.0042). Per-course comparisons using the Student's t-test, shown in Figure 2, indicated that on the second acclimation course users with visual cue had significantly higher levels of perceived difficulty ($T_{1,22}$=2.54; p=0.0185) while on the second assessment course, users without visual cue had higher levels of perceived difficulty ($T_{1,22}$=-2.13; p=0.0444). We did not observe any significant differences for other courses.

### 5.4 Physical Falls

The number of times users fall down indicates their ability to maintain balance while using the Virtusphere. The mean number of physical falls for each person in the group trained without the visual cue was 0.42 falls per course, while people who were trained with the visual cue had an average of 0.31 physical falls per course. Although the mean values are different, our analysis did not reveal any significant differences for this measure.

### 5.5 Questionnaire Results

We ran a Chi-Square analysis to compare the subjective ratings given in the post questionnaires. Participants with visual cue felt significantly more difficulty focusing ($\chi^2_6$=7.2; p=0.03). We did not observe any significant differences for other measures. Overall, 58.3% of participants reported moderate to severe levels of sweating and 25% reported moderate to severe fatigue.

## 6 Discussion

Most of the effects of visual cue were positive. The number of virtual falls improved significantly when the visual cue was used for acclimation (Figure 2), and this difference was seen primarily on the assessment courses, after the visual cue had been taken away. Perceived difficulty was also significantly lower during assessment (Figure 2) after acclimation with the visual cue. Providing the visual cue did not have any negative effects on completion time and number of physical falls.

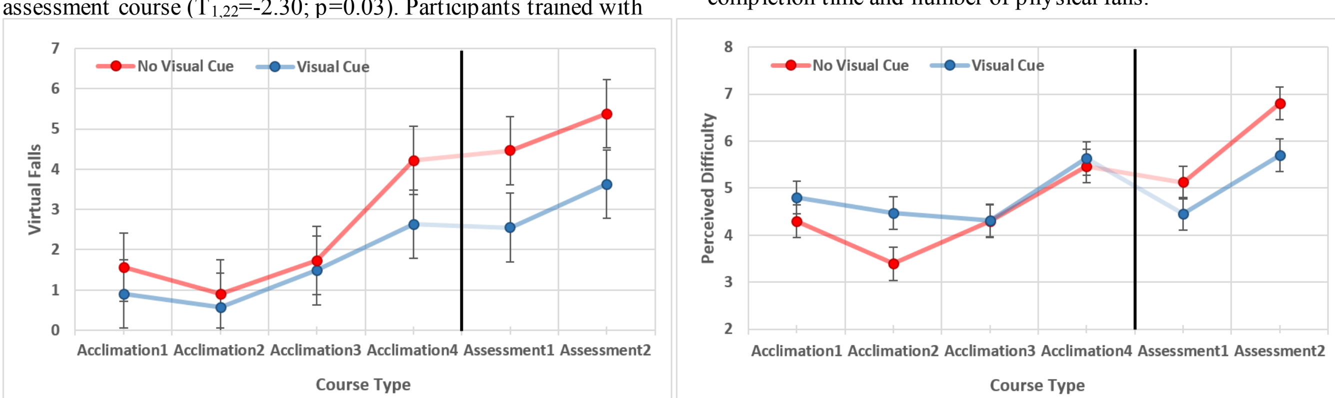


Figure 2 - Measure of virtual falls and perceived difficulty for the acclimation and assessment phases.

The virtual sphere we designed keeps the users aware of the fact that they are rolling a ball through the environment rather than walking on a flat surface. We believe that this helped the users better understand the required forces and adjust the way they moved to be more appropriate for the Virtusphere. This better understanding helps users to have a better overall experience. Although the conditions for the assessment courses were the same for both groups, the visual cue group had a better experience due to better understanding and control over the Virtusphere.

We did not observe any significant difference for completion time and physical falls, which suggests that the visual cue did not affect walking speed and balance control. The increase in accuracy was not a result of walking more slowly. We cannot say for certain whether the visual cue caused any differences in balance control although the visual cue group did have fewer physical falls in the assessment phase.

Semi-natural locomotion interfaces like the Virtusphere often have low performance and poor usability when users try to walk naturally. Our results show that appropriate visual assistance can help the user learn how this interface is different and how she should adapt her actions to it. To improve realism and not distract the user, the visual cue can be removed after the acclimation phase. Our results show that even without the visual cue, what users learned during acclimation can unconsciously help them to better understand their interaction and have better control.

Most of the participants who received the visual cue did not like it. We received several comments about the visual cue distracting users and occluding their view: "Virtual sphere did not help, I liked it when it was removed;" "It was not useful and occluded my view." Some users liked the visual cue at the beginning of their acclimation, but preferred it to be removed after several acclimation courses: "At first the virtual sphere was useful, but after I got used to walking in the ball, it was better when you removed it." The frustration of some users with the visual cue at the beginning is noticeable in the results. As shown in Figure 2, users with the visual cue perceived the second training course to be significantly more difficult than the group without the cue. Nonetheless, in the assessment phase, users in the visual cue group perceived significantly less difficulty and performed more accurately. It seems that, like vegetables for children, this visual aid actually helped participants to perform better despite their dislike of it. Thus, we jokingly refer to the virtual sphere as a "vegetable cue."

## 7 Conclusions and Future Work

Users often require acclimation to be able to easily and effectively employ semi-natural locomotion interfaces. We designed a visual cue that helps to acclimate users to the differences in forces and walking movements between the Virtusphere and real walking. We found that acclimating with this visual assistance helps users better understand their interaction with the locomotion interface and be able to more easily cope with the novel technique they are using. Our results indicate that acclimating users with this visual cue can improve their accuracy and reduce the perceived difficulty of complex walking tasks after the cue is removed, while it does not harm the walking speed and balance. Even if users do not prefer having a visual aid, providing an effective cue can improve their performance.

In the future, we plan to study other types of sensory cues (e.g., audio or haptic cues) for acclimation. This study was specific to the Virtusphere device. We can also extend this work and study effectiveness of acclimation aids for other locomotion devices.

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