Influence of Vertical Navigation Metaphors on Presence

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Abstract

A sense of spatial presence as a feeling of "being there" is an important part of the virtual experience. Navigation is a fundamental task in virtual environments and the specific navigation methods that are employed influence a user's sense of presence. In this paper we investigate how different metaphors for vertical navigation impact spatial presence. We introduce a new elevator metaphor for vertical navigation in virtual environments which includes a multimodal simulation. In a user study our approach is compared to the existing flying and teleportation metaphors with respect to spatial presence, comfort, real world awareness and other parameters. The results show that our elevator simulation increases the sense of presence and is more natural and realistic for vertical navigation in multilevel virtual environments than previous methods.

Keywords (max. 6): Vertical Navigation; Spatial Presence; Haptic Feedback; Realism; Virtual Reality

Introduction

In general virtual reality systems aim to provide the most compelling experience to a user in such a way that he feels being present in the computer generated environment. This sense of “being there” is referred to as presence or more specifically as spatial presence (Schubert, 2009). It depends on multiple factors and the nature of a task in the virtual environment (VE) may also influence the sense of presence (Lombard & Ditton, 1997).

Navigation is one of the most universal tasks performed in real and virtual environments (Bowman, Kruijff, LaViola Jr., & Poupyrev, 2005). Natural and intuitive navigation is generally performed by walking. Natural locomotion has been shown to be beneficial in terms of presence (Usoh et al., 1999) and spatial updating (Chance, Gaunet, Beall, & Loomis, 1998) in comparison to other artificial means of locomotion e.g. using hand-held controllers. However, the physical space available for horizontal locomotion is limited. A good vertical navigation method will support the effective use of physical space and will significantly extend the reachable virtual space without negative impact on presence. Previous research on horizontal locomotion suggests that the sense of presence is enhanced when users are able to move through a VE in a more natural way (Slater, Usoh, & Steed, 1995; Usoh et al., 1999; Zanbaka et al., 2004). Similarly, a difference in vertical navigation approaches is to be expected. However, there are no comparisons of vertical navigation methods with regard to presence.

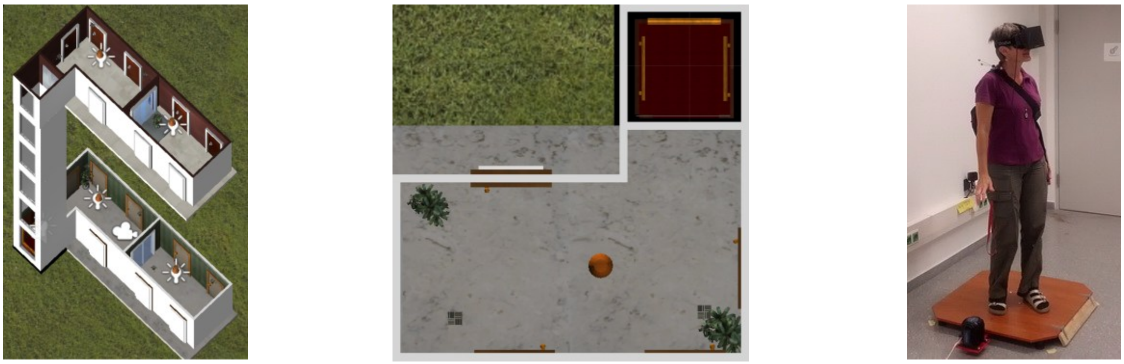
In this paper we introduce a new elevator metaphor for vertical navigation in VEs with multimodal feedback simulation that is directly connected to our everyday experience. We conduct an experimental comparison of our new approach to already existing magical metaphors such as flying and teleportation (Bruder, Steinicke, & Hinrichs, 2009; Usoh et al., 1999). As each metaphor provides different cues for the user, we investigate their influence on presence, comfort, real world awareness and other parameters.

Related Work

The problem of navigation within a limited real world space, while being in a virtual environment, has been solved in a number of different ways. The most natural way is real walking or its indirect analog walking-in-place (Razzaque, 2005). The seven league boots (Interrante, Ries, & Anderson, 2007) and jumper (Bolte, Steinicke, & Bruder, 2011) magical metaphors use unnaturally accelerated transfer to a desired virtual location. These approaches are very effective for navigation on a flat surface, but do not address navigation to places above or below walkable area – heights in particular.

Vertical navigation in a VE was implemented via flying (Usoh et al., 1999). A difference in sense of presence was reported between real walking, walking-in-place and flying (Usoh et al., 1999). Another magical metaphor "portal" (Bruder et al., 2009) is an universal instrument for location change, but it might require a miniature VE representation for controllable use. To our best knowledge only flying was evaluated in terms of presence.

In literature there are multiple concepts of presence (Lombard & Ditton, 1997). We chose to follow Schubert's concept of spatial presence as an immediate, always positive, informative feeling with intensity and tones, caused by unconscious spatial cognition (Schubert, 2009). There are subjective measures of presence that combine the evaluation of individual subjective sensations together with other aspects of the virtual experience and objective measures that asses physiological and behavioral responses (Lombard & Ditton, 1997). For the measurement of the subjective feeling of presence, a variety of questionnaires such as Slater-Usoh-Steed, Witmer-Singer, ITC-Sense of Presence Inventory and others have been published (Dinh, Walker, Song, Kobayashi, & Hodges, 1999; Lessiter, Freeman, & Keogh, 1998; Lombard et al., 2000; Slater, Khanna, Mortensen, & Yu, 2009; Usoh, Catena, Arman, & Slater, 2000; Witmer & Singer, 1998). These questionnaires were used as guidelines during compilation of short questionnaires for our very specific experiment.



(a) (b) (c)

Figure 1 – (a) Virtual environment model, (b) floor layout in the virtual environment, (c) user on the haptic platform in the tracked space

Virtual Environment and Setup

As a testbed for the vertical navigation metaphors we have created a VE that consists of a building with two accessible floors that are connected by an elevator well (see Figure 1a). There are windows along the well that designate the floors. The building is surrounded by an environment consisting of hills and multiple buildings that are visible to the user through the windows of the well. The outside environment is used to provide visual clues on the position change in the VE. The floors differ in color and design elements. The layout of the walkable virtual space is shown in Figure 1b and matches the size of the tracked lab space sized 3.5×3.5 meters. As acceptance of a virtual body has a great impact on presence (Usoh et al., 1999) we chose not to implement any avatar. We provided an additional training session that allowed user to feel more comfortable in the tracking space.

For equal comparison of the navigation metaphors we keep the virtual and real world environment consistent for all navigation metaphors. Our implementation unites real walking with one-to-one mapping and vertical navigation methods in a way that can be accommodated within the physical space limits. All vertical navigation techniques are triggered automatically by the user's position, whenever the user steps on a haptic platform that corresponds to the virtual elevator well (see Figure 1c).

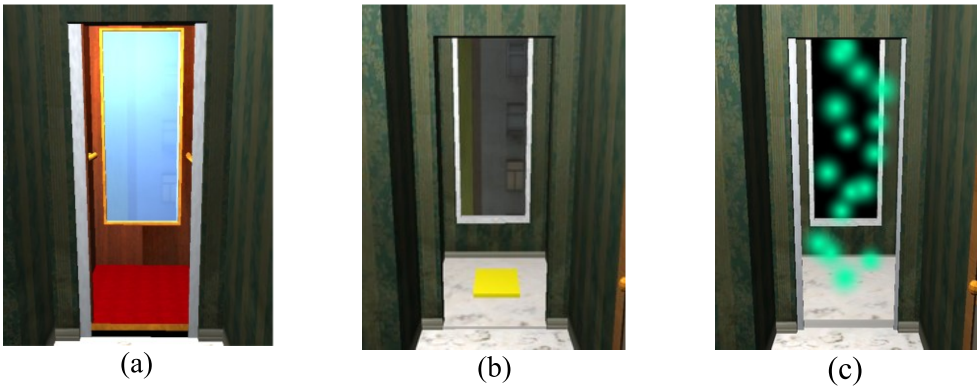


Figure 2 – Navigation metaphors implementations.

(a) Elevator model, (b) Flying setup, (c) activated Teleport

Elevator

For vertical navigation between the floors we created an elevator model (see Figure 2a) and augmented it with visual flow, audio and tactile feedback. We use a recording of a real elevator which is input to the audio transducer to induce audio synchronized vibration to a platform (see Figure 1c). Nearby buildings that can be seen through the semi-transparent windows, serve as visual cues in the elevator. The transition between floors takes approximately 20 seconds. While our elevator metaphor might be considered to be similar to the flying metaphor, the corresponding haptic and audio feedback together with a significant occlusion of surroundings (e.g. of objects below, to avoid fear of heights) make it different.

Flying

The flying metaphor does not involve any sound or vibration augmentations. The user is able to see the whole inner space of the elevator well below and above his position. He can clearly observe his position change in the virtual building as well as in the VE by using external objects visible through the well's windows. To keep the physical setup consistent we do not remove the platform from the tracked space. In the middle of the well a small virtual yellow plate is added as a cue for the elevated physical floor. Users might feel uncomfortable stepping into an empty elevator without support under their feet, therefore the plate is supposed to reduce potential fear of heights during navigation from the upper floor (see Figure 2b). The virtual movement between floors lasts 20 seconds as in the elevator metaphor.

Teleportation

Inspired by Bruder et al. (2009) we adapted a portal to our VE and implemented it in a similar magical form of a teleport. The teleport is positioned at the same location as the elevator and is represented as a small room with a window. Teleportation is accompanied by activating a particle system animation and a short audio sequence typically associated with such transportation in entertainment industry. To avoid a mismatch in the physical space we did not remove the wooden platform from the tracked space. The virtual floor is elevated by about 10cm to indicate the necessity to step onto the platform. No vibration is used. The teleportation procedure takes approximately 10 seconds. The window in the well is blocked for one second to reduce the impact of the abrupt change in virtual camera position on the user's balance that was identified during the pilot phase of the experiment design.

Technical Setup

Users were equipped with a wireless setup of the Oculus Rift HMD. We used the Rift's built in sensors for smooth tracking of head rotation and attached a retro-reflective rigid body marker to the user's shoulder to track his torso position. The marker was tracked with the optical sub-millimeter precision tracking system iotracker (Pintaric & Kaufmann, 2007). Tracking and rendering was done on an Intel Core i7 CPU PC with 12 GB RAM and an Nvidia Geforce GTX 690 graphics card. Audio feedback was provided via a 5.1 audio system. As an audio transducer we used Buttkicker LFE (400-1500W) connected with a metal mounting to the wooden platform sized 85×85×10 cm (see Figure 1c).

Methods

We followed a within-subjects study design and used questionnaires to measure the spatial presence, subjective spatial perception and general comfort. Our objective was to investigate if: 1) a real world based navigation metaphor improves the sense of presence; 2) a real world based navigation metaphor improves the subjective spatial perception of the VE; 3) simulation of a conventional method for vertical navigation improves the general comfort.

Study Design

30 users (11 females and 19 males) aged from 23 to 39 (mean 27.73) participated in this study. The participants were recruited from university employees and the general public. 24 participants stated that they play video games less than 2 hours per week; however 18 had 5 or more years of prior video games experience. 9 participants identified themselves as experienced with 3D gaming environment and 12 participants as completely inexperienced.

In the beginning of the experiment each participant was randomly assigned to one of the six possible sequences of the navigation metaphors, asked to provide general information about himself (age, gender, video games and 3D environments experience) and filled in a simulator sickness pre-questionnaire (Kennedy, Lane, Berbaum, & Lilienthal, 1993). Next, an HMD was adapted to the user's vision using the Oculus Rift calibration tool. The user was asked if he can sharply see the text and objects, and if he has 3D perception. Then user was trained to walk in the virtual environment and to get on and off the platform with a virtual representation in an open space scene. After the user confirmed being comfortable, we proceeded with the experimental trials. All participants were informed that they can discontinue the experiment at any moment.

Each participant was instructed to navigate by real walking to the upper floor of the VE, to walk and observe an object upstairs, different for each trial, and to return back. After each trial the participant filled in a trial questionnaire (TQ) shown below:

1. How real was the virtual environment for you?
2. How comfortable were you in the virtual environment?
3. How strong was your awareness of the real world surroundings while in the VE?
4. How well could you keep track of your location in the virtual environment?

5. How strong was your sense of being (present) in the virtual environment?
6. How real/compelling was your sense of moving between the floors?
7. How well could you keep track of your location (and orientation) in the real world?
8. How comfortable you were while moving between the floors?

Participants rated each question on a Likert scale 1-7 (1 – Not at all, 7 – Very much so). For this questionnaire we adapted the questions that appeared in presence research literature. We kept the questionnaire short in order to maintain the experiment timing below one hour time limit. Each participant had to perform the experiment three times using elevator, flying and teleportation metaphors, as described above. The order of metaphors was counterbalanced. After finishing the last trial the participant filled in the simulator sickness post questionnaire and was asked to fill in the comparison questionnaire (CQ) rating each metaphor with a score from 1-7 (1 – Not at all, 7 – Very much so) according to the following statements:

1. How present (being there) you felt in the virtual environment while moving between the floors?
2. How natural it is to use for movement between the floors?
3. How realistic it felt in the virtual environment while moving between the floors?
4. How clear it is that your location on virtual space changed (you moved up or down)?
5. Rate the navigation methods according to your preference

Finally, user was asked to provide a feedback about the experience.

Results

In the first part of the study we have focused on the presence (TQ, questions 1, 4, 5, 6), and comfort (TQ, questions 2, 8) in contrast to real world awareness (TQ, questions 3, 7). We performed a principal factor analysis (PCA) with orthogonal rotation in order to identify

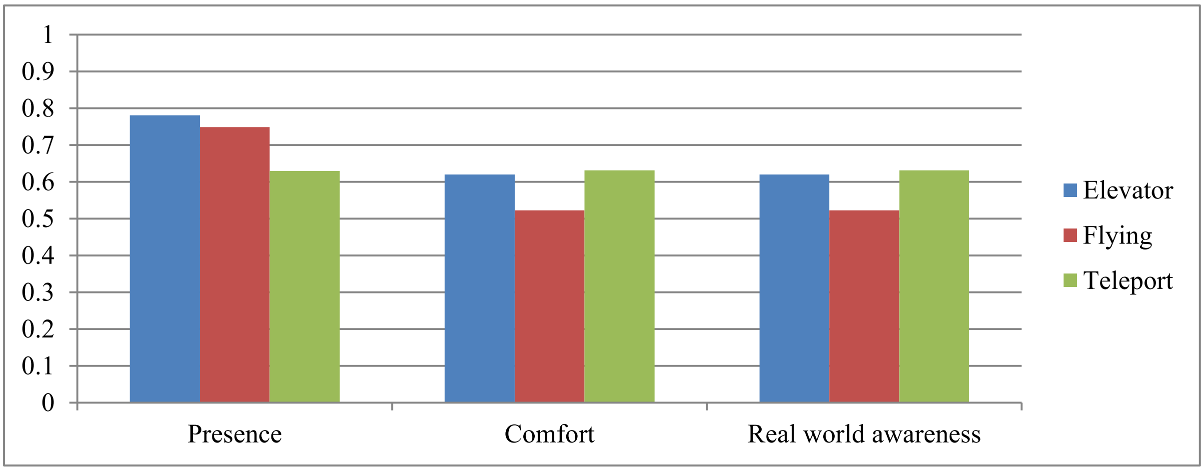


Figure 3 – Means of presence, comfort and real world awareness factors for the metaphors

underlying factors of the used questionnaires using aggregated data across conditions. The Keiser-Meyer-Olkin measure KMO = 0.59 verified the sample adequacy for the analysis.

Bartlett's test of sphericity $\chi^2(28)=141{,}64$, $p < 0.001$, indicated that correlations between items were sufficiently large for PCA. We identified three factors: (1) presence, (2) comfort, and (3) real world awareness. The resulting factors formed reliable compounds with Cronbach's alphas $\alpha_1= 0.68$, $\alpha_2= 0.65$, $\alpha_3= 0.65$ respectively. Relatively small alpha values are caused by the small number of questions per factor.

We computed the means of the question groups for elevator, flying, and teleportation readjusting them to scale from 0 to 1 (see Figure 3). After that we performed a three-way repeated measures ANOVA.

The results show that the treatment conditions significantly affected the presence. For this factor Mauchly's test indicated that the sphericity assumption was not met, $\chi^2(2) =7.503$, $p < 0.05$, therefore, to obtain valid estimates, we corrected degrees of freedom using Greenhouse- Geisser estimates of sphericity ($\varepsilon = 0.402$, $F(1.6, 46.96) = 19.46$, $p < 0.05$).

The results suggest that teleport has a significantly smaller Presence score than the flying metaphor, while there is a trend for difference between elevator and flying that is not

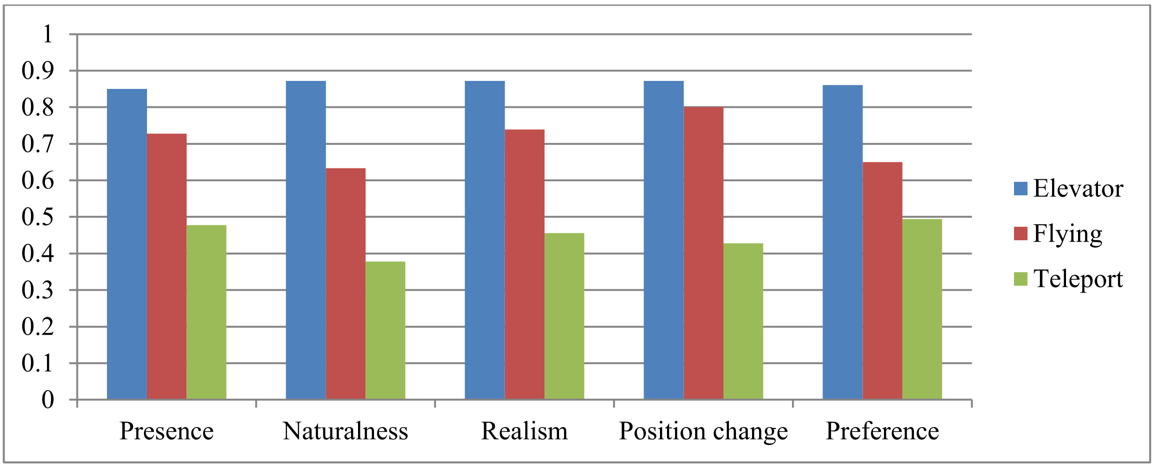


Figure 4 – Means of comparison rating for the metaphors by presence, naturalness, realism, position change perception and user's preference

significant. The elevator metaphor is significantly more comfortable than flying ($F(2, 58) = 4.54$, $p < 0.05$), but not significantly different from teleportation. The factor of the real world awareness was significantly smaller for the flying metaphor than for elevator and flying ($F(1,29) = 6.23$, $p < 0.05$; $F(1,29) = 7.57$, $p < 0.05$).

The final ratings were conducted with the comparison questionnaire for each metaphor. We performed repeated measures ANOVA on the results of each question of the CQ. If the sphericity assumption was not met, we used Greenhouse-Geisser correction (GGC). All ratings had significant differences between metaphors. Figure 4 shows the comparison of the rating means.

To have a deeper look at the dependences in the final scores we explored the partial correlation between the rating parameters. This way presence shares 57% of variance with realism and 37% with naturalness. At the same time realism shares 62% of variance with naturalness and 52% with the position change. Finally, preference is sharing 45% of variance with both naturalness and realism, 35% with presence and 32% with position change.

The simulator sickness questionnaire designated no symptoms of cyber-sickness, proving that the system and metaphors implementations were functioning properly and did not impede the scores.

Discussion

The findings of this study suggest that by replicating real world experience and means of travel it is possible to enhance the sense of presence and comfort in comparison to already existing magical approaches for vertical navigation. There is a noticeable difference between presence in TQ and CQ results for the flying and elevator metaphors. Both experiences are described with a high sense of spatial presence, but in comparison the elevator exhibits a stronger feeling of presence. There is a surprising lack of difference between the elevator and teleportation in terms of comfort and real world awareness, while the flying metaphor has significantly lower scores. This may be explained by the fact that elevator and teleportation do not provide as much height or depth information, while the flying metaphor was often accompanied by exclamations like “Oh, my God!” while looking down. We speculate that fear might be drawing attention from the real world surroundings, which correlates with the horizontal locomotion comparison (Usoh et al., 1999) as well as the study of fear of heights (Regenbrecht, Schubert, & Friedmann, 1998). From this perspective almost equal comfort and real world awareness measures of elevator and teleport might be interpreted as average levels in the current setup. We see a possibility to improve their measures and therefore increase the sense of presence in an ideal setup, where the haptic platform would not differ from the floor in height. The final scores significantly differ between the metaphors. The teleportation received the lowest scores. Given that both presence and preference parameters share a large percentage of their variance with realism and naturalness, we assume that the possible cause lies in users’ expectations. As one of the participants pointed out “Teleportation is cool, but didn’t do it for me”. As there is a strong connection between variations of realism, position change, and presence in our VE, it is possible to improve the spatial presence together with overall experience by providing additional information about the VE for easier orientation.

"Sound and shaking made it very real" was a common description of experience with the elevator metaphor. Our data together with users' comments confirm the results of previous research that multi-sensory input contributes to the sense of presence (Dinh et al., 1999), especially if the users' expectations were met.

The CQ results represent an explicit comparison between the metaphors in presence and other characteristics that may contribute to it. Combining together the TQ presence factor with CQ mean scores we can conclude that the elevator metaphor outperforms the flying and teleportation metaphor by invoking a stronger sense of spatial presence and understanding of one's position in the VE by being more natural and realistic which leads to the strongest users' preference.

Conclusion

In this paper we proposed a new elevator metaphor with multimodal feedback for vertical navigation. We performed a user study which compared our approach with already existing flying and teleportation metaphors for vertical navigation. Our investigation focused on the sense of spatial presence and perception together with comfort real world awareness, naturalness, realism and users' preferences. The obtained results suggest that a real world based elevator simulation is accommodating a stronger sense of spatial presence and in the future will be a good solution for extending the virtual space with the help of vertical navigation.

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