Evaluation of Reorientation Techniques for Walking in Large Virtual Environments

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ABSTRACT

Virtual environments (VEs) that use a real-walking locomotion interface have typically been restricted in size to the area of the tracked lab space. Techniques proposed to lift this size constraint, enabling real walking in VEs that are larger than the tracked lab space, all require reorientation techniques (ROTs) in the worst-case situation–when a user is close to walking out of the tracked space. We propose a new ROT using distractors–objects in the VE for the user to focus on while the VE rotates—and compare our method to current ROTs through two user studies. Our findings show ROTs using distractors were preferred and ranked more natural by users. Users were also less aware of the rotating VE when ROTs with distractors were used.

Keywords: Virtual Environments, Walking, Locomotion, User Studies, Reorientation Techniques

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities H.5.2 [Information Interfaces and Presentation]: User Interfaces—Evaluation/methodology I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual Reality

1 INTRODUCTION

Real-walking in virtual environments (VEs) is more natural and produces a higher sense of presence than other locomotion techniques [14, 16]. However, VEs using a real-walking locomotion interface have typically been restricted in size to the area of the tracked lab space. Techniques have been proposed to lift this size constraint, enabling real walking in VEs that are larger than the tracked space [7, 9, 10, 8, 15, 17, 18]. Each of these large-area walking VE methods relies on a reorientation technique (ROT) to handle the case when the technique fails and the user is close to walking out of the tracked space. When such an event happens, ROTs must stop the user and rotate the VE around her current virtual location, placing the immediately expected user path back within the tracked space. The user must also reorient herself by turning around in the real environment so she can follow her desired path in the newly-rotated VE.

ROTs are required to enable free exploration of infinitely large VEs without the use of joysticks, walking-in-place interfaces, treadmills, or bicycles [1, 2, 3, 5, 11]. We hypothesize that current ROT implementations cause breaks in presence, which detract from the immersive VE experience. In this paper we introduce a new ROT and compare our method to existing ROTs through two user studies. We evaluate each ROT based on *presence*, user-ranked *preference*, and user-ranked *naturalness*.

Our method introduces a distractor, an object in the VE for the user to focus on while the VE rotates, reducing perception of the rotation, and thus reducing the likelihood of a break in presence. In the studies we compared the new distracter technique to previously reported techniques. The methods introduced by Razzaque [9, 10, 8] and Williams [17, 18] induce the user reorientation via audio instructions, rotating the VE while the user is following the instructions. Nitzsche and Su rotate the VE without warning or additional instructions [7, 15].

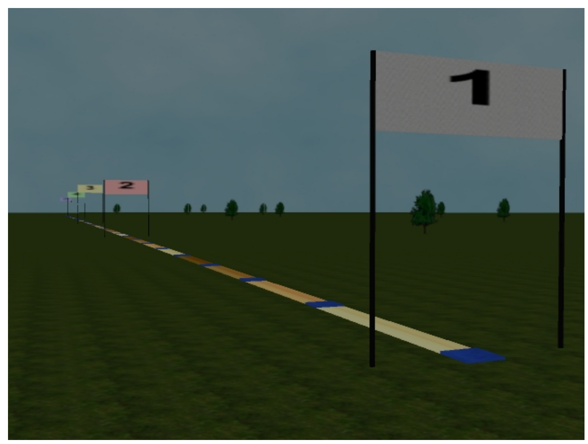

Figure 1: Virtual Environment used in Experiment 2

Figure 2: Laboratory Layout used in Experiment 2

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2 BACKGROUND

Three real-walking techniques exist for exploring large immersive VEs and each method suggests its own ROT to enable free exploration. Redirected Walking (RDW) [9, 10, 8] is a technique that exploits the imprecision of human perception of self-motion–the motion of humans based on sensory cues–and modifies the direction of the users gaze by imperceptibly rotating the VE around the user. The primary design goal of this technique is that it be imperceptible by the user. Razzaque suggests a ROT with a loudspeaker in the VE that asks the user to stop, turn her head back and forth, and continue walking in the same direction. Razzaque determined that a user is least likely to notice extra rotation while she is turning her head because of the imprecision of human self-motion perception-the motion of humans based on sensory cues. RDW rotates the VE during such moments, moving the users path so that it falls within the tracked environment. This ROT encourages imperceptibility of the VE rotation.

Motion compression (MC) [7, 15] rotates the VE such that the predicted user path is the largest possible arc that can fit into the tracked lab space and, like RDW, continuously updates the location and the rotation of the VE relative to the lab space. Unlike RDW, MC does not make imperceptibility of rotation a goal. The ROT used in MC is built into the system: as the user approaches the edge of the tracked space, the VE rotates the predicted user path into the tracked area (following the computed arc of minimum curvature) causing the user to feel that the VE is spinning around.

Scaled translational gain [17, 18] increases the translational step size of the user in the VE without modifying rotation. Instead of scaling the user's step size [4] scaled the VE. Three methods have been explored for manipulating the VE when the user nears the edge of the tracked space [19]. One technique involves turning the HMD off, instructing the user to walk backwards to the middle of the lab, and then turning the HMD back on. The user will then find herself in the same place in the VE but will no longer be near the edge of the tracked space. The second technique turns the HMD off, asks the user to turn in place, and then turns the HMD back on. The user will then find herself facing the same direction in the VE, but facing a different direction in the tracked space. Preliminary research [19] suggests that the most promising technique uses an audio warning to ask the user to stop and turn 360°. The VE rotates at twice the speed of the user and stops rotating after 180°. The user is supposed to reorient herself by turning only 180° but should think she has turned 360°. The ROT attempts to trick the user into not noticing the extra rotation.

Current techniques have characteristics that we believe are likely to cause breaks in presence: audio instructions (unrelated to the content of the VE) and unexpected large rotations of the VE. Our method differs from the current methods in that it does not unexpectedly rotate the VE or use unnatural audio cues. We distract the user with a moving object in the VE, similar to a method implemented by Kohli[6]. While the user is rotating her head to follow the object, the VE is rotated around her. This method exploits the imprecision of vestibular perception suggested by Razzaque. We hypothesize that the visual distraction will make the rotation of the VE less noticeable to the user and will not detract from the immersive virtual experience. We conducted two user studies to evaluate our method and compare it to ROTs suggested by Razzaque, Williams, and Nitzsche.

3 METHODS

We conducted two University of North Carolina IRB approved within-subjects user studies to evaluate ROTs and compare distractors to current ROTs. Experiment 1 showed that of the current ROTs, users preferred our method as well as the method suggested in [8]. We modified our distractor technique based on user feedback from the first study and then conducted a follow-on study comparing the improved distractor ROT to our original method and to the method suggested in [8].

3.1 Equipment

Each participant wore a Virtual Research Systems V8 head-mounted display tracked using a 3rdTech HiBall 3000. Participants were permitted to walk in an 8m x 6m tracked space. The environment, see Figure 1 was rendered at 100fps on a Pentium D dual-core 2.8GHz processor machine with an NVIDIA GeForce 6800 GPU with 2GB of RAM.

3.2 Experiment 1

Our first study evaluated the ROTs suggested or implemented by [7, 9, 10, 8, 15, 19] plus our distractor technique. The measures were *presence*, user-ranked *preference*, and user-ranked *naturalness*.

3.2.1 Participants

Twenty-four introductory psychology students (13 men and 11 women) participated in the experiment. Each subject visited the laboratory once for a session lasting approximately 1 hour and received class credit for participation. All subjects had normal or corrected to normal vision and were naive to the purpose of the study. Participants were not informed about ROTs and were initially unaware that the VE would rotate.

3.2.2 Experimental Design

The experiment consisted of two parts, both taking place in the same VE. The VE was an outdoor space featuring a 200-meter straight wooden path with circular markers placed 5 meters apart along the path. To walk the virtual path, subjects walked 5 meters across the lab to a marker, turned 180° and walked back across the lab to the next marker. The rotation of the VE occurred only during reorientation. Subjects received instructions before the experiment began and received trial-specific instructions before each trial. Subjects were instructed to walk along the path in the environment and to stop at each marker. Once a subject reached a marker, the subject experienced one of four reorientation techniques.

Turn without instruction (T). When the user reaches the marker the VE immediately rotates 180° around the user at 0.035 radians per frame. All rates were determined from pilot experiments. The rotation relocates the virtual path so it is located within the tracked environment. The user needs to reorient herself in the VE by turning 180°. This is similar to the technique used by [7, 15].

Turn with audio instruction (TI). Via audio instructions in the VE, the user is asked to turn 360° and continue along the path; however, the VE rotates 180°. The rotation of the VE is controlled by the user's head and rotates at twice the speed of the user's head. The user is deceived to think that she has turned 360° in both the virtual and real worlds when she has only turned 180° in the real world. The user needs to reorient herself in the VE by turning only 180°. This is similar to a method described by [19].

Head turn with audio instruction (HT). The user is asked via audio instructions in the VE to turn her head back and forth and then continue walking along the path. While the user turns her head the VE rotates 0.3 times faster than the user's head until the VE has rotated 180°. The rotation of the virtual environment should only be increased in the direction the head is turning and in the direction the VE is rotating. The participant reorients herself by rotating 180° in the real world. This is similar to a method described by [8].

Head turn with visual instruction, Distractor (D). A moving sphere appears in front of the user. The user watches the sphere

Table 1: Experiment 1 - Mean HIGH scores on SUS Presence Questionnaire

ROT	$\bar{x}$
D	0.47917
HT	0.50000
TI	0.28472
T	0.44444

as it moves in a sinusoidally-timed horizontal arc and continues walking along the path once the sphere disappears. While the user is turning her head to watch the sphere the VE rotates 0.5 times faster than the user's head until the VE has rotated 180°. The distractor moves at 0.0025 radians per frame. The user reorients herself by rotating 180° in the real world.

Part I of the experiment assessed the users subjective sense of presence in the environment and consisted of four trials, each using one of the four reorientation techniques. The order of the trials was counterbalanced among subjects. Each trial was comprised of four sub-trials in which the subject walked along the virtual path and stopped at a marker along the path. When the subject reached a marker, an ROT would stop the subject and rotate the VE. Each trial consisted of walking to four markers and experiencing the same reorientation technique four times. Subjects then removed the HMD and filled out a presence questionnaire.

Part II consisted of 12 trials, each with two reorientation techniques. Trials were counterbalanced and every ROT was compared to every other ROT twice with order reversed to remove the possibility of order effects. Each trial required the subject to walk to a marker, experience an ROT, then walk to the next marker, and experience a different ROT. The subject then made a forced choice regarding which ROT they preferred and which ROT was most natural. At the end of each trial subjects were orally asked to explain why they chose one ROT over another.

At the end of the experiment, subjects filled out an exit survey and were asked to describe the differences between the four ROTs, explain what they liked or disliked about each of the ROTs, and rank the four ROTs based on naturalness and preference.

There are many ways to assess the subjective sense presence; we used a modified SUS presence questionnaire [12, 13] Naturalness and preference were each measured in two ways: at the end of the experiment subjects ranked the ROTs, and during the experiment subjects made a forced-choice ranking between pairs of ROTs.

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D  – Distractor
HT - Head turn with audio instruction
TI – Turn with audio instruction
T  - Turn without instruction
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Figure 3: Experiment 1–Legend

3.2.3 Results

Figures 3 through 7 show our results from Experiment 1. The SUS presence scores were analyzed using the same binomial logistic regression techniques as applied in previous uses of the questionnaire [14]. The response to each question was converted from the 1 to 7 scale to a binary value: responses of 5, 6, or 7 were converted to HIGH (1) and values less than 5 were converted to LOW (0). This conversion lets us avoid treating the subjective ratings as interval data. After this conversion, we further transformed the data to create a new response variable for each participant: the count of their HIGH responses. Tables 1 and 2 show the average proportion of HIGH responses for each of the four conditions as well as the pairwise contrasts of conditions using logistic regression adjusted for multiple observations for each participant. There is a statistically significant effect between *HT* vs. *TI* ($\chi^2(1) = 11.97, p < 0.05$) and *T* vs. *TI* ($\chi^2(1) = 6.39, p < 0.05$) and we found a trend between *D* vs. *TI* ($\chi^2(1) = 3.35, p = 0.0672$).

Table 2: Experiment 1 - Results of Logistic Regression of SUS Presence Questionnaire

Contrast	$\chi^2(1)$	$p(\alpha = 0.05)$
D vs. HT	0.15	0.6980
D vs. TI	3.35	0.0672
D vs. T	0.02	0.8912
HT vs. TI	11.97	0.0005
HT vs. T	0.46	0.4986
T vs. TI	6.39	0.0115

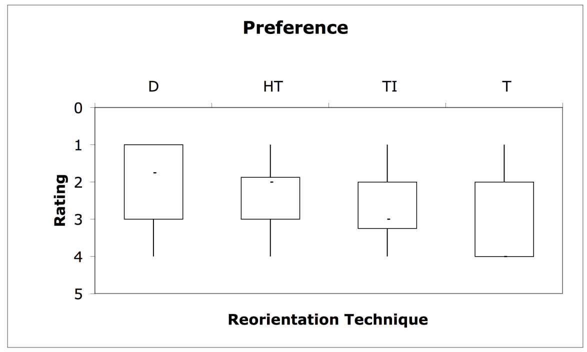

Figure 4: Experiment 1–User rated preference

Figures 4 and 5 show the average user rankings of preference and naturalness by ROT respectively. The data was analysed using Friedmans ANOVA. User-ranked naturalness was significantly different between ROTs: $\chi^2(3) = 9.524, p < .05$, as was user-ranked preference, $\chi^2(3) = 10.958, p < .01$. Wilcoxon tests were used to expand on this finding and a Bonferroni correction was applied. All effects are reported at a .0125 level of significance. The Wilcoxon test statistic is *T* and should not be confussed with our condition *T*. Subjects significantly found *HT* to be more natural than *TI*, *T* = 220.00, *r* = .38 and significantly preferred *D* and *HT* to *T*, *T* = 237.50, *r* = .37 and *T* = 235.50, *r* = .36 respectively.

Figures 6 and 7 show user preference and user-ranked naturalness of paired ROTs. The frequency at which a subject preferred

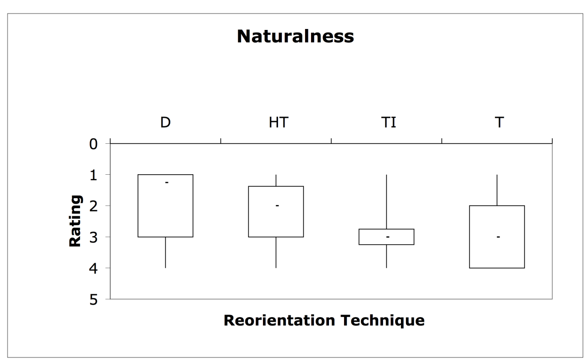

Figure 5: Experiment 1–User rated naturalness

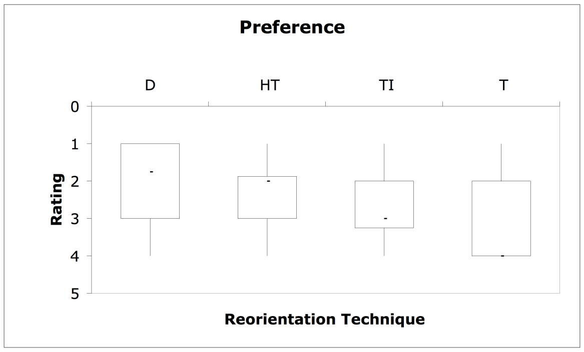

Figure 6: Experiment 1–User comparisons of preference across ROTs

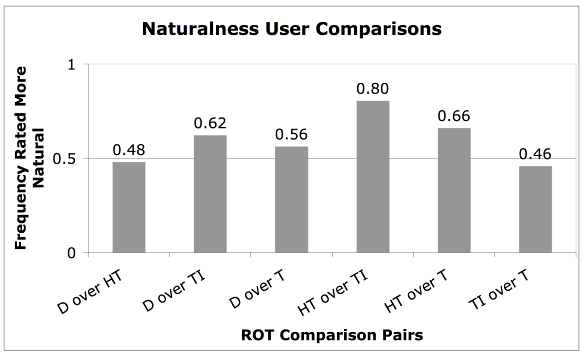

Figure 7: Experiment 1–User comparisons of naturalness across ROTs

one ROT over another was compared to random choice, a frequency of .50 using Wilcoxon tests. We found subjects significantly preferred *D* over *TI* ($T = 184.00, p < .05, r = .31$), *HT* over *TI* ($T = 176.00, p < .05, r = .35$), and *HT* over *T* ($T = 165, p < 0.5, r = .28$) and subjects significantly considered *HT* to be more natural than *TI*, T = 170.00, $p < .01, r = .50$.

3.2.4 Discussion

Subjects' exit surveys and responses during the experiment provided useful information about each ROT. Subjects' reasons for favourably rating ROTs included: the method provided instruction, either through audio or visual, they did not notice rotation, and the method was realistic or natural. We believe that *D* and *HT* were rated higher by subjects than *T* and *TI* because both rotate the VE while the subject is stimulating the vestibular by turning her head and is less likely to notice the rotation of the VE. We found subjects were confused during the first few sub-trials of *T* and often needed extra instruction from the experimenter to determine which direction to walk in the lab. After the first sub-trial of *T* one subject exclaimed, "Where am I?" and had to be stopped before walking out of the lab space. This occurred with several subjects, however after three sub-trials subjects often no longer needed extra instruction to determine the correct direction to walk in the lab. Subjects described *T* as dizzying, and complained about having no orientation in the VE after the world "spun." Some subjects found *T* to be "fun" and simple because you just wait for "the flip" and then the virtual would moves as you expect.

Subjects were occasionally confused by the audio instructions in *TI* asking for the subject to turn 360° but seeing the VE stop rotating after the subject only turned 180°. Subjects would occasionally turn 360° in the real world and then turn an additional 180° to walk the correct direction along the path. Subjects also noticed the VE spinning at a much faster rate than they were turning. One subject complained about the disembodied voice that did not fit into the environment. Subjects praised this technique for giving them some control over the VE by spinning when the subject turned. Subjects also found audio instructions helpful for determining how to turn around in the VE.

When using *HT*, subjects complained about noticing the path in VE not being in the right place once they started turning their heads but also commented on not seeing the rotation as much as other ROTs. Some subjects would occasionally stop turning their heads before the VE had rotated 180° and would stand and wait until given more instruction to continue turning their heads. These subjects would no longer need extra instruction after three sub-trials. Subjects liked having control over the rotation of the VE that was offered by turning their heads.

Subjects commented that the distractor was dizzying because it moved too fast, or that they would not be able to turn their heads fast enough to keep it in view. Subjects also complained that a "big red ball is not normal." Some subjects also complained about the ball's sudden appearance and disappearance. Other subjects found *D* entertaining and engaging and found that when looking at the ball they were not paying attention to the moving scenery.

Our results revealed that *D* and *HT* were significantly better ROTs than *TI* and *T* by producing increased presence, having higher user preference and being more natural to the user. However user feedback suggested further improvements.

3.3 Experiment 2

Based on the results and user feedback from Experiment 1, we improved our distractor method by using a butterfly instead of a sphere because it is more natural for the environment. We also had the butterfly fly in and out of the VE instead of suddenly appearing and disappearing. We compared our improved distractor to the most promising ROTs from Experiment 1: our original red sphere distractor and head turn with audio instruction [8].

To have the butterfly appear more lifelike we slowed the speed at which it flew around the subject. To compare the difference in natural versus unnatural distractors we also changed the speed of the sphere to match that of the butterfly.

3.3.1 Participants

Twelve participants from the general population (6 men and 6 women), most computer science graduate students in their twenties, participated in the experiment. Each subject visited the laboratory once for a session lasting approximately 1 hour and received $7.50 for participation during the week and $10.00 for weekend participation. All subjects had normal or corrected to normal vision and were naive to the purpose of the study. Participants were not informed about ROTs and were initially unaware that the VE would rotate.

3.3.2 Experimental Design

The experiment consisted of two parts, both taking place in the same VE. The VE was a similar outdoor space to Experiment 1 with a 180-meter straight wooden path with square markers placed 5 meters apart along the path. Subjects were instructed to walk along the designated path in the environment and to stop at each marker along the path. Once a subject had reached a marker, the subject experienced one of three reorientation techniques:

Head turn with audio instruction (HT). The user is asked via audio instructions in the VE to turn her head back and forth and then to continue walking along the path. While the user is turning her head the VE rotates 0.3 times faster than the user's head until the VE has rotated 180°. The participant reorients herself by rotating 180° in the real world. This is similar to the method described in [8].

Head turn with visual instruction, distractor (D). A moving sphere appears in front of the user. The user watches the sphere as it moves in a sinusoidally-timed horizontal arc and continues walking along the path once the sphere disappears. While the user is turning her head to watch the sphere the VE rotates 0.5 times faster than the user's head until the VE has rotated 180°. The distractor moves at 0.0005 radians per frame. The user reorients herself by rotating 180° in the real world.

Head turn with visual instruction, Improved distractor (ID). A butterfly flies into the scene to the subject, and then flies in a sinusoidal horizontal arc in front of the subject. The subject continues walking along the path once the butterfly flies away. While the user is watching the butterfly the VE rotates 0.5 times faster than the user's head until the VE has rotated 180°. The distractor moves at 0.0005 radians per frame. The user reorients herself by rotating 180° in the real world.

Part I of the experiment assessed the users subjective sense of presence, how aware the user was of turning around, and how aware the user was of the VE rotation. Part I consisted of three trials, each using one reorientation technique. The order of the trials was counterbalanced among subjects. Each trial was comprised of eight sub-trials requiring the subject to walk along the virtual path to the next marker along the path. Once the subject reached a marker a ROT would stop the subject and rotate the VE. Each trial consisted of walking to eight markers, experiencing the same reorientation technique eight times. Subjects then removed the HMD and filled out the SUS presence questionnaire. In addition to the presence questionnaire, subjects also answered the following question:

Did you notice anything unnatural or odd during your virtual experience? Please rate the following on a scale from 0 to 7. 0 = did not notice or happen, 7 = very obvious and took away from my virtual experience.

___I felt like I was turning around
___I saw the virtual world get smaller or larger
___I was the virtual world flicker
___I saw the virtual world rotating
___I felt like I was getting bigger or smaller
___I saw the virtual world get brighter or dimmer

We imbedded questions of concern about the VE rotating and the subject turning and analyzed only the results from these answers.

Part II consisted of 6 trials, each with two reorientation techniques. Trials were counterbalanced and every ROT was compared to every other ROT twice with order reversed to remove the possibility of order effects. Each trial required the subject to walk to a marker, experience an ROT, and then walk to the next marker and experience a different ROT. The subject then made a forced-choice decision as to which ROT they preferred and which ROT was most natural. Subjects were also asked to explain why they chose one ROT over another.

At the end of the experiment, subjects filled out an exit survey and ranked the three ROTs based on naturalness and preference.

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ID – Improved Distractor
D  – Distractor
HT - Head turn with audio instruction
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Figure 8: Experiment 2–Legend

Table 3: Experiment 2 - Mean HIGH scores on SUS Presence Questionnaire

ROT	$\bar{x}$
ID	0.52778
D	0.45833
HT	0.41667

Table 4: Experiment 2 - Results of Logistic Regression of SUS Presence Questionnaire

Contrast	$\chi^2(1)$	$p(\alpha = 0.05)$
ID vs. D	1.09	0.2974
ID vs. HT	1.72	0.1895
D vs. HT	0.63	0.4291

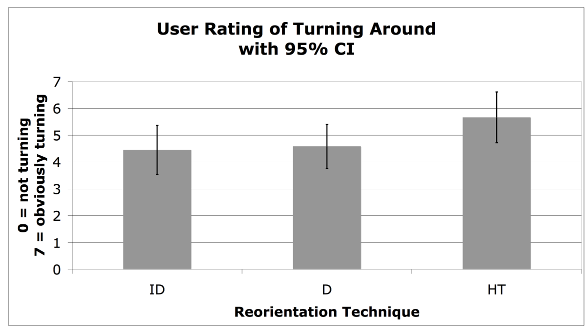

Figure 9: Experiment 2–User rating - "I felt like I was turning around"

3.3.3 Results

Figures 8 through 13 show our results from Experiment 2. The analysis of the SUS presence scores was done in the same manner as reported in Section 3.2.3. Tables 3 and 4 show the proportion of HIGH responses for each of the three conditions and the results of the pairwise contrasts of conditions. We found no statistical significance with user reported presence scores between ROTs.

Figure 9 shows average user scores by ROT of response to the question about feeling like they were turning around. We analysed the data using Friedmans ANOVA and found significant differences between ROTs: $\chi^2(2) = 7.550, p < .05$. Wilcoxon tests were used to follow-up this finding. A Bonferroni correction was applied and all effects are reported at a .025 level of significance. Subjects significantly felt like they were turning more in *TI* than *D*, T = 51.50, r = .74, and a trend was found with subjects feeling like they were turning more in *TI* than *ID*, T = 46.50, r = .56.

Using Freidmans ANOVA we found no significant difference between ROTs and subjects noticing that the VE (Figure 10) was rotating $\chi^2(2) = 3.630, p = .187$.

Trends were found between ROTs and subject ranked preference (Figure 11) $\chi^2(2) = 4.667, p = .108$ and subject ranked naturalness (Figure 12) $\chi^2(2) = 5.167, p = .080$.

Figure 13 shows user preference and user-ranked naturalness of paired ROTs, with 1 being the highest preference and 4 being the lowest. The frequency at which a subject preferred one ROT over another was compared to random choice, a frequency of .50 using Wilcoxon tests. Subjects preferred both *ID* and *D* to *HT*, T = 65.00, r = .47, and T = 77.00, r = .51 respectively, and ranked *ID* and *D* to be more natural than *HT*, T = 82.50, r = .44, and T = 65.00, r = .47

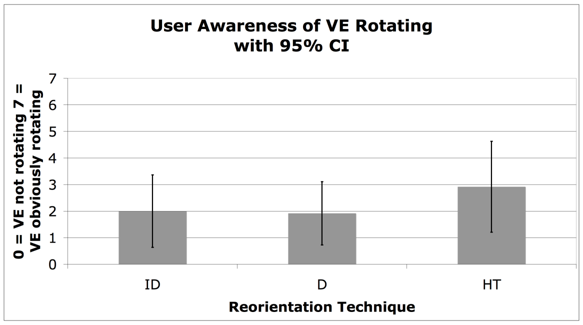

Figure 10: Experiment 2–User rating - ”I saw the virtual world rotating””

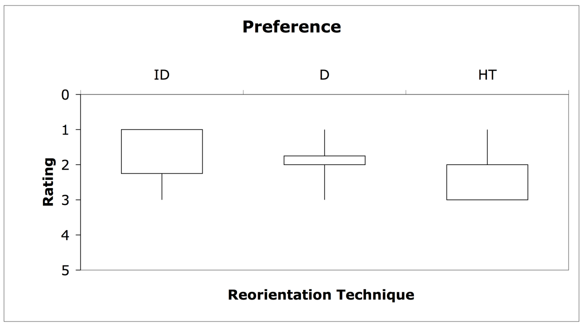

Figure 11: Experiment 2–User rated preference

respectively. A trend suggests that *ID* is more natural than *D*, $T = 63.00$, $r = .28, p = .11$.

3.3.4 Discussion

The results from Experiment 2 suggest ROTs that use distractors reduce the likeness of a user feeling like they are turning around when being reoriented. The results also suggest that subjects prefer ROTs with distractors and think they are more natural. We account for the difference between *D* and *HT* in Experiment 2 versus Experiment 1 by the reduced speed of the sphere.

Exit surveys and responses during the experiment again provided useful information about each ROT. Subjects found turning their heads back and forth for no reason to be annoying and ”silly.” One subject noted, ”The voice destroys being there.” Subjects were aware that the path had moved when they rotated their heads and complained of being more lost than with visual instruction. Two subjects found *HT* to provide more freedom and the ability to look around the environment during reorientation.

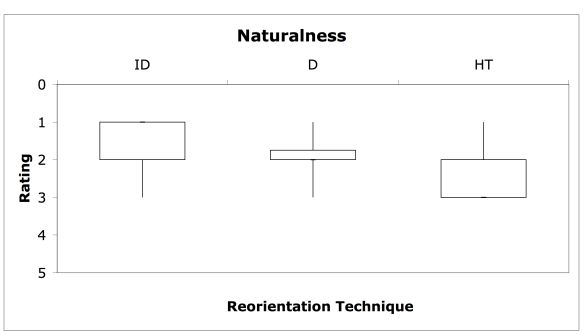

Figure 12: Experiment 2–User rated naturalness

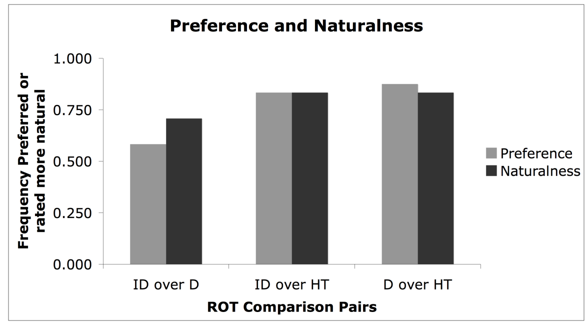

Figure 13: Experiment 2–User comparisons of preference and naturalness across ROTs

Subjects found *D* to be easy to follow and some subjects found *D* less distracting than the flapping butterfly wings of *ID*. Subjects continued to complain about the sphere not being natural to the environment and claim that it ”defies the laws of physics.” Subjects commented on the naturalness of the butterfly but some subjects found the flapping of the butterfly wings ”annoying.” Subjects enjoyed watching the butterfly fly in and out of the scene but, in Experiment 2, no comments were made against the sudden appearance and disappearance of the sphere. Based on the numerous complaints about the sudden appearance and disappearance of the sphere from Experiment 1, we still think the distractor should travel in and out of the scene.

4 Conclusion

We successfully implemented and tested a ROT using distractors to minimize the observed rotation of a VE during reorientation. ROTs using distractors were preferred and ranked more natural by users than current ROTs without distractors. We also found subjects were less aware of turning around in the VE when reorienting using a distractor.

Based on user feedback, ROTs should be realistic and the user should not notice the rotation of the VE. Unlike current ROTs, distractors can be realistic and our results suggest distractors reduce the likelihood of perceiving VE rotation during reorientation. distractors should also exhibit smooth movements that are easy and interesting to watch. We still believe distractors should be natural to the environment even though our data does not support our theory. Additional improvements to distractors may increase user presence and reduce the likeliness of a user noticing the rotation of the VE.

We believe Distractors are VE dependent and should be designed to naturally distract the user in each VE. Possible real world implementations of distrators include: Exploring a virtual house and having a dog run by, walking through a virtual art museum and having a guide point you to a new direction, or training unmounted infantry to successfully navigate enemy territory while snipers move in the distance.

Acknowledgements

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