Simulator Sickness and Presence in a High FOV Virtual Environment

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1. Introduction

As part of a process to identify potential simulator sickness issues with our NAVE (Non-expensive Automatic Virtual Environment), a new virtual environment display system developed at Georgia Tech, we have conducted a study to address the experience of simulator sickness and presence under different display and user role configurations. The NAVE has three 8' x 6' screens. The two side screens are positioned at 120-degree angles to the central screen to give a three-sided display area that is sixteen feet wide and approximately seven feet deep. This allows for two different field of view configurations, a one-screen set-up that provides a 60-degree FOV, and a three-screen set-up that provides a 180-degree FOV. Users are seated in front of the center screen and navigate with a joystick. The virtual environment used in this study could be displayed in the NAVE stereo-visually or in mono, providing us with a second experimental factor, display fidelity. Lastly, we were interested in determining whether or not the user's role in the environment would affect their experience of simulator sickness and presence as suggested by Stanney and Kennedy [3]. This provided us with our third factor user role, with its two levels, driver and passenger. For a more detailed description of the NAVE itself please see the article published in the conference abstracts for SIGGRAPH 2000 [2].

2. Method, Design, and Procedure

156 undergraduate students, including 133 males and 23 females between the ages of 17 and 38, participated in this study. The assessment instrument that administered the Presence, Immersive Tendencies, and Simulator Sickness questionnaires was coded in HTML and displayed on PCs [4], [1].

A 2 x 2 x 2, within subjects design was used to assess the effect of three independent variables, field of view (1 screen vs. 3 screen), display fidelity (stereoscopic vs. monoscopic), and user role (driver vs. passenger), on the dependent variables of simulator sickness and presence. The dependent variables were measured through administration of the SSQ and PQ/ITQ, respectively. Participants were randomly assigned to four separate experimental groups: One Screen Mono, Three Screen Mono, One Screen Stereo, and Three Screen Stereo. User role as driver or passenger was also randomly assigned following group assignment.

Participants were run two at a time (one driver and one passenger) through the experimental procedure. At the beginning of a session, each participant completed the Immersive Tendencies Questionnaire and a pre-exposure administration of the Simulator Sickness Questionnaire. Once finished, the participants were led into the NAVE, supplied with passive stereoscopic glasses and seated. Participants remained in the environment for exactly ten minutes regardless of their progress toward the session objectives. If, at any time during the session, either of the participants exhibited or expressed nausea or discomfort, the session was immediately terminated.

Upon leaving the NAVE, the participants were escorted back to the PCs to complete the second phase of the assessment instrument. This included the Presence Questionnaire and the post-exposure portion of the Simulator Sickness Questionnaire. Once the instrument was completed the subject was debriefed and excused.

3. Results

An alpha level of .05 was used for all statistical test reported below. No significant correlation was shown between total scores on the PQ, ITQ or SSQ. However, when the three experimental factors are controlled for, the PQ correlated r=.171, p=.035 with the ITQ.

No significant differences existed among the experimental groups on total score for the ITQ. This result indicates the tendency to become immersed was evenly distributed among the experimental groups and that all were equally likely to experience presence as predicted by ITQ score.

A multivariate ANOVA performed on the Presence Questionnaire data indicated that a significant main effect on PQ total score of both the FOV and user role factors, $F(1,148)$=11.26, p=.001 and $F(1,148)$=14.13, p=.001 respectively.

Specifically, drivers reported a higher experience of presence than passengers, and participants in the high FOV conditions reported feeling more present that those in the low FOV conditions. No significant interactions were detected among the factors on PQ total score.

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No significant differences among the groups existed on the pre exposure SSQ Total or on any of the three weighted subscales, Nausea, Occulomotor, and Disorientation. A multivariate ANOVA performed on the post-exposure SSQ data uncovered several significant effects of the experimental factors. Score on the nausea subscale showed a main effect of the FOV factor, $F(1,148)=4.76$, $p=.031$, and a significant interaction of user role and FOV, $F(1,148)=8.25$, $p=.005$. The main effect indicates that users in the high FOV conditions reported higher levels of nausea than those in the low FOV conditions. The interaction of FOV and user role is largely driven by the huge difference in nausea ratings by high FOV passengers $M=30.8$, versus low FOV passengers $M=13.2$, as opposed to drivers.

Scores on the occulomotor stress subscale also showed a significant effect for the interaction of user role and FOV, $F(1,148)=10.27$, $p=.002$. Again this effect seems to be propelled by the difference in occulomotor stress ratings by high FOV passengers $M=31.7$, versus low FOV passengers $M=17.1$.

Scores on the disorientation subscale showed another significant effect of the FOV by user role interaction, $F(1,148)=4.74$, $p=.031$, as well as an effect of the interaction of FOV and display fidelity, $F(1,148)=5.704$, $p=.018$. This latter interaction seems to be principally driven by the considerable difference in disorientation scores between the One Screen Mono participants, $M=11.14$, and the Three Screen Mono participants, $M=28.19$.

SSQ total score showed a significant effect of both of the above described interactions, $F(1,148)=11.79$, $p=.001$, and $F(1,148)=4.35$, $p=.039$ for user role by FOV and FOV by display fidelity, respectively. No significant main effects on SSQ total were shown.

4. Discussion and Conclusion

The results from the ITQ and PQ indicate that drivers of this particular virtual environment feel more immersed and present than do passengers. Significantly higher scores for drivers on the PQ's involvement/control subscale corroborate this conclusion, $F(1,154)=24.96$, $p=.001$. The active nature of the driver role in the virtual environment seems to give rise to a greater sense of involvement and immersion in the surroundings, while the passenger's sense of presence is not enhanced by the passive nature of their role.

Similarly, participants who experienced the virtual environment with a high FOV reported higher feelings of presence than those in the low FOV conditions. This is unsurprising, in that the 180 degree FOV creates a much more compelling visual display, and in the low FOV case, the two blank side screens are quite visually conspicuous, serving to remind users that they are in a simulator.

With respect to the SSQ, participants in the high FOV conditions reported higher levels of nausea than those in the lower FOV conditions. This nauseating effect of the high FOV configuration was compounded non-additively by user role, as high FOV passengers reported the highest nausea ratings. It seems that the bright, rapid motion of the optical flow created by the side screens was hard to attenuate attentionally, and that these stimuli proved uncomfortable to users of the VE. Furthermore, the unexpected shifts in this optical flow experienced by the passengers who were not in control of their own movement enhanced the nauseating effects. This conclusion seems to be recapitulated by the significant interactive effect of FOV and user role on occulomotor stress ratings that showed exactly the same pattern. With respect to the disorientation subscale, the effect of the FOV by display fidelity interaction seems to indicate that while the high FOV creates vestibular disturbance, the addition of stereoscopic cues to a low FOV environment creates a similar level disorientation. These explanations seem to hold in characterizing the interactive effects on SSQ total score as well.

For the display and virtual environment investigated in this study, the most important determinant of the experience of both simulator sickness and presence seems to be field of view. Its main effect on both and involvement in every significant interaction suggest that a large field of view is a double-edged sword, it makes you feel like you are really there, but it can make you feel pretty sick.

The lack of significant correlation, positive or negative, between the presence and simulator sickness measures do not support the intuitive notion that simulator sickness and presence are inverse quantities. Neither the SSQ total score nor any of its subscale scores correlate in any kind of significant fashion with the PQ results. It's as if the participants in the high FOV conditions are telling us that they feel like they are really there, but that they would like to leave pretty soon.

5. References

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