

Burak Çiflikli
Veysi İşler*

Middle East Technical University
Department of Computer
Engineering
06531 Ankara, Turkey

Uğur Güdükbay

Bilkent University
Department of Computer
Engineering
06800 Bilkent, Ankara, Turkey

Increasing the Sense of Presence in a Simulation Environment Using Image Generators Based on Visual Attention

Abstract

Flight simulator systems generally use a separate image-generator component. The host is responsible for the positional data updates of the entities and the image generator is responsible for the rendering process. In such systems, the sense of presence is decreased by model flickering. This study presents a method by which the host can minimize model flickering in the image-generator output. The method is based on pre-existing algorithms, such as visibility culling and level of detail management of 3D models. The flickering is minimized for the visually important entities at the expense of increasing the flickering of the entities that are out of the user's focus using a new perception-based approach. It is shown through user studies that the new proposed approach increases the participants' sense of presence.

I Introduction

Flight-simulation systems have been developed over the last few decades, and are used especially in the defense industry. A flight simulator is a system that simulates the experience of aircraft flight. In flight simulation, moving 3D models (like planes or ships) function to make the simulated environment look realistic. Presence in the virtual environment, as sensed by the users of a simulator, cannot be directly linked to a specific type of technology; it is a product of the mind (IJsselsteijn & Riva, 2003). Models with high-resolution textures and a large number of polygons make a simulation session more realistic, and the smooth movement of 3D models should also be a concern. A flickering aircraft is not something that one would face in daily life. Such a virtual situation decreases one's willingness to suspend disbelief and decreases one's sense of presence (Lombard & Ditton, 1997).

In recent years, separate image-generator components have been used for visual systems in flight simulators. An image generator's host system bridges gaps between its components and the rest of the simulator system. Rendering is the task of image generators; the host only makes information updates such as positional updates for 3D models or weather-condition changes.

During a 3D model management of a simulation environment, the host does not deal with model geometry, textures, level of detail management, and the like; these are the tasks of the image generator. The host does, however, update

model-related information, including position, orientation, switch numbers, and submodel orientation.

The host controls the image generator via interface instructions called operational codes (opcodes). Image generators with different interfaces make replacement and integration very difficult. The common image-generator interface (CIGI) has been promoted by the Simulation Interoperability Standards Organization (SISO) since 2006. CIGI is a standardized interface between a real-time simulator host and an image generator and, in another sense, is an open interface serving to promote commonality in the visual-simulation industry (Lance & Phelps, 2008).

The host may be considered a simple interface system using just some get-and-set functions. In general, the realization of entities' smooth movement depends on more than simply pipelining positional data to an image generator.

This study identifies problems causing 3D-model flickering in flight simulators' visual systems. The goal of the research is to design an image generator host for effective entity-motion management. The system aims to eliminate model flickering totally but if that is not possible, then the system drives flickering to entities that are visually less important for the user. This new approach increases the users' sense of presence.

The organization of the paper is as follows: In Section 2, we provide some background on the scope and describe the algorithm we propose. In Section 3, we present the methodology used to test the proposed algorithm. Section 4 presents and discusses the results and Section 5 concludes the paper.

2 Proposed Algorithm

The proposed approach combines computer graphics algorithms with smooth entity motion (see Figure 1). In the preprocessing step, bounding volumes for the entities are constructed to be used in culling algorithms. In the first pass, smoothing and dead-reckoning algorithms, as presented in the IEEE Standard for DIS Application Protocols (IEEE, 1995), are applied to the incoming target positional data. Second, the targets are culled with an algorithm based on view frustum and

```
//PreProcessing step
for each entity
    construct bounding volume

//Main Loop
while simulation continues

    receive entity positions from tactical interface

    //First Pass
    predict missing entity positions by dead reckoning
    smooth incoming positions

    //Second Pass
    view frustum culling
    occlusion culling with bounding boxes

    //Third Pass
    perception - based culling

    construct entity position update opcodes for remaining entities
    send opcodes to image generator

end while
```

Figure 1. The pseudocode of the proposed algorithm.

occlusion culling. Third, the entities are culled with respect to some perceptual criteria, such as size, position, the time they were sent, and the distance to the view point. Finally, the remaining entities are converted to moving model control opcodes and these opcodes are sent to the image generator.

The three steps of the algorithm are executed serially. The host waits until the end of the simulation frame before executing the transmission step. The opcodes prepared in the first three steps are sent to the image generator at the beginning of the next frame. Messaging with a constant frame rate is achieved even if the execution periods of the three steps differ between frames.

2.1 Smooth Entity Motion

For smooth entity motion, the information packets of the entities should be pipelined at the host update rate (typically 30 or 60 Hz). In a simulation frame, some of these packets may not be pipelined, due to network jitter, latency, packet loss, or inadequate bandwidth. This may cause the loss of entity-situation information. In addition, some tactical environment-management systems broadcast position updates or status changes at lower rates so as not to exacerbate network traffic. In

such cases, the position and orientation of the missing entity should be predicted. The IEEE Standard for Distributed Interactive Simulation Application Protocols (IEEE, 1995) presents a material-based prediction algorithm called dead reckoning. A first-order extrapolation is generally used for orientation estimation and a second-order extrapolation is used for position estimation (Katz, 1994).

For smooth entity motion, predicting missing information is a very important step but it is not enough. An image-generator host cannot directly use an information packet that is pipelined by the tactical interface because this causes jumps and flickering in the movement of the entity on the rendered output. To overcome this problem, smoothing should be applied to the incoming data (IEEE, 1995). The difference between the incoming data and the calculated results in the extrapolation step is divided by the number of smoothing steps. This value is then added to the extrapolation result. In other words, the entity is not directly positioned in relation to the incoming data; it is positioned in steps.

2.2 View Frustum and Occlusion Culling

It is possible to forward any realistic number of entity-position update opcodes to an image generator, but it is not possible for the image generator to process all of them. The major concern for today's image generators is to achieve more realistic output imagery with higher-resolution textures and 3D models with a higher number of polygons. Most of the frame time is consumed by rendering the constructed scene. In most cases, the scene of a frame is constructed from the previous frames because the dynamic entities continue to follow their paths unless an update opcode is received. Today's powerful image generators can handle nearly 50 to 100 entity-position update opcodes if there are no other tasks, such as mission functions or database and model rendering. Culling techniques should be used to reduce the number of entities whose positions need to be updated. As it is not possible to eliminate an entity from the scene, culling techniques should adjust the entities' update frequencies. To this end, we utilize level of detail (LOD) techniques and culling algorithms.

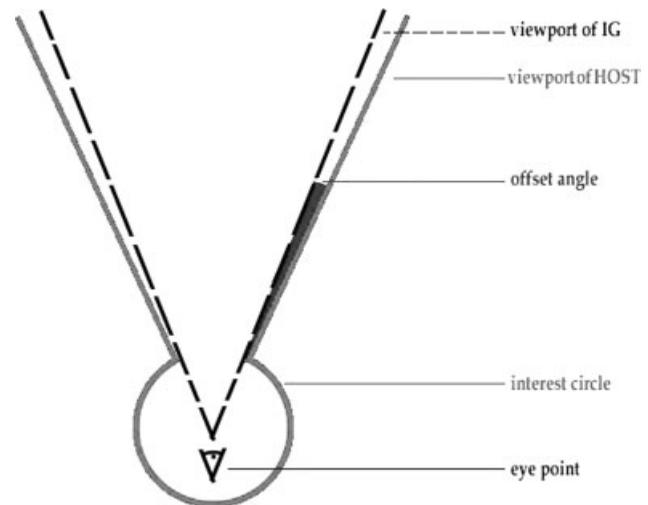


Figure 2. View frustum of the host.

There are three kinds of visibility culling that are used in computer graphics: view-frustum culling, back-face culling, and occlusion culling (Law & Tan, 1999). These techniques avoid processing a scene's invisible portions by discarding polygons that are off-screen, oriented away from the viewer, or occluded. In our study, we use view-frustum culling and occlusion culling.

View-frustum culling uses no geometry; it uses only the positions of the entities. In our implementation, an entity is eliminated if its center of gravity is not within the frustum. The frustum is illustrated in Figure 2. An offset angle is added to the viewport of the image generator so as not to miss the entities running into the viewport. The center of gravity may be out of bounds, but some subsections of the entity's body may already be inside the frustum. The entities that are near to the eye point are marked as "within the interest circle" and are also counted as inbounds. The entities that are within the view frustum are then passed to the occlusion culling stage.

In the occlusion-culling step, the bounding volumes constructed in the preprocessing step are used. To use occlusion culling, we need the geometries of the models, which are stored in the image generator. Bounding volume dimensions for each entity used in the simulation are stored in the host. When an entity is spawned, its bounding volume is constructed to be used in the occlu-

sion-culling step. A scene formed from the remaining entities is rendered within the host, and the bounding volume of each entity is rendered with a different color. Each pixel of the output image is then examined and entities with bounding volumes of colors that are not in the final image are eliminated, as they are occluded by the others. The remaining entities then pass to the next step.

2.3 Perception-Based Culling

Brown, Cooper, and Pham (2003) introduced a new approach to LOD management on the basis of visual attention. Their method for determining the LOD of each visible object uses the calculated visual importance of the object.

In the third step of our algorithm, we calculate an importance value for each entity. Then we select the most important entities. The number of entities that are selected depends on the image generator.

Four features are used in this step: size, distance from eye point, altitude, and time since the last update. Each feature has weight coefficients, and the importance value is calculated according to the summation of the weighted features (Equation 1):

$$I = W_{\text{size}} \times I_{\text{size}} + W_{\text{dist}} \times I_{\text{dist}} + W_{\text{alt}} \times I_{\text{alt}} + W_{\text{lst}} \times I_{\text{lst}}, \quad (1)$$

where W_{size} is the weight of size, I_{size} is the size, W_{dist} is the weight of distance, I_{dist} is the distance, W_{alt} is the weight of altitude importance, I_{alt} is the altitude importance, W_{lst} is the weight of the time since the last update, and I_{lst} is the time since the last update.

The occluded parts of the entities are not visible to the users. The size feature used in the importance value calculation depends on which geometry is not occluded by other entities. The number of pixels for each entity in the final image rendered in the second step of the algorithm is used as its size importance feature.

The distance feature depends on the distance between the entity and the eye point. It should be noted that the weight for the distance feature is inversely proportional to the distance.

Color is an important factor in visual perception. However, we use altitude instead of color in the visual-importance calculation. Military pilots fly close to the Earth's surface, so altitude is adapted to reflect the ground's contours and cover to avoid enemy detection (About.com, 2010). Entities flying at low altitudes relative to the user's own aircraft are more likely to be masked by the terrain in the final image produced by the image generator, while entities at higher altitudes are more likely to draw the user's attention. The importance value for the altitude criterion is maximized if the target has an altitude greater than or equal to the user's own aircraft. The importance value starts to decrease when the target altitude decreases relative to the observer's altitude.

The time since the last update is included in the final pass because otherwise the same entities will always be selected. Entities with low-weight features will not be updated.

3 Method

The third step of the proposed algorithm introduces a novel perception-based approach to entity culling. To evaluate this new approach, we prepared two simulation sessions. During the first session, participants experienced the algorithm that includes all three steps (complete algorithm, CA), whereas in the second session they experienced the algorithm without the perception-based culling (algorithm excluding perception-based culling, AEPC). Participants attended both sessions and we measured the sensed presence using a presence questionnaire. Since experiencing the environment for the second time might have caused a quicker adjustment to the control and display systems, we counterbalanced the order of the sessions.

3.1 Procedure

Before the sessions began, we explained to the participants that the aim of our study was to increase presence in virtual environments. We told them that they would experience our approach in only one of the sessions and we did not say which approach (AEPC or CA)

they would experience first. The participants received a brief introduction to the system components (controls and display) before the sessions. Between the sessions, participants took a 5 min break. Questionnaires were applied directly after each session.

The participants' task was to follow an F/A-18 Hornet model. The participants were able to move in 6 DOF and were able to change the speed of their aircraft. The Hornet flew on the same prescribed path during all sessions. The Hornet changed its altitude, speed, and orientation during the flight and thus the participants were forced to use all the capabilities of the control mechanism. The sessions ended when the participants reached the end point.

3.2 Test Environment

We used a multi-purpose viewer (MPV) in a single-channel configuration on a standard PC including a graphics card with a GeForce 8500GT chipset. There was one rendering channel, which communicated directly with the host. We used a 19-inch LCD monitor with a resolution of 1024×768 . The field of view was $40^\circ \times 30^\circ$ ($H \times V$). The host and image generator (i.e., the MPV) were physically connected via an Ethernet crossover cable.

We constructed the tactical environment with 10 models. The number of models that the image generator (IG) can handle was limited to five. Half of the models were eliminated, and only positional updates of the remaining models were involved in each simulation frame.

The simulator host was also a standard PC. A Microsoft Sidewinder Precision 2 joystick was plugged into the host and served as the control system of the aircraft. A throttle control was also available within the Sidewinder. The Simple DirectMedia Layer (SDL) was used for interfacing the joystick. Further information on joystick interfacing can be found at the SDL website (Simple DirectMedia Layer, 2010).

3.3 Participants

A total of 20 participants (four females, 16 males) took part in the experiment. All of the participants were

already simulator pilots and had accumulated at least 10 hr of flight experience with a flight simulator. Their ages were between 25 and 40 (the median age was 28).

3.4 Presence Metrics

The effectiveness of a virtual environment corresponds to the sense of presence reported by users of that virtual environment. For Biocca (1997), the presence that emerges is not just a side benefit, but an end goal. When the presence evoked by the virtual environment is increased, the user learns more effectively from it (Lombard & Ditton, 1997).

A variety of measures of presence have been proposed (Regenbrecht, Schubert, & Friedmann, 1998). Witmer and Singer (1998) developed the most comprehensive presence questionnaire (PQ), and they have introduced an immersive tendencies questionnaire (ITQ) to measure differences in the tendencies of individuals to experience presence. Researchers have been using these questionnaires to evaluate the relationships among reported presence and other parameters. Since the development of their questionnaire, Witmer and Singer have dropped some questionnaire items that did not contribute to the reliability of the PQ and ITQ scales (Witmer & Singer).

We used the immersive tendencies questionnaire to measure differences in individuals' experience-related tendencies and used the presence questionnaire to measure sensed presence in the simulation environment.

4 Results and Discussion

First, the participants' PQ total scores were calculated. Second, the Pearson product-moment correlation coefficient of the questionnaire items were calculated (see Appendix A). Questionnaire items 25, 28, and 29 were not in correlation with the PQ total score, so they were excluded from the total score calculation process.

Figure 3 presents the total scores of the presence questionnaires. For most of the participants, the PQ total score of the CA was greater than the PQ total score of the AEPC. A paired sample *t*-test showed that the presented perception-based algorithm significantly increased the participants' sense of presence, $t(19) = 6.38$,

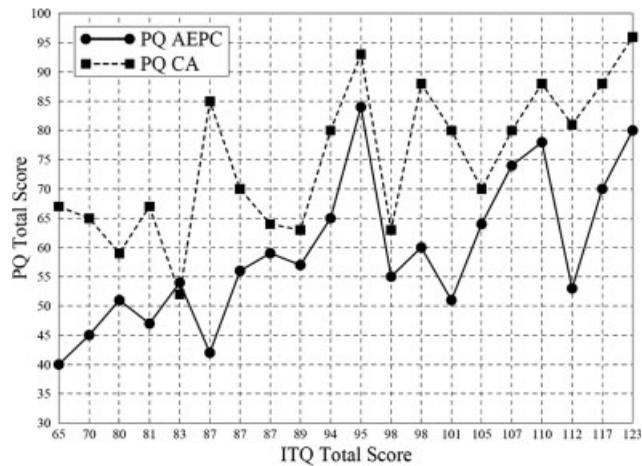


Figure 3. PQ total scores of the two sessions, ranked in increasing order of participants' ITQ total scores. Participants' PQ total scores after the AEPC are marked as PQ AEPC and PQ total scores after the CA are marked as PQ CA on the Y axis.

Table 1. Pearson Product-Moment Correlation Coefficients Between ITQ Total Scores and PQ Total Scores

	ITQ total score to PQ AEPC total score	ITQ total score to PQ CA total score
Pearson r	0.68	0.72

$p < .001$. The mean (SD) total PQ scores for the AEPC session were 59.25 (12.65), and for the CA session were 74.95 (12.47).

An important aspect influencing human virtual-environment performance is the effect of user differences. Designers in this field should identify user characteristics that significantly influence virtual-reality experiences, because only in this way can virtual-environment systems accommodate users' unique needs (Stanney, Mourant, & Kennedy, 1998). In order to determine whether the tendencies of the participants to experience presence had affected our simulated virtual environment, we examined the participants' ITQ total scores.

Table 1 presents the Pearson product-moment correlation coefficients for questionnaire results. There were high correlations ($p < .01$) between ITQ total scores

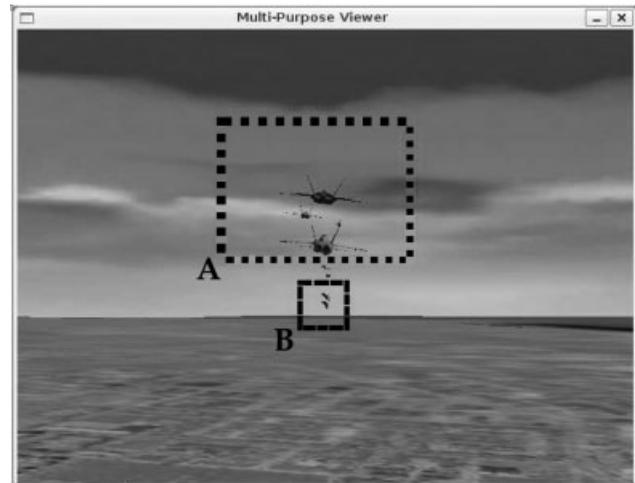


Figure 4. The importance of the entities in the scene. The entities within the dotted lines (A) are the most important and those within the dashed lines (B) are the least important. Flickering is driven to the models within the dashed lines.

and PQ total scores, which means there is a positive linear relationship between the tendencies of the participants to experience presence and the presence of the simulated environment.

The average item score for PQ item 28 was 3.35 for the AEPC and 2.65 for the CA (see Appendix A). There were flickering models in both sessions, but the presented algorithm drove flickering to the models that were less important for the given user (see Figure 4). The participants' task in the experiment was to follow a flying 3D model. As the wingman and other important models followed smoother paths, visual display quality as a distraction factor for the assigned task yielded a decreased total score in the CA.

The participants reported that the control mechanism in the CA was more natural (PQ item 7, Appendix A). Also, the control device as a distraction factor for the assigned task yielded a decreased item score in the CA (PQ item 29, Appendix A). The control device and the control mechanisms were identical in the sessions. The users performed task-oriented actions; for example, when the wingman followed a smoother path, participants more accurately anticipated that position. This accuracy was a result of the given wingman following a

smooth path, but participants thought the control mechanism had been enhanced.

5 Conclusion

One of the most important groups of tasks for which presence-evoking devices have been designed and used involves skills training; users learn more effectively from high presence devices (Lombard & Ditton, 1997). Flight simulators have been used by the aviation industry to train pilots and crew members in both civil and military aircrafts. Using simulators, pilots train for situations that can have catastrophic consequences and thus are not safely duplicable in a real aircraft. These situations include engine failures, aircraft system malfunctions, threat avoidance, and so forth.

Flickering 3D models in the simulation environment are commonly observed in complex tactical environments and, as they decrease pilots' sense of presence in training sessions, so the effectiveness of the training is decreased. To minimize flickering, this study has presented an algorithm applicable to host systems using an image-generator component.

We performed a user study that is composed of two sessions to test the benefit of the algorithm. During the first session, the participants experienced the CA, whereas in the second session they experienced the AEPC. We administered the PQ twice to cover both sessions. We observed that participants' sense of presence increased if the algorithm featured the perception-based culling step.

We also examined the influence that participants' presence-sensing tendencies had on the results of our study. We observed a high correlation between ITQ total scores and PQ total scores, which means there was a positive linear relationship between the tendencies of the participants to experience presence and the sensed presence in the simulated environment. Namely, the participants who exhibited a greater tendency to experience presence within a virtual environment tended to exhibit a greater immersion in the tested simulation environment.

5.1 Possible Extensions

In the perception-based culling step of the algorithm, the feature with the greatest effect on culling is scenario dependent and thus changes continuously during the simulation. Statistical data should be collected from various tactical environments to determine which feature would have the greatest effect on culling. Further, our experiment uses static weights for the features; one could consider using dynamic weights instead. In addition, new features, such as magnitude of lateral motion, could be added to the importance value calculation.

The effectiveness of virtual dead-reckoning and smoothing algorithms does not take entity aerodynamics into consideration. An algorithm using entity type as a parameter should be developed for more realistic entity motion.

Within every simulation frame, the presented algorithm selects the entities whose positional data will be sent to the image generator. The number of these entities is bounded to the number of opcodes the image generator component can process. Increasing the limit would improve the overall performance of the system. Providing additional interfaces for entity control opcodes and parallelization of the opcode handling process could also be considered at this point.

Acknowledgments

We are grateful to Rana Nelson for proofreading and suggestions. We would like to thank Havelsan, Inc. for providing resources for the test environment.

References

- About.com. (2010). US Military Glossary. Retrieved from <http://usmilitary.about.com/od/glossarytermst/g/t6334.htm>
- Biocca, F. (1997). The cyborg's dilemma: Embodiment in virtual environments. *Proceedings of the Second International Conference on Cognitive Technology Humanizing the Information Age*.
- Brown, R., Cooper, L., & Pham, B. (2003). Visual attention-based polygon level of detail management. *Proceedings of the*

- 1st International Conference on Computer Graphics and Interactive Techniques in Australasia and South East Asia (GRAPHITE'03)*, 55–62.
- IEEE (1995). *IEEE Standard 1278. IEEE Standard for Distributed Interactive Simulation Application Protocols, 1–1995*. Piscataway, NJ: IEEE.
- IJsselstein, W., & Riva, G. (2003). *Being there: The experience of presence in mediated environments*. In G. Riva, F. Davide, & W. A. IJsselstein (Eds.), *Being there: Concepts, effects and measurements of user presence in synthetic environments* (pp. 3–16). Amsterdam: IOS Press.
- Katz, A. (1994). Synchronization of networked simulations. *Proceedings of the 11th DIS Workshop on Standards for the Interoperability of Distributed Simulation*, 81–87.
- Lance, D., & Phelps, B. (2008). *Interface control document for the common image generator interface, Version 3.3*. Retrieved from Common Image Generator Interface: http://sourceforge.net/projects/cigi/files/CIGI_ICD/Version_3.3/CIGI_ICD_3_3.pdf/download
- Law, F.-A., & Tan, T.-S. (1999). Preprocessing occlusion for real-time selective refinement. *Proceedings of the Symposium on Interactive 3D Graphics (I3D)*, 47–53.
- Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication*, 3(2). Retrieved from <http://jcmc.indiana.edu/vol3/issue2/lombard.html>
- Regenbrecht, H. T., Schubert, T. W., & Friedmann, F. (1998). Measuring the sense of presence and its relations to fear of heights in virtual environments. *International Journal of Human-Computer Interaction*, 10(3), 233–249.
- Simple DirectMedia Layer. (2010). Retrieved from <http://www.libsdl.org>
- Stanney, K. M., Mourant, R. R., & Kennedy, R. S. (1998). Human factors issues in virtual environments: A review of the literature. *Presence: Teleoperators and Virtual Environments*, 7(4), 327–351.
- Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and Virtual Environments*, 7(3), 225–240.

Appendix A: Presence Questionnaire Items

Major Factor Category	
CF	Control factors
SF	Sensory factors
DF	Distraction factors
RF	Realism factors

Subscales	
INV/C	Involvement/control
NATRL	Natural
AUD	Auditory
HAPTC	Haptic
RES	Resolution
IFQUAL	Interface quality
ITCorr	Pearson correlation coefficients between PQ item scores and the PQ total score with all questions (including items 25, 28, and 29).
	Note: * $p < .05$
	** $p < .01$

		Factors	Subscale	ITCorr	Average score PQ AEPC	Average score PQ CA	Rate of increase (%)	SD PQ AEPC	SD PQ CA
1	How much were you able to control events?	CF	INV/C	0.41*	3.45	4.25	23.19	1.5035	1.44641
2	How responsive was the environment to actions that you initiated (or performed)?	CF	INV/C	0.87**	3.65	4.75	30.14	1.13671	1.25132
3	How natural did your interactions with the environment seem?	CF	NATRL	0.79**	3.5	4.3	22.86	1.27733	1.41793
5	How much did the visual aspects of the environment involve you?	SF	INV/C	0.46*	3.55	4.6	29.58	1.19097	0.99472
7	How natural was the mechanism which controlled movement through the environment?	CF	NATRL	0.66**	3.55	4.85	36.62	0.99868	1.08942
10	How compelling was your sense of objects moving through space?	SF	INV/C	0.47*	3	4.5	50	1.33771	1.19208
12	How much did your experiences in the virtual environment seem consistent with your real-world experiences?	RF,CF	NATRL	0.62**	2.65	4.5	69.81	0.87509	1.27733
13	Were you able to anticipate what would happen next in response to the actions that you performed?	CF	INV/C	0.46*	4.8	5.3	10.42	1.43637	1.12858

		Factors	Subscale	ITCorr	Average score PQ AEPC	Average score PQ CA	Rate of increase (%)	SD PQ AEPC	SD PQ CA
14	How completely were you able to actively survey or search the environment using vision?	RF, CF, SF	INV/C	0.54**	3.45	3.95	14.49	1.31689	1.43178
18	How compelling was your sense of moving around inside the virtual environment?	SF	INV/C	0.57**	3.55	4.3	21.13	1.5035	1.38031
19	How closely were you able to examine objects?	SF	RESOL	0.56**	3.85	4.6	19.48	1.22582	1.0463
20	How well could you examine objects from multiple viewpoints?	SF	RESOL	0.8**	3.7	4.6	24.32	1.52523	1.42902
23	How involved were you in the virtual environment experience?		INV/C	0.4*	3.8	4.65	22.37	1.43637	1.46089
25	How much delay did you experience between your actions and expected outcomes?	CF	INV/C	0.17	4.7	2.9	-38.3	1.30182	1.51831
26	How quickly did you adjust to the virtual environment experience?	CF	INV/C	0.63**	4.1	5.35	30.49	1.91669	1.42441
27	How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?	CF	INV/C	0.55**	3.65	4.95	35.62	1.7252	1.2763

		Factors	Subscale	ITCorr	Average score PQ AEPC	Average score PQ CA	Rate of increase (%)	SD PQ AEPC	SD PQ CA
28	How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?	DF	IFQUAL	-0.04	3.35	2.65	-20.9	1.78517	1.49649
29	How much did the control devices interfere with the performance of assigned tasks or with other activities?	DF, CF	IFQUAL	-0.08	3.6	3.15	-12.5	1.90291	1.56525
30	How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?	DF	IFQUAL	0.52**	5	5.5	10	1.41421	1.14708

Appendix B: Immersive Tendency Questionnaire Items

Subscales	
INVOL	Tendency to become involved in activities
FOCUS	Tendency to maintain focus on current activities
GAMES	Tendency to play video games

ITCorr: Pearson correlation coefficients between ITQ item scores and the ITQ total score

Note: * $p < .01$

** $p < .001$

		Subscale	ITCorr
1	Do you ever get extremely involved in projects that are assigned to you by your boss or your instructor, to the exclusion of other tasks?		0.26*
2	How easily can you switch your attention from the task in which you are currently involved to a new task?		0.26*
3	How frequently do you get emotionally involved (angry, sad, or happy) in the news stories that you read or hear?		0.27*
5	Do you easily become deeply involved in movies or TV dramas?	FOCUS	0.49**
6	Do you ever become so involved in a television program or book that people have problems getting your attention?	INVOL	0.47**
7	How mentally alert do you feel at the present time?	FOCUS	0.4**
8	Do you ever become so involved in a movie that you are not aware of things happening around you?	INVOL	0.56**
9	How frequently do you find yourself closely identifying with the characters in a story line?	INVOL	0.53**
10	Do you ever become so involved in a video game that it is as if you are inside the game rather than moving a joystick and watching the screen?	GAMES	0.55**
13	How physically fit do you feel today?	FOCUS	0.3**
14	How good are you at blocking out external distractions when you are involved in something?	FOCUS	0.46**
15	When watching sports, do you ever become so involved in the game that you react as if you were one of the players?		0.43**
16	Do you ever become so involved in a daydream that you are not aware of things happening around you?	INVOL	0.56**
17	Do you ever have dreams that are so real that you feel disoriented when you awake?	INVOL	0.5**
18	When playing sports, do you become so involved in the game that you lose track of time?	FOCUS	0.46**
20	How well do you concentrate on enjoyable activities?		0.49**
21	How often do you play arcade or video games? (Often should be taken to mean every day or every two days, on average.)	GAMES	0.35**
22	How well do you concentrate on disagreeable tasks?		0.29**
23	Have you ever gotten excited during a chase or fight scene on TV or in the movies?	FOCUS	0.51**
25	Have you ever gotten scared by something happening on a TV show or in a movie?	INVOL	0.42**
26	Have you ever remained apprehensive or fearful long after watching a scary movie?	INVOL	0.31**
28	How frequently do you watch TV soap operas or docudramas?		0.28**
29	Do you ever become so involved in doing something that you lose all track of time?	FOCUS	0.49**