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Measuring Presence in Virtual Environments

Bob G. Witmer and Michael J. Singer
U.S. Army Research Institute

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Witmer, Bob G.; and Singer, Michael F.

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U.S. Army Research Institute for the Behavioral and Social Sciences
ATTN: PERI-IF
5001 Eisenhower Avenue
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A primary argument for the efficacy of Virtual Environments (VE) applications is that the user is "present" in the simulated environment. Presence is defined as the subjective experience of being in one environment (there) when physically in another environment (here). Presence may be based on external factors and internal tendencies that support both awareness of the current situation and the transition from the immediate physical location (here) to a remote or artificial environment (there). These factors are labeled as immersive because they may lead to the experience of presence. Some major immersive factors identified in current literature or hypothesized as contributing to presence are briefly reviewed in this report. These concepts and ideas have been used as the basis for two questionnaires. An Immersive Tendencies Questionnaire (ITQ) was developed to investigate possible correlates that may indicate an individual's tendency to experience more or less presence in artificial environments. The Presence Questionnaire (PQ) addresses different factors or features peculiar to the artificial environment that may affect the experience of presence, or the capability to immerse oneself, in that environment. The results of

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administration of these questionnaires, in conjunction with an experiment on the performance of basic tasks in VE, are presented. These results should be considered preliminary and interpreted with caution because of the small number of subjects involved. Analyses indicate reasonable reliability values for the ITQ and PQ. An investigation of some subscales and performance measures indicates a relationship between some subscales and performance of movement and manipulation tasks. Correlations between the PQ and a standard Simulator Sickness measure revealed significant negative correlations both between the overall scores and several subscales. These results are discussed in connection with revisions made to the scales and plans for further research.

Technical Report 1014

Measuring Presence in Virtual Environments

Bob G. Witmer and Michael J. Singer
U.S. Army Research Institute

Simulator Systems Research Unit
Stephen L. Goldberg, Chief

Training Systems Research Division
Jack H. Hiller, Director

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
Department of the Army

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Human Performance Effectiveness and Simulation

FOREWORD

Training requirements and technological capabilities are driving simulation systems toward increasing sophistication in real-world representation. One focus of this process is in the development and application of Virtual Environments (VE). At this time, information on the effectiveness of learning and skill acquisition in virtual environments is extremely limited. One major issue is whether the task performance of users are tied to their feelings of presence; i.e., whether the degree to which users are involved in and feel part of the task environment influences their performance. If presence produces or is associated with better learning and performance, then systems designed to foster presence may produce better learning and performance. The work reported here represents initial steps toward a reliable and valid measure of the presence phenomenon. This report also presents the first information linking presence, immersive factors, task performance, and simulator sickness.

These issues and others are being addressed by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) as part of their support for the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM, Memorandum of Understanding (MOU) for Technical Coordination, May 1983; MOU Establishing the ARI Field Unit, March 1985; Memorandum of Agreement (MOA) on Advanced Technology for the Design of Training Devices, October 1991). The Simulator Systems Research Unit of ARI has established the task titled "VIRTUE: Virtual Environments for Combat Training and Mission Rehearsal." This task represents ARI's efforts under the most recent MOA to investigate the wide range of issues involved in using new technology to advance and improve training and rehearsal. The information presented in this report provides the first step toward understanding the concept of presence. All information being generated by the VIRTUE research program is being provided to the Engineering Directorate at STRICOM for use in the future Distributed Interactive Simulation (DIS) Individual Combatant Simulator. It is also being disseminated to virtual environments researchers throughout the United States.

EDGAR M. JOHNSON
Director

MEASURING PRESENCE IN VIRTUAL ENVIRONMENTS

EXECUTIVE SUMMARY

Requirement:

The U.S. Army is making a considerable effort to increase the use of distributed simulations for providing realistic training and rehearsal environments. There are a considerable number of vehicle and equipment simulators being developed and integrated to support large-scale, battlefield-like, training and rehearsal for soldiers. Technologically advanced Virtual Environments (VE) hold the possibility of placing individual soldiers in simulations so real that they could practice warfighting tasks as if they were on the battlefield. However, the same problems that have plagued training device developers for many years are relevant to the development of increasingly detailed and technologically advanced simulations for dismounted soldiers. Chief among these issues is the amount of realism needed for adequate learning and transfer. The question is whether providing such high levels of fidelity produces better learning or transfer. One key measure for fidelity or realism may be whether the users feel that they are "present" in the simulated environment. The hypothesis has been presented by VE developers and researchers that being present in the simulated environment is better. This hypothesis must be investigated to determine whether presence is synonymous with fidelity; whether there is a relationship between presence, learning, and performance; and whether measurement of presence can be used to predict training effectiveness or transfer.

Procedure:

As a part of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) research program into virtual environments, a series of abstract tasks were developed to test performance in virtual environments. These tasks were performed while wearing a helmet-mounted display unit and using either a joystick or a spaceball™ to navigate through the VE or manipulate objects in the VE. The tasks included perceptual tests, locomotion tasks, and manipulation tasks. An Immersive Tendencies Questionnaire (ITQ) and a Presence Questionnaire (PQ) were developed and then administered to 24 participants in conjunction with the tasks. The questionnaires used a 7-point scale with opposing descriptors at the scale ends to collect responses to the items. Responses to this trial administration of the questionnaires were analyzed using correlational methods that

examined the relationship between questionnaires, questionnaire items, and clusters of items. The questionnaires and item clusters were also correlated with task performance results and the responses from a Simulator Sickness Questionnaire (SSQ).

Findings:

Results from this trial administration of the questionnaires suggest that the ITQ and PQ have satisfactory internal consistency. Four of six pre-identified clusters on the Presence Questionnaire were supported by item correlations, and an additional cluster was identified for analysis. These subscale clusters focused on immersive factors labeled Control Responsiveness, Sensory Exploration, Interface Awareness, and Control Distractions and a direct measure of the subjective experience of presence labeled Involvement. The PQ total and three of the clusters were significantly negatively correlated with several task performance times and significantly positively correlated with accuracy measures. Correlational analyses on the subscales indicate that the effect of immersive factors like Control Responsiveness on presence seems to be mediated by the task requirements. The PQ total and three of the clusters were also significantly negatively correlated with the SSQ total and subscales. This indicates that there is an inverse relationship between simulator sickness and presence. Results must be interpreted with caution because this was the first administration of the questionnaires and the sample size on which the analyses were performed was small.

Utilization of Findings:

We have developed a research instrument (the PQ) that we believe measures at least some aspects of the phenomenon referred to as presence. The PQ measures presence following exposure to a virtual environment. We have also developed an initial version of a questionnaire (the ITQ) that was designed to measure (a priori) an individual's tendency to experience presence in virtual environments or to become involved in an activity. The initial results with the ITQ led us to develop a revised version that pursues a wider range of issues with more detailed questions. The results of our correlational analyses on the PQ indicate that several immersive factors may be involved in the subjective experience of presence that would have implications for VE developers and users. The negative relationship between presence and simulator sickness is important and may mean that simulator sickness is itself an immersive factors. The results with the PQ also led us to develop a revised version. Further evaluation of the revised questionnaires with additional subjects under varying conditions will be required to confirm our preliminary conclusions.

MEASURING PRESENCE IN VIRTUAL ENVIRONMENTS

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MEASURING PRESENCE IN VIRTUAL ENVIRONMENTS

Introduction

The new technological field of **Virtual Environments** (VE) and the associated fields of Teleoperations and Telerobotics have spawned a new phenomenon. This phenomenon is being referred to as **telepresence** (Held & Durlach, 1992), or in connection with simulated environments as **presence** (Rheingold, 1991; Sheridan, 1992). There is even a journal by that name for articles on the new technology of Teleoperations and Virtual Environments (VE). Presence is being generally defined as the subjective experience of being in one place when one is physically in another. In telerobotics or teleoperations this means experiencing the situation as if one were at the robot's location, or were present at the remote work-site. In VE the concept refers to experiencing the computer generated environment rather than the actual physical locale. The phenomenon of presence is being used as the basis for predicting potential new gains in the effectiveness of learning, comprehension and insight, performance, and even transfer of training (e.g., Sheridan, 1992; Held & Durlach, 1992).

The claims for increased effectiveness and transfer are made despite the lack cf any experimentally based indicating that such a phenomenon exists, that the phenomenon can be measured, that there is any relation between presence and performance in virtual environments, or that performance while "present" in a virtual environment has any effect on performance in the real world. There are two problems that can arise from acceptance of this partially described and anecdotally based phenomenon. One is that hypothetical concepts are often difficult to concisely explain and measure. Second, since everyone has some understanding of the concept, we often proceed as if we all agree about all facets of the concept.

In this paper, we address the concept of presence, indicate factors involved in "being there," and provide two initial measurement instruments for presence that might tap tendencies for immersion or factors influencing an immersive experience. The sparse literature on presence either alludes to or makes direct reference to a number of factors that may be related to presence (e.g., Zeltzer, 1992; Sheridan, 1992; Held & Durlach, 1992). After careful consideration of some of this literature (see below), it was clear that many factors may be related to presence and hence might provide the basis for the development of a presence questionnaire. The next section in this report reviews those factors and related literature. That section also describes the structure of two developed questionnaires and touches on the basis for the items used. The first questionnaire is the Immersive Tendencies Questionnaire (ITQ), which addresses a person's propensity for being "present" in some task environment. The second questionnaire is the Presence Questionnaire (PQ), which addresses the subjective experience of presence in the task environment. The third section describes a basic experiment in task performance that we have conducted. The questionnaires were administered in conjunction with that experiment, with analyses on reliability, item correlations, presence and immersive factors scales, and the correlation between total scores, subscales, and performance. The relationship between a Simulator Sickness Questionnaire (SSQ, Kennedy, Lane, Berbaum, & Lillienthal, 1993) and the PQ is also investigated. The conclusions section presents our thoughts regarding the preliminary findings and about possible relationships in the data. Revisions made to the questionnaires are also presented with plans for further research.

Presence and Immersion

According to Sheridan (1992), presence is a subjective sensation, much like "mental workload" and "mental model" - it is a mental manifestation, not easily amenable to objective physiological definition and measurement. Therefore, as with mental workload and mental models, subjective report is the essential basic measurement. However, the strength of the experience of being present in a virtual environment may vary both as a function of individual differences and the characteristics of the virtual environment that is being experienced. These individual differences, traits, abilities, etc., may enhance or detract from the experience of presence in a given VE. The different characteristics of the VE may also support and enhance, or detract and interfere with the presence experience. These individual aspects and VE equipment/task characteristics are what we consider as immersive factors. These factors may be necessary but are not sufficient for the experience of presence.

According to Fontaine (1992), presence seems to be a matter of focus. This focus is continually shifting in everyday life, as is obvious from the amount of presence required in performing everyday tasks like commuting. This common and well-practiced task can often be performed while thinking about other things and may even occur without memorable consequences. Alternatively, when experiencing a novel environment people are typically more aroused, and broadly focused on the tasks to be performed. Fontaine (1992) claims that this is different from a narrow task focus in that the experiencer is broadly aware of the entire task environment. The novelty, immediacy, and uniqueness of the experience requires the broad focusing of attention on all aspects of the environment. Fontaine (1992) relates findings that support the wide focus phenomena in novel environments to possible VE experiences, arguing that the broad focus is also necessary for a high level of presence in virtual environments.

For VE experiences, an alternative explanation may be that the experience has aspects similar to selective attention, which has been shown to be meaningfully guided in experiments (Triesman, 1963; Triesman & Riley, 1969). In that research, subjects were required to track information presented only to one ear, while being distracted by input to the other ear. The results indicated that all the sensory information was being processed to some extent, and that task meaningfulness or information with a high level of salience to the subject (e.g. their name) was guiding or influencing performance. Our argument is that the perception of being present in a remote operations task or a virtual environment requires the ability to focus on one meaningfully coherent set of stimuli (in the VE) to the exclusion of unrelated stimuli (the physical location).

This argument is closer to the argument presented by McGreevy (1992) that the experience of presence is based in attention to continuities, connectedness, and coherence of the stimulus flow. The coherence of the VE characteristics and stimuli thus enable the focussing of attention, but does not force that on the experiencer. This concept of enabling without forcing gives us the distinction between the experience of presence and the immersive factors that can support the experience. Someone has to attend before they can be aware, and awareness is the basis for presence. Indeed, being 100% aware is synonymous with being completely present.

Presence has been addressed in many ways by the literature we have reviewed. However, we have only found one article detailing an attempt to measure presence and relate that measurement to possible immersive factors. Barfield and Weghorst (1993) surveyed people after "flythrough" experiences with two different VEs. Most of their questions dealt with possible immersive factors, with three questions asking directly about "Being there," "Inclusion" in the VE, and "Presence." Responses to the "Being there" question were correlated with comfort, presentation quality, and location information. Responses to the "Inclusion" question were even more strongly associated with general comfort, ease of interaction and movement, and the ability to introspect. The responses to the direct question about "Presence" were strongly associated with enjoyment, orientation, and presentation quality. In generating our questionnaires (see below) we have independently focused on many of the same factors, although we do not rely on a simple query about presence or involvement.

The literature we reviewed before developing our questionnaires was theoretical in nature, and raised or discussed some of the following factors as being related to or forming the basis of the presence experience. Not all of the literature reviewed here influenced item development, as some of it (e.g., Fontaine, 1992, Barfield & Weghorst, 1993) was not available during the period of item development. In identifying factors and in developing items we drew heavily on the theoretical concepts discussed by Sheridan (1992) and Held & Durlach (1992). We have grouped the factors into the following major categories: Control Factors, Sensory Factors, Distraction Factors, and Realism Factors. The factors within the major categories almost certainly interact with one another. It is also possible that factors may interact across the major categories.

Control Factors

Degree of control. In general, the more control a person has over the task environment or in interacting with the virtual environment, the greater the experience of presence. This includes the ability to control the relation of sensors to the environment (Sheridan, 1992). Fontaine (1992) considers control over the situation as separate from presence, but his work does show it to be positively related to presence (which is defined more experientially, see above).

Immediacy of control. When a person acts in an environment, the consequences of that action should be appropriately apparent to the actor, affording expected continuities (McGreevy, 1992). In other words, the interaction between the person and the environment should be appropriately coupled, based on the physical model used by the environment, as pointed out by Heeter (1992). Noticeable delays between the action and the result should tend to diminish the sense of presence in an environment (Held & Durlach, 1992). The exception would be when these delays are perceived as providing information about or fitting the user's understanding of the physics of the environment.

Anticipation. Individuals probably will experience a greater sense of presence in an environment if they are able to anticipate or predict what will happen next, whether or not it is under personal control (an issue raised by Held & Durlach, 1992). It seems likely that predictability and presence are curvilinearly related; that the best level of presence is when the environment is somewhat predictable, but is neither completely known and predictable, nor completely unknown. This factor is related to Immediacy of Control (see above) and Multimodal presentation (see below) in that people are probably building a model of the VE world, as a way to understand the effects of themselves and others on that world (Heeter, 1992; Loomis, 1992).

Mode of control. Presence in a situation may be enhanced if the manner in which one interacts with the environment is a natural or well practiced method of interacting with that environment. If the mode of control is artificial or especially if it requires learning new responses in the environment, presence may be diminished until those responses become well-learned (Held & Durlach, 1992). For example, if locomotion requires the use of hand controls rather than normal walking motions to move through the environment then the experience of presence would probably be diminished.

Physical environmental modifiability. Presence should increase as one's ability to modify physical objects in that environment increases (Sheridan, 1992). This refers to the extent of motor control to physically change the characteristics of objects in the environment or their relation to one another in space. For instance, one expects to be able to manipulate light switches, move objects, mold clay, leave footprints, etc., and these experiences verify the control one has over the Virtual Environment. That impression of control, of knowing what actions cause which changes, in turn validates one's sense of being present in that environment (Heeter, 1992).

Sensory Factors

Sensory modality. The modality through which the information is presented may affect how much presence is experienced. There may be a hierarchy of modalities in the experience of presence. Much of the information that we normally attend to comes through visual channels, therefore the type or relevance of information presented visually may strongly influence presence. Information presented through the auditory or tactual modes also contributes to the experience of presence but perhaps less than the information presented visually. Certainly the quality of the display or interface will also affect the perception of presence (Barfield & Weghorst, 1993). If a disjunct exists between visual and auditory information, the visual input may be assigned as "real" because of this weighting, and the auditory ignored as irrelevant or unimportant. Alternatively, the disjunct could be accepted and used but leave the operator with a low sense of presence (Held & Durlach, 1992).

Environmental richness. The greater the extent of sensory information transmitted to appropriate sensors of the observer, the stronger will be the sense of presence (Sheridan, 1992). An environment that contains a great deal of information to stimulate the senses should generate a strong sense of presence; conversely an environment that is stimulus poor and conveys little information to the senses may engender little presence. This immersive factor may interact with some of the control factors, however. For example, if an informationally rich visual environment (which would support a higher sense of presence) is used in conjunction with controls that provide barely sufficient interaction for a complex task, a low level of presence might be the best that could be achieved (Zeltzer, 1992). Alternatively, adding more color and detail may increase the richness of the environment without improving either performance or presence because the extra richness provides minimal or minimally relevant information.

Multimodal presentation. As argued above, the more completely and coherently all the senses are stimulated, the greater should be the capability for a sense of presence. Limiting the VE to only one or two senses can limit the level of involvement that could be experienced. For example, adding normal movement, with kinesthetic motion and proprioceptive feedback, should increase the capability for an experience of presence (Held & Durlach, 1992).

Consistency of multimodal information. The information received through all modalities should describe the same objective world (Held & Durlach, 1992). If information from one modality gives a message that is different from that experienced through a different modality, the presence experienced may be diminished. Obviously the multiple stimuli must combine to present a coherent framework for interaction. Disjuncts would probably preclude the experience of presence, and may actively interfere with performance. Some disjuncts may also contribute to simulator sickness.

Degree of movement perception. Presence can be enhanced if the observer perceives movement through the environment. Similarly, to the extent that objects appear to move relative to the observer, presence will be enhanced. This relates to and interacts with several of the control factors, in that control over movement is required - which implies that immediacy, anticipation, mode, and degree will interact with the perception of movement. These aspects, combined as "movement ease" have already been shown to be predictive of the perception of "inclusion" in VE (Barfield & Weghorst, 1993).

Active search. The degree to which an environment permits active control of relation of sensors to that environment increases the sense of presence (Sheridan, 1992). To the extent that an observer can modify their viewpoint to change what they see, or to reposition their head to affect binaural hearing, or to search the environment haptically, they will experience a greater sense of presence. This is supported by the results of Barfield and Weghorst (1993), in finding that ease of interaction correlated with judgments of "inclusion" in a VE.

Distraction Factors

Isolation. Devices that maximize your isolation from the environment in which you physically reside may increase presence in an alternate environment. For example a head mounted display that isolates the user from the real world may increase the sense of being present in the virtual environment in comparison to a common two-dimensional flat-screen display. Headphones that reduce local ambient noise could also support increased presence even when no VE associated auditory input is provided.

Selective attention. The ability or willingness of the observer to ignore distractions that are external to a portrayed environment should increase the amount of presence experienced in that environment. The ability to focus on one set of stimuli and attenuate processing of other stimuli was shown in research on dichotic listening experiments during the 50's and 60's (Cherry, 1953; Triesman, 1963; Triesman & Riley, 1968). It is possible that being able to focus on a partial, coherent set of VE stimuli (e.g., sound, vision, movement, response capability, etc.), while attenuating the surrounding real world stimuli, would enhance the experience of presence and improve learning and memory.

Interface awareness. The intrusion of unnatural, clumsy, artifact-laden interface devices would obviously interfere with the direct and effortless interpretation of and interaction with a VE (Held & Durlach, 1992). This distraction is probably associated with the degree to which the control devices or sensory input devices require cognitive resources and concerted effort. Excessive operator requirements would diminish or delay (until the artifact intrusion could be overcome by learning) the experience of being present in the alternate environment (Loomis, 1992).

Realism Factors

Scene realism. Presence increases as a function of the realism of the scene in the alternate environment (as determined by scene content, texture, resolution, light sources, Field Of View (FOV), dimensionality, etc.). This realism doesn't necessarily mean relation to the real world, but refers to the connectedness and continuity of the stimuli being experienced. If the texture and parallax do not provide coherent depth cues, or the shadows and light sources are out of synchronization, the visual array might be perceived as artificial. That artificialness would then decrease the experience of presence and thus hinder task performance.

Consistency of information with the objective world. The more consistent the information conveyed by an alternate environment is with that learned through experience in the normal world, the more presence will be experienced in that environment (Held & Durlach, 1992). This is a tricky issue. Minor inconsistencies may create novelty and actually enhance involvement. The core of this factor may be in the perceived consistency of the environment (see the control factors section, above).

Meaningfulness of experience. Presence will increase as the situation presented to the individual becomes more meaningful to that individual. Meaningfulness is often related to many other factors, such as motivation to learn or perform, task saliency, previous experience, etc. If meaningfulness of a VE experience is due to individual levels of these factors, presence would be only partially due to the equipment and VE scenario. The VE scenario, in order to develop or maintain an adequate level of presence, would have to adjust to individual differences like motivation, level of expertise, task relevancy, etc.

Separation anxiety/disorientation. Individuals may experience disorientation or anxiety when returning from an alternate environment to the real world. The amount of this disorientation may increase as the presence experienced in the alternate environment increases.

Presence Questionnaires

We have developed, tested, and revised two trial questionnaires. They are referred to as the Immersive Tendencies Questionnaire (ITQ, Appendix A) and the Presence Questionnaire (PQ, Appendix B). The objective of the questionnaires is to provide research instruments that measure: 1) the capability or tendency to be immersed (ITQ) and 2) the experience of being present and the influence of possible immersive factors (PQ). These questionnaires rely exclusively on self report information.

Both questionnaires use a 7-point scale that in format is based on the semantic differential principle (Dyer, Matthews, Stulac, Wright, and Yudowitch, 1976). Like the semantic differential, each item is anchored at the ends by opposing descriptors. Unlike the semantic differential the scale includes an anchor at the midpoint. The anchoring descriptors are based on the content of the question stem and, in that respect, are more like the anchors used in common rating scales. The instructions accompanying the questionnaires encouraged the respondents to use the entire range of possible responses in order to provide a more accurate accounting of the frequency that they experienced the condition described in each question.

Immersive Tendencies Questionnaire

The ITQ questionnaire (see Table 1) is designed to be administered to subjects before introducing them to the virtual environment. The goal is to identify and measure possible individual differences in the abilities or tendencies of subjects to immerse themselves in different environmental situations. In later experiments this information may be used to stratify the subject population into evenly matched subgroups or used to predict a subject's immersion in the virtual environment or their performance in VE.

There is no attempt in the ITQ to investigate other possible underlying abilities or skills that could support the allocation of attentional resources or influence presence. Neither is there any attempt to investigate other possibly associated major dimensions such as sex, socio-economic background, intelligence, etc. Some data on these factors is being collected and analyzed, although not as independent variables, during the course of our program of VE research.

The ITQ items were analyzed as a single scale. Since the first Immersive Tendencies Questionnaire was developed and used, a new version has been developed and is being used (see Appendix A). As with the first version, no subscales have been identified, but there are two items that require score reversal (items 19 & 24). The only score generated for the analysis reported below was the total of scale responses for each question item. The left end anchor (typically identified as no amount or instance of the variable or dimension addressed) up to the first interval mark, was scored as one (1). Any mark appearing in the last segment on the right (usually identified as often, all the time, frequently, etc.) were scored as seven (7). Scale reversal was done by subtracting the score from eight (8). Scale responses were not weighted in any way.

Table 1

Immersive Tendencies Questionnaire Item Stems (Version One)

1. Do you ever become so involved in doing something that you lose all track of time?
2. Do you ever become so involved in a book that people have trouble getting your attention?
3. Do you ever become so involved in a television program that people have trouble getting your attention?
4. Do you ever become so involved in a movie that you are not aware of things happening around you?
5. 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 a screen?
6. As a spectator, do you ever become so involved in a sporting event or competition that you react as if you were one of the players.
7. Do you ever become so involved in a daydream that you are not aware of things happening around you?
8. Do you ever have dreams that are so real that you feel totally disoriented when you awake?
9. How many times have you been hypnotized?

Presence Questionnaire

PQ items are intended to identify and measure the degree to which a virtual environment aspect (a single factor or sensory domain) engender a sense of presence for a subject. The PQ should also be useful in identifying and measuring individual differences in immersion in the VE or as a correlate of task performance in the virtual environment. The item stems used by the initial version of the PQ are listed in Table 2.

The following scoring instructions are for PQ version two, provided in Appendix B. Comparable procedures were followed for the first version. The first step in scoring the PQ is to adjust the responses to several questions by reversing their values. The questions that require adjustment are 8, 9, 11, 24, 25, 28, and 29. The responses are adjusted by subtracting the original score for each question from eight (8) and replacing the original score with the result. The total immersion score is simply the total of the scale responses (after inversion) for all questions. Several subscales have been identified (see below) and can be scored by totaling the scale responses for the appropriate items, again after adjusting the appropriate question responses.

Table 2

Presence Questionnaire Item Stems (Version One)

1. To what degree do you feel that you were able to control events?
2. How responsive was the environment to actions that you initiated (or performed)?
3. How natural did your interactions with the environment seem?
4. How completely were <u>all</u> of your senses engaged?
5. How much did the <u>visual</u> aspects of the environment involve you?
6. How much did the auditory aspects of the environment involve you?
7. How natural was the mechanism which controlled movement through the environment?
8. How aware were you of events occurring in the real world around you?
9. How aware were you of your display and control devices?
10. How compelling was your sense of objects moving through space?
11. To what degree did you experience disconnects or inconsistencies between the information coming from your various senses?

(Continued)

Table 2 (con't)

Presence Questionnaire Item Stems (Version One)

12. To what degree did your experiences in the virtual environment seem consistent with your real world experiences?
13. To what degree were you able to anticipate what would happen next in response to the actions that you performed?
14. How completely were you able to actively survey or search the environment using vision?
15. How well could you identify sounds?
16. How well could you localize sounds?
17. To what extent were you able to actively survey or search the virtual environment using touch?
18. How compelling was your sense of moving around inside the virtual environment?
19. How closely were you able to examine objects?
20. Were you able to examine objects from multiple viewpoints?
21. Were you able to move or manipulate objects in the virtual environment?
22. To what degree did you feel confused or disoriented at the beginning of breaks or at the end of the experimental session?
23. How involved were you in the virtual environment experience?
24. Was the control mechanism distracting?
25. How much delay did you experience between your actions and expected outcomes?
26. How quickly did you adjust to the virtual environment experience?
27. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?
28. To what extent did the visual display quality interfere or distract you from performing assigned tasks or required activities?
29. To what extent did the control devices interfere with the performance of assigned tasks or with other activities?
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?
31. Did you learn new techniques that enabled you to improve your performance?
32. Were you involved in the experimental task to the extent that you lost track of time?

Presence Questionnaire Subscales

Before the first use of the questionnaire, PQ items were sorted into six subscales by the senior author based on the apparent similarities among the items. The categories were generated based upon an estimation of important aspects and immersive factors in the experience of presence as discussed above. Prior to experimental administration, four researchers from our group were also asked to independently sort the items into the identified subscales. Five of the six subscales represent immersive factors; areas that when rated well could be expected to support the perception of presence. The sixth is a direct elicitation of how engaged or wrapped up in the experience the person felt. The resultant sorted items were grouped into the subscales which are described next.

Sensory exploration. This item cluster addresses the degree to which the VE configuration permits active search or survey of the environment and/or examination of objects in that environment using one's senses.

Involvement. The items in this cluster attempt to elicit a direct report of the degree to which the participant feels involved or thinks they are more engaged in the virtual environment experience.

Interface awareness. These items address how aware is the participant of the display that portrays the virtual environment and of the control devices used for responding in it. The major dimension addresses how natural the interface seems to be.

Control Responsiveness. These items address a participant's judgment of how quickly and how well the VE responds to attempts to control or interact with it.

Reality/fidelity. This grouping addresses the extent to which the VE experiences are consistent with real world experiences.

Adjustment/adaptation. These items directly address the speed and extent to which the participants adjust to idiosyncracies of the virtual environment.

Virtual Environment Performance Assessment Battery

A Virtual Environments laboratory has been established at the Institute for Simulation and Training, associated with the University of Central Florida, in Orlando, Florida. The lab has helmet mounted displays, Silicon Graphics™ image generators, a Fakespace™ Boom2, color monitors, spaceballs, joysticks, and generic mice. The lab is also developing several types of movement interface devices such as treadmills and trampolines, different gloves, and auditory equipment. Even as a low end technological implementation of Virtual Environments, the equipment ensemble allows the investigation of basic learning and performance parameters in Virtual Environments.

In the first experiment conducted in the laboratory (Lampton, et. al., in press), 24 subjects performed several generic tasks that were developed on the theoretical basis of their ubiquitousness in future virtual environments. One subject could not complete the tasks because of severe simulator sickness. The tasks included self-movement tasks of several kinds: navigating hallways both linear and curved (figure-eights), moving through rooms and doorways, or flying through rooms with windows. The task battery also included several kinds of manipulation tasks; moving objects from bin to target bin, moving slides to set positions, changing dials, or just reaction time responses. There were also several different types of tracking and search tasks.

Two separate experimental sessions were conducted in order to obtain data on the entire set of measurements and tasks without taxing the subjects (see Table 3). Before and after each session several questionnaires and tests, including the first versions of the ITQ and PQ, were administered. The separation of experimental session led to some subjects dropping out, which combined with some instances of simulator sickness and equipment failures to produce some incomplete data sets for the questionnaire analyses.

Table 3

Virtual Environment Tasks by Experimental Sessions

SESSION ONE	SESSION TWO
Snellen Chart	Flying-thru-Windows
Color Perception Test	Elevator
Distance Estimation	Bins
Backing-up	Slide Manipulation
Hallway Turns	Dial Manipulation
Figure 8 Hallway	Simple Reaction Time
Doorways	Choice Reaction Time
	Stationary Target Acquisition
	Moving Target Acquisition

The VE task performance measures were time to complete and accuracy of response. Obviously, a better performance is typically associated with less time required for completion. For movement tasks, accuracy was the number of collisions, which means that better performance is indicated by lower scores. For manipulation tasks accuracy was a count of incorrect movements, uncompleted trials, or other errors; which again means that lower is better. The scoring method for both the ITQ and PQ is to sum the responses on the 7-point scales (reversing the scores for negative stems), yielding a total score for each.

If a significant negative correlation occurs between time and/or accuracy and the ITQ, then we can conclude that a higher overall level of immersive tendencies are associated with or predict better performance on the tasks. In the same fashion, if there is a significant negative correlation between the task measures and the PQ then a greater level of subject involvement in the VE experience (as measured by the PQ) is associated with better performance in the VE tasks.

Performance Assessment Experiment

Method

Subjects. Subjects were recruited from the University of Central Florida, Seminole Community College, and Valencia Community College. Twenty-four (24) subjects participated, 16 males and 8 females. The age range was 17 to 37 years. Not all subjects finished all conditions in the experiment, and thus a few administrations of the questionnaires were not available for analysis.

Apparatus. The VEs were developed with WorldToolKit software by Sense8 Corporation. Stereoscopic images of the VE were generated using two linked IBM-compatible 486/DX50 mhz PCs equipped with Intel Action Media graphics boards. A Virtual Research Flight Helmet with an 83 degree horizontal and 41 degree vertical field of view displayed the virtual environment to the subjects. The Flight Helmet presented full color images, consisting of 234 lines of 238 pixels for each eye. Two standard color monitors displayed the subjects' right-eye and left-eye views of the VE to the experimenter. A Polhemus Isotrack tracked subjects' head movements and provided head-tracking coordinates in roll, pitch and yaw.

Materials. The Immersive Tendencies Questionnaire and Presence Questionnaire were developed as described above (see Appendices A and B). Other tests, questionnaires, and performance measures were developed and used, as documented by Lampton, et. al. (in press).

Procedure. The ITQ questionnaire was administered in conjunction with other tests and questionnaires prior to subjects participating in the experimental conditions. After each of two experimental sessions, the PQ was administered, again in conjunction with other tests and questionnaires. The experimental sessions differed by requiring different tasks to be performed. The experimental conditions required half of the subject group (12) to use a spaceball for movement, manipulation of position or objects, and tracking while the others used a joystick to perform the same tasks. As mentioned above, not all subjects finished all conditions or tasks in the experiment.

Analyses. Except as noted, all analyses used Pearson r to determine the extent to which a linear relationship exists among items, subscales or total scores for the ITQ and PQ scales and between these scales and other measures. In all cases the analyses involved small sample sizes, and the results should therefore be interpreted with caution. Scores on the ITQ and PQ scales were shown to approximate an interval scale in that they were normally distributed. According to Gaito (1980), demonstrating that the data follow a normal distribution indicates that the data would be of an interval scale nature because the intervals between any data points are known in terms of probabilities. Some of the PQ subscale scores deviated from normality, but Kirk (1968) suggests that it is common practice to use more powerful parametric statistical tests, such as Pearson's r, even if the assumptions are only approximately fulfilled. And Gaito (1980) argues convincingly that scale properties are not a requirement for the use of various statistical procedures and should have no effect on the choice of a statistical technique. Therefore we chose the most powerful tool available, Pearson's r, for analyzing the linear relationships among our measures.

Results

Immersive Tendencies Questionnaire. Internal Consistency measures of reliability were calculated as part of the initial examination of results. One requirement for questionnaires is that they have construct validity. One measure or indication of construct validity is the internal consistency of the questionnaire (Guion, 1965). The internal consistency of the questionnaire was calculated using Cronbach's Alpha, and was satisfactory (.74). Item-total correlations were also calculated in order to investigate the relation between each item and the overall questionnaire index. The statistically significant correlations are presented in Table 4.

All items (except item 9) correlated significantly with the total, with items 4, 6, 7, and 8 being significant at the $p=.01$ level or better. Number of times hypnotized (#9) was consistently negative (no experiences) and was therefore dropped from analysis. Correlations were also inspected to check relationships between the items. The strongest correlations were between movie involvement and television involvement (items four and three), and movie and spectator involvement (items four and six). There were also strong significant relationships between real dreams (item eight) and daydreams (item seven), and real dreams and video game involvement (item five).

The mean of the total ITQ score was 33.88 and the standard deviation was 9.39. The overall ITQ score was not significantly correlated with any of the performance measures, although 92% of the correlations were in the predicted direction.

Table 4

Correlations Between ITQ Items and With the ITQ Total Score

		Item							
Item	Total	1	2	3	4	5	6	7	8
1 Lose track of time	.48*	--							
2 Book involvement	.48*	.44*	--						
3 TV involvement	.50*			--					
4 Movie involvement	.88**	.46*	.41*	.62**	--				
5 Video game involv.	.50*				.42*	--			
6 Spectator involv.	.73**				.61**		--		
7 Daydreams	.59**						.48*	--	
8 Real dreams	.62**					.54**		.58**	--

* = $p<.05$; ** = $p<.01$

<u>Presence Questionnaire</u>. Test-Retest and Internal Consistency measures of reliability were calculated as part of the initial examination of results. The Internal Consistency of the questionnaires was calculated using Cronbach's Alpha. The two PQs were found to have satisfactory internal consistency (.74 and .87 for the first and second administrations of the PQ). The total score for the first administration of the PQ (PQ-1) was also significantly correlated with the second administration (PQ-2; $r=.61$, $p<.01$, $N=16$). As discussed and presented above in the analysis of the ITQ, the relationship between each item and all other items was investigated by calculating the item to total correlation. We have also performed correlations between individual items, and between items and their subscales. This was done for both administrations of the PQ. The item-total(TOT) correlations are presented in Tables five and six, in conjunction with the calculated item-item and item-subscale(SS) correlations.

The mean total score for the first administration of the PQ was 144.29 and the standard deviation was 16.68. For the first administration of the PQ, nine of the 32 items were significantly correlated with the total score at the .05 level, and an additional seven were significant at the .01 level or better. The highest correlation was $r=.34$, between item 4 (complete engagement of all senses) and the total score. There were also four items that were negatively correlated with the total score, the largest being item eight (awareness of real world events), although none of the negative correlations were significant (see Table 5).

The mean total score for the second administration of the PQ was 138.29 and the standard deviation was 23.32. For items on the second administration of the PQ, there were six item-total correlations significant at the .05 level, and an additional thirteen significant correlations at the .01 level or better. The highest of these was between item two (VE response to input actions) and the total (r=.79). There were no negative item-total correlations in the second administration of the PQ. Two items that had near zero negative correlations with the total score on the first administration had positive and significant correlations with the total score for the second administration (items 11 - experience disconnects between sensory inputs [r=.56], and 14 - active visual search [r=.63]). Finally, twelve of the items that were significantly correlated with the PQ-1 total were also significantly correlated with the PQ-2 total.

Pearson correlation coefficients between ITQ total scores and PQ total scores were computed for each administration of the PQ. The ITQ correlated r=.01 with PQ-1 and r=.35 with PQ-2. Neither coefficient was significant at the $p<.05$ level.

All items from each administration of the PQ were correlated to investigate any natural grouping or clustering of similar items, and to determine whether these item clusters were consistent with the predetermined PQ subscales. The first step in the strategy used to identify natural groups was to list all item-item correlations at the $p<.01$ level. The next step checked the correlated items for correlation with at least two other items in order to be included in a cluster. (Using this approach, the smallest cluster would consist of three items.) The PQ-1 had only one small group of items that met these requirements; items 3, 4, 18, and 20. These items fit the predefined Sensory Exploration subscale (see Table 5).

The procedure for identifying item clusters was repeated at the $p<.05$ level. One small cluster consisting of items 24, 29 and 30, corresponding to the predefined Interface Awareness subscale, was identified for the PQ-1. No additional clusters were found in the PQ-1 responses that fit the predefined subscales.

Table 5

Subscale Item Correlations With PQ-1 Total, Subscale Totals, and Subscale Items

Control Responsiveness (Mean = 43.58; SD = 5.60)

Item#	TOT	SS	1	2	3	7	11	13	14	19	25
1	.34	.74**	--								
2	.51*	.63**	.64**	--							
3	.39	.64**	.53**		--						
7	.48*	.46*				--					
11	-.02	.38					--				
13	.41*	.55**	.42*					--			
14	-.04	.18							--		
19	.28	.46*								--	
25	.44*	.41*									--

Sensory Exploration & Adjustment (Mean = 38.13; SD = 6.81)

Item#	TOT	SS	3	4	14	18	20	21	26	27
3	.39	.59**	--							
4	.84**	.82**	.54**	--						
14	-.05	.04			--					
18	.62**	.74**	.50*	.64**		--				
20	.57**	.74**	.57**	.59**		.53**	--			
21	.51**	.50*		.42*				--		
26	.16	.35							--	
27	.55**	.54**								--

Involvement (Mean = 36.75; SD = 4.46)

Item#	TOT	SS	5	8	10	12	23	28	32
5	-.12	.03	--						
8	-.23	.44*		--					
10	.52**	.72**			--				
12	.54**	.58**				--			
23	.60**	.71**			.60**		--		
28	.48**	-.11						--	
32	.33	.67**					.54**	-.48*	--

Interface Awareness (Mean = 16.21; SD = 5.08)

Item#	TOT	SS	21	24	29	30
21	.51*	.50*	--			
24	.38	.86**		--		
29	.47*	.75**		.63**	--	
30	.45*	.66**		.62**	.41*	--

* = $p<.05$; ** = $p<.01$ (Continued)

Table 5 (Continued)

Subscale Item Correlations With PQ-1 Total, Subscale Totals, and Subscale Items

Control Distraction (Mean = 21.92; SD = 5.82)

Item#	TOT	SS	7	24	28	29	30
7	.48*	.62**	--				
24	.38	.84**		--			
28	.48*	.76**	.74**	.49*	--		
29	.47*	.72**		.63**		--	
30	.45*	.81**	.46*	.62**	.49*	.41*	--

* = $p<.05$; ** = $p<.01$

Further inspections at the $p<.05$ level revealed a group of correlated items from the first administration that did not match the initially established subscales. This subscale (consisting of items 7, 24, 28, 29, and 30) was labeled Control Distraction (see Table 5) and included in the later correlation studies. All of the items in this subscale address either the quality of the user interface or how much the interface interferes with the performance of the assigned tasks. This new subscale has considerable overlap with the Interface Awareness subscale, with three items in common.

No cluster of correlated items was found that would correspond to the VE Reality/Fidelity subscale on either administration of the PQ. Items that had been sorted under the subscale called Adjustment/Adaptation were clustered with the Sensory Exploration Items and hence did not form a separate subscale (see Table 6). The items making up each subscale and their correlations are listed in the respective item-subscale correlation tables (see Table 6). Although all items correlated significantly with the subscale totals, there were a few non-significant correlations between subscale items and the total score. Those correlations are presented in the TOT column in these tables.

Table 6

Subscale Item Correlations With PQ-2 Total, Subscale Totals, and Subscale Items

Control Responsiveness (Mean = 38.43; SD = 9.72)

I#	TOT	SS	1	2	3	7	11	13	14	19	25
1	.73**	.78**	--								
2	.79**	.89**	.82**	--							
3	.64**	.74**	.51*	.54**	--						
7	.62**	.73**	.55**	.56**	.45*	--					
11	.56**	.73**	.56**	.58**	.50*	.48*	--				
13	.41	.62**		.47*	.47*	.61**	.53*	--			
14	.63**	.76**	.51*	.57**	.58**	.48*	.46*	.57**	--		
19	.48*	.47*			.44*				.54**	--	
25	.49*	.66**	.50*	.73**							--

Sensory Exploration & Adjustment (Mean = 39.86; SD = 8.43)

I#	TOT	SS	3	4	14	18	20	21	26	27
3	.64**	.62**	--							
4	.46*	.64**		--						
14	.63**	.56**	.58**		--					
18	.66**	.84**		.66**		--				
20	.51*	.65**		.44*	.50*		--			
21	.75**	.85**	.51*			.77**	.53*	--		
26	.41	.70**		.47*		.81**		.74**	--	
27	.72**	.80**	.55**			.61**	.74**		.45*	--

Involvement (Mean = 36.14; SD = 7.45)

I#	TOT	SS	5	8	10	12	23	28	32
5	.35	.70**	--						
8	.05	.48*		--					
10	.57**	.87**	.53*		--				
12	.57**	.79**	.61**		.63**	--			
23	.39	.78**	.48*	.63**	.62**	.45*	--		
28	.55**	.69**	.65**		.49*	.77**		--	
32	.52*	.75**		.46*	.73**		.56**		--

Interface Awareness (Mean = 17.14; SD = 5.53)

I#	TOT	SS	21	24	29	30
21	.75**	.61**	--			
24	.48*	.92**	.47*	--		
29	.31	.75**		.67**	--	
30	.58**	.86**	.52*	.73**	.49*	--

* = $p<.05$; ** = $p<.01$

Item clusters corresponding to four of the six a priori subscales were verified by significant item to item correlations

($p<.05$) from the second PQ administration. These clusters fit the original Control Responsiveness, Involvement, Interface Awareness and Sensory Exploration subscales. As was done in investigating the internal consistency of the questionnaire, items were checked for correlation with the subscale totals. These item-subscale correlations are also presented in the item-subscale correlation tables (see Table 6).

Three item clusters could be identified in the PQ-2 responses at the $p<.01$ level. The first of these consisted of items 1, 2, 7, and 11. These items fit the pre-administration category of Control Responsiveness. The second group (consisting of items 10, 18, 23, and 32) fit the Involvement subscale. The third item cluster contained items 18, 21, 26, and 27 which fits the Sensory Exploration subscale. All of these items were highly ($p<.01$) correlated with the respective a priori subscales.

There were significant correlations observed between subscales and totals for each administration of the PQ, as well as between subscales within each administration (see Tables 7 & 8). The correlations between the subscales and the totals supports the argument for reliability. A significant correlation between Control Responsiveness and Sensory Exploration in both administrations and demonstrates the obvious connection between using controls and exploring the VE. The correlation between Control Distraction and Interface Awareness should be discounted due to item overlap.

Table 7

First Administration Presence Questionnaire Correlations Between Subscales and the Total Score

	Total	PQ-1 Subscales				
		1	2	3	4	5
PQ-1 Subscales						
1 Controller Responsive	.62**	--				
2 Interface Awareness	.67**		--			
3 Sensory Exploration	.85**	.64**	.45*	--		
4 Involvement	.62**	.51*			--	
5 Control Distraction	.59**	.50*	.88**			--

* = $p<.05$; ** = $p<.01$

Table 8

Second Administration Presence Questionnaire Correlations Between Subscales and the Total Score

	Total	PQ-2 Subscales 1	2	3	4
PQ-2 Subscales					
1 Controller Responsive	.84**	--			
2 Interface Awareness	.65**	.46*	--		
3 Sensory Exploration	.84**	.70**	.45*	--	
4 Involvement	.62**			.71**	--

* = $p<.05$; ** = $p<.01$

The PQ Involvement subscale might be expected to be positively related to the ITQ total because all items on the ITQ purport to measure a tendency to become involved. The Involvement subscale scores for PQ-1 were positively correlated with the ITQ, $r=.19$, $p=.39$, as were the PQ-2 Involvement subscale scores, $r=.45$, $p=.042$. While only the correlation between the ITQ Involvement subscale scores the second administration of the PQ was statistically significant, the direction of these results suggests that the tendency to become involved in books, movies, etc. as measured by the ITQ can predict the amount of involvement experienced in a virtual environment.

Presence and Task Performance. When the total PQ score was correlated with the task performance measures, few significant correlations were found. There were negative, but non-significant, correlations between the totals for both administrations of the PQ and performance measures on almost all of the tasks. The total score for the second administration of the PQ was significantly correlated with the accuracy measure ($r=-.51$; $p<.05$) and the performance time ($r=-.48$; $p<.05$) in the windows task, and the accuracy in the bins task ($r=.46$; $p<.05$). Further, there were only six significant correlations between the subscales and performance on the experimental tasks over both administrations. The supposition we made from this finding was that there was masking variance in the performance measures that might be obscuring possible relationships.

A possible source of this masking variance is the type of control device used by the subjects. If one of the control devices was more difficult to use than the other, then subjects using that device might experience less presence than subjects who had the more user-friendly device. Slight differences in the mean presence scores between joystick users and spaceball users were reported for both the PQ-1 (*M*=142.5 with the joystick vs *M*=146.1 with the spaceball) and for the PQ-2 (*M*=143.5 with the joystick vs *M*=131.3 with the spaceball), but neither difference was statistically significant at the $p<.05$ level.

The performance measures for the tasks were then adjusted for experimental condition (via partial correlations) and correlated with the results of the PQ administrations (both totals and subscales). The net effect of using partial correlations is to reduce the variance of the performance measure that is associated with the different control devices in the experiment.

After adjustment for experimental condition (i.e., type of control input device - spaceball vs joystick), the total score for PQ-1 was significantly correlated with five of the eleven tasks (Windows, Bins, Slide, Choice Reaction, and Simple Reaction Time; see Table 9). The total score for the second administration of the PQ was significantly correlated with only three tasks (Windows, Slide, and Choice Reaction; see Table 9). The five subscales (Control Responsiveness, Sensory Exploration, Involvement, Interface Awareness, and the post hoc subscale Control Distractions) were also significantly correlated with the tasks (Table 9). Table 9 also shows the magnitude of correlations that did not quite reach the .05 level of significance ($p<.10$), but that support the pattern established by the significant correlations.

Table 9

Adjusted Task Performance Measures Correlations With the PQ and Subscales

	Windows		Bins		Slide	
	Time	Acc.	Time	Acc.	Time	Acc.
PQ-1	-.44*	-.57**	-.45*	.40*	-.68**	.50*
PQ-2	-.42*	-.47*		.39	-.43*	.58**
Control Responsiveness						
ONE	-.50*	-.61**	-.47*	.44*	-.67**	.43*
TWO	-.44*	-.52*			-.37	.50*
Sensory Exploration						
ONE					-.55**	.48*
TWO				.46*	-.50*	.67**
Involvement						
ONE	-.32		-.55**	.43*	-.74**	.50*
TWO			-.33	.45*	-.32	.37
Interface Awareness						
ONE	-.44*	-.46*				
TWO	-.49*				-.46*	.35
Control Distraction						
ONE	-.63**	-.61**	-.43*	.41*	-.45*	

	Dial		Choice Reaction		Simple Reaction
	Time	Acc.	Time	Acc.	Time
PQ-1	.36		-.53*		-.43*
PQ-2	.36			-.47*	
Control Responsiveness					
ONE	.37	.44*	-.51*		-.61**
TWO				-.42*	
Sensory Exploration					
ONE		.35	-.57**		-.56**
TWO	-.37	.49*	-.35	-.50*	-.33
Involvement					
ONE	-.60**	.55**	-.42*		-.42*
TWO	-.39	.48*		-.40	-.41*

* = $p<.05$; ** = $p<.01$

Presence and Simulator Sickness. Significant negative correlations were obtained between the Simulator Sickness Questionnaire (SSQ, Kennedy, Lane, Berbaum, & Lillienthal, 1993) and presence as measured by the PQ. PQ-2 was significantly correlated with both the first and second administrations of the SSQ (see Table 10). PQ-1 was significantly negatively correlated with the Disorientation subscale of SSQ-1, while PQ-2 evidenced the same relationship with the Oculomotor subscale (see Table 10). PQ-2 was also significantly negatively correlated with the Nausea subscale calculated from SSQ-1. There were also two

Simulator Sickness subscales (Nausea-2 and Oculomotor-1) that showed strong but non-significant relationships with PQ-2.

Table 10

PQ and Subscale Totals Correlated With Simulator Sickness and Subscale Totals

	NAUSEA		OCULOMOTOR		DISORIENT		SSQ TOTAL	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
PQ-1					-.37*			
PQ-2	-.50*	-.35	-.34	-.41*			-.40*	-.45*
Control Responsiveness								
ONE	-.53**	-.69**	-.47*	-.67**	-.58**	-.52**	-.57**	-.69**
TWO		-.46*		-.38		-.40		-.48*
Sensory Exploration								
ONE					-.35			
TWO		-.48*		-.55**		-.37		-.58**
Involvement								
ONE		-.32		-.37		-.38		-.42*
TWO				-.55**				-.41*
Control Distraction								
ONE		-.42			-.30			

* = $p<.05$; ** = $p<.01$

In general, the Control Responsiveness subscale of the PQ was strongly related to all of the SSQ subscales, as well as to the total scores for the SSQ administrations (see Table 10). The Control Responsiveness subscale measured in the first administration was significantly negatively related with all subscales from both SSQ administrations. The second administration of the Control Responsiveness subscale was significantly negatively correlated to the Nausea subscale from the SSQ-2. Again, strong but not significant correlations appeared in the negative relationships between Control Responsiveness and the Oculomotor and Disorientation subscales from the second administration.

The relationship between the PQ and the SSQ is further supported by the significant negative correlations between the other PQ subscales and SSQ subscales. Sensory Exploration subscale was significantly correlated with two of the three SSQ subscales (with the third correlation approaching significance, see Table 10). Sensory Exploration was also significantly and negatively correlated with the total SSQ score from the second administration. The Involvement subscale also had strong negative correlations with several SSQ subscales, although the only significant subscale correlations were on the second administration with the SSQ Oculomotor discomfort subscale. Overall, the total score and subscale correlations across both administrations indicate a strong and negative relationship between the our measurement of presence and a good measure of simulator sickness (Kennedy, et. al., 1993).

Discussion

Internal Consistency. Both the initial versions of the ITQ and the PQ have adequate levels of internal consistency, as indicated by the test for reliability and supporting correlations. Part of the further support for concluding that the PQ is reliable is that the two administrations were significantly correlated. There were also a number of significant item correlations with the totals for each PQ administration (16 of 32 for PQ-1; 19 of 32 for PQ-2). Only six of the PQ-1 items did not correlate significantly with their respective subscales and all items were significantly correlated with their subscales in PQ-2, which also supports the reliability of the questionnaire. Additionally, all subscales were highly correlated with the total scores for their administrations of the PQ.

Immersive Tendencies Questionnaire. It is not clear why there was no significant relationship between the Immersive Tendencies Questionnaire and the two administrations of the Presence Questionnaire. Our initial presumption is that the ITQ was too short and insufficiently comprehensive to capture a sufficiently wide range of focused activities that might relate to different aspects of the VE experience. This has led us to expand the ITQ to the size and form presented in Appendix A.

There were no significant correlations between the Immersive Tendencies Questionnaire and the tasks performed in the VE. Almost all of the correlations between the ITQ and VE tasks were in the predicted direction, however. Hence, the concept of a relationship between a tendency toward involvement in normally diverting activities or phenomena and performance of tasks in a Virtual Environment is not negated.

Presence Questionnaire. One of the major hypotheses of interest was that greater levels of presence would be associated with better performance. There were 50 significant correlations between task performance measures and presence as measured by the PQ total and subscales (out of a possible 230). In addition, a large percentage of the correlations (including non-significant ones) between the presence questionnaire and task performance measures were in the predicted direction. At the very least, the limited data provides indications that the hypothesis should be pursued further under varying conditions and with larger samples.

The only significant relationship between movement tasks and the PQ occurred in the second session. The performance measures used in this research were time-to-perform and accuracy (better accuracy being fewer collisions). [It should be remembered that the task data used in the correlations had been adjusted (via partial correlations) to remove the effects of the different control devices used in the experiment.] The significant negative correlations between perceptions of control responsiveness and the time and accuracy of performing the Windows task represents the relationship expected between all of the movement-type tasks and that subscale. The expected relationship is that the better the control response, the faster the task can be performed and fewer errors made (e.g. bumping into window frames or walls). The second session also provided interesting correlations between the presence subscales and some of the manipulation tasks. There were significant negative correlations with time-to-perform and significant positive correlations with task accuracy and the Control Responsiveness, Sensory Exploration, and Involvement subscales. These three subscales are at the theoretical "heart" of the PQ, and the correlations support the idea that interactivity leads to involvement and better performance.

What is not clear is why the PQ and associated subscales didn't have a significant correlation with all tasks in both sessions. One reason may be that correlations between performance and presence ratings can only appear after people adapt to the VE situation. In other words, the manipulation tasks were significantly related to presence because they were performed in the second session, after some general adaptation to the VE situation could be presumed to have occurred. It is also possible that these manipulation tasks did not push the VE equipment performance envelope (in terms of frame rate generation and system response times) to the same extent as the movement tasks. When the VE equipment has a comfortable margin for execution, system response may seem more natural and it may be easier for someone to become immersed in the activity. The significant correlations with the Windows task in the second session would seem to support the former rather than the latter explanation.

The movement tasks could have also presented a different set of dynamics for the perception of Control Responsiveness, Sensory Exploration, Involvement, and Interface Awareness. Because of the implementation of collision detection routines, one could get stuck or hung up on a wall in the Hallways, Figure-eight, and Doorways tasks. These collisions might lead to negative perceptions about Control Responsiveness, Sensory Exploration, and Involvement but may have not significantly degraded task performance . The Windows task, on the other hand, was perhaps the most difficult task in the movement group. The easy part was traversing the rooms between windows. The hard part was getting through the windows. This is because the body model used in the movement tasks had width and height associated with the viewpoint. Thus the "shoulders" could get stuck on a wall as mentioned above in connection with the other movement tasks. In the Windows task, the "feet" and "head" could also impede progress. These factors combined to make the necessary adjustment for maneuvering through a window more difficult to perceive and execute. This fits the logic presented above and matches the correlations presented in Table 10, in that the subject would perceive difficulty in the control responsiveness, experience awareness of interface problems, and be less involved (because of the difficulty) when actually performing slower and with less accuracy. Those subjects that could perform more quickly and accurately would also judge the responsiveness better, the sensory exploration as easier, and presumably have a higher level of involvement.

Presence Questionnaire Subscales. Four of the six originally proposed subscales were supported by item correlation patterns, with one "new" subscale being identified. The originally proposed Reality/Fidelity subscale was not supported and the items assigned to the Adjustment/Adaptation subscale were clustered with items from the Sensory Exploration subscale. That the subscale items correlated more highly with the subscale totals than with PQ total scores provided further support for these separate subscales. Together these results suggest that the structure of the presence questionnaire is quite similar to that which was hypothesized a priori.

The pattern of correlations between subscales suggest that there may be separate contributing factors associated with presence as measured by the PQ. The pattern of significant Involvement subscale (presence) correlations with the Immersive subscales (all others) in the two experimental sessions implies that the effect of immersive factors on presence is mediated by task requirements. Involvement and Control Responsiveness were significantly correlated after the first session. But they were not correlated after the second session, where Involvement was significantly correlated with Sensory Exploration. Without putting too much emphasis on the limited data available here, the difference may be based on the task requirements. The first session required using the controls to move without exploration (e.g., down hallways), while the second required more exploration and manipulation (e.g., looking for targets and cursors). Supporting evidence is that the Control Responsiveness mean dropped considerably in session 2.

The correlations between immersive factors also seems to indicate that the immersive factors subscales are significantly related to one another, or have in common a relationship with some other factor. In both sessions, Control Responsiveness and Sensory Exploration were correlated. Sensory Exploration and

Interface Awareness were also correlated in both sessions (although to a lesser degree in the second session). Interface Awareness and Control Responsiveness were only correlated in the second administration of the PQ.

Presence and Simulator Sickness. Because perceived viewpoint movement (vection) has been hypothesized to contribute to both the presence experience and simulator sickness, a positive relationship was expected (Kennedy, Lane, Berbaum, & Lillienthal, 1993). The fact that a gross subjective measure of presence and a measure of simulator sickness were negatively correlated is truly interesting. The indicated inverse relationship between simulator sickness and the degree of presence seems to be relatively solid, given the subscale correlations and in spite of the low numbers. Because the results are correlational, there are three possibilities.

One reasonable explanation is that the immersive factors that increase presence also decrease or prevent simulator sickness. In other words; Disorientation, Oculomotor distress, and Nausea will decrease when individuals can accept and use the VE configuration in what they perceive to be natural, controlled, and predictable ways. The opposing corollary is that the perception of an uncontrolled situation, with unpredictable disjuncts from expectations, limited opportunity to explore or control responses, and general inadequate support for building a sense of presence may lead to disorientation, oculomotor distress, and nausea.

A second alternative is that simulator sickness may interfere with or decrease the effect of immersive factors and hence the experience of presence. When the experiencer, for whatever reason, begins to experience nausea, oculomotor distress, or disorientation then the focus or attention shifts to the feeling of sickness. This precludes effective use of controls, limits sensory exploration, and probably prevents development of a feeling of involvement with the task experience. In other words, the onset of simulator sickness could disrupt the ability to control, to explore the VE, and then prevent the experience of being there. The participant is simply unable to focus on the VE experience due to concentration on feelings of discomfort.

There is also a remote possibility that there is some other factor or set of factors that both causes an increase in simulator sickness, decreases the immersive factor ratings, and decreases the perception of presence. However, the negative relationship between Involvement and Oculomotor Discomfort, between Sensory Exploration and both Nausea and Oculomotor Discomfort, as well as the very strong relationship between the Control Responsiveness subscale and all aspects measured by the

Simulator Sickness Questionnaire, seems to support one of the first two arguments presented.

Conclusions

Our first attempt at constructing an instrument that measures at least some aspects of the phenomenon being referred to as presence appears promising. The instruments were reliable in measuring subjective estimations of presence and associated immersive factors. Approximately 89% of the correlations between presence and task performance for these data were in the predicted direction. This suggests that the obtained results were neither coincidental nor a statistical artifact. Given the current relatively poor state of the art in VE equipment, the degree to which people can apparently accept the disjuncts and still report being immersed is remarkable. Nevertheless, it will be necessary to replicate these results with much larger samples before any definitive statements about these questionnaires can be made.

Based on the limited data collected to date, there appear to be four main subscales in our instrument that address aspects of presence: Control Responsiveness, Sensory Exploration, Interface Awareness, and Involvement. The Control Responsiveness subscale measures perceptions of control within the virtual environment. The Sensory Exploration subscale provides some measure of sensory interaction in the environment. Together, it seems, these two factors combine to enable some level of presence as measured by the Involvement subscale.

The negative relationship between presence and simulator sickness is perhaps the most important one discovered. The negative relationship that we observed may mean that simulator sickness (or the lack of it) is itself an immersive factor, or an indication that immersive factors are or are not working. This relationship is odd since vection, the perception of motion, is often associated with simulator sickness. Some predictions have been made in the literature that a compelling sense of presence and self-motion may lead to the same types of simulator sickness problems found in flight simulation systems applications (Kennedy, Lane, Lillienthal, Berbaum, & Hettinger, 1992). Our research results are contrary to this prediction in that increasing levels of presence tend to occur with decreased levels of VE sickness. If this negative relationship holds up with additional administrations of the questionnaires, it could change current thinking about presence and simulator sickness, and about the role of vection in producing either simulator sickness or presence. The vection issue is complex, and it alone would require a whole report to introduce VE-appropriate issues and review all the relevant research results.

Much more work remains on the relationship between immersive factors, presence, and both performance in and transfer from the VE. It may be that people rate responsiveness, the ability to explore, and involvement directly based on perceptions about their own performance. On the other hand, people may perceive actual differences in VE capability that then directly affect or enable their performance. It should also be noted that the VEPAB tasks used in this research were simple discrete tasks that did not necessarily form a meaningful coherent task environment, and this may have reduced the amount of presence experienced in this situation.

When used for training, the key issue for any VE system will still center on transfer. The problem for equipment and training developers remains the same, even with Virtual Environments, adequate experiments that demonstrate transfer effects are extremely difficult to conduct. Our limited data suggest that better performers report more involvement in the immediate experience. It may be that task appropriate equipment configurations enable presence and performance, and better performance may also increase learning and transfer. That is a major focus of our research program.

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Appendix A

IMMERSIVE TENDENCIES QUESTIONNAIRE
Version 2, Bob Witmer & Michael J. Singer

Indicate your preferred answer by marking an "X" in the appropriate box of the seven point scale. Please consider the entire scale when making your responses, as the intermediate levels may apply. For example, if your response is once or twice, the second box from the left should be marked. If your response is many times but not extremely often, then the sixth (or second box from the right) should be marked.

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?

|_______|_______|_______|_______|_______|_______|_______|

NEVER — OCCASIONALLY — OFTEN

2. How easily can you switch your attention from the task in which you are currently involved to a new task?

|_______|_______|_______|_______|_______|_______|_______|

NOT SO EASILY — FAIRLY EASILY — QUITE EASILY

3. How frequently do you get emotionally involved (angry, sad, or happy) in the news stories that you read or hear?

|_______|_______|_______|_______|_______|_______|_______|

NEVER — OCCASIONALLY — OFTEN

4. How well do you feel today?

|_______|_______|_______|_______|_______|_______|_______|

NOT WELL — PRETTY WELL — EXCELLENT

5. Do you easily become deeply involved in movies or tv dramas?

|_______|_______|_______|_______|_______|_______|_______|

NEVER — OCCASIONALLY — OFTEN

6. Do you ever become so involved in a television program or book that people have problems getting your attention?

|_______|_______|_______|_______|_______|_______|_______|

NEVER — OCCASIONALLY — OFTEN

7. How mentally alert do you feel at the present time?

NOT ALERT			MODERATELY			FULLY ALERT

8. Do you ever become so involved in a movie that you are not aware of things happening around you?

NEVER			OCCASIONALLY			OFTEN

9. How frequently do you find yourself closely identifying with the characters in a story line?

NEVER			OCCASIONALLY			OFTEN

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?

NEVER			OCCASIONALLY			OFTEN

11. On average, how many books do you read for enjoyment in a month?

NONE	ONE	TWO	THREE	FOUR	FIVE	MORE

12. What kind of books do you read most frequently? (CIRCLE ONE ITEM ONLY!)

Spy novels	Fantasies	Science fiction
Adventure novels	Romance novels	Historical novels
Westerns	Mysteries	Other fiction
Biographies	Autobiographies	Other non-fiction

13. How physically fit do you feel today?

NOT FIT			MODERATELY FIT			EXTREMELY FIT

14. How good are you at blocking out external distractions when you are involved in something?

|________|________|________|________|________|________|________|

NOT VERY GOOD — SOMEWHAT GOOD — VERY GOOD

15. When watching sports, do you ever become so involved in the game that you react as if you were one of the players?

|________|________|________|________|________|________|________|

NEVER — OCCASIONALLY — OFTEN

16. Do you ever become so involved in a daydream that you are not aware of things happening around you?

|________|________|________|________|________|________|________|

NEVER — OCCASIONALLY — OFTEN

17. Do you ever have dreams that are so real that you feel disoriented when you awake?

|________|________|________|________|________|________|________|

NEVER — OCCASIONALLY — OFTEN

18. When playing sports, do you become so involved in the game that you lose track of time?

|________|________|________|________|________|________|________|

NEVER — OCCASIONALLY — OFTEN

19. Are you easily disturbed when working on a task?

|________|________|________|________|________|________|________|

NEVER — OCCASIONALLY — OFTEN

20. How well do you concentrate on enjoyable activities?

|________|________|________|________|________|________|________|

NOT AT ALL — MODERATELY WELL — VERY WELL

21. How often do you play arcade or video games? (OFTEN should be taken to mean every day or every two days, on average.)

|_______|_______|_______|_______|_______|_______|_______|
NEVER OCCASIONALLY OFTEN

22. How well do you concentrate on disagreeable tasks?

|_______|_______|_______|_______|_______|_______|_______|
NOT AT ALL MODERATELY WELL VERY WELL

23. Have you ever gotten excited during a chase or fight scene on TV or in the movies?

|_______|_______|_______|_______|_______|_______|_______|
NEVER OCCASIONALLY OFTEN

24. To what extent have you dwelled on personal problems in the last 48 hours?

|_______|_______|_______|_______|_______|_______|_______|
NOT AT ALL SOME ENTIRELY

25. Have you ever gotten scared by something happening on a TV show or in a movie?

|_______|_______|_______|_______|_______|_______|_______|
NEVER OCCASIONALLY OFTEN

26. Have you ever remained apprehensive or fearful long after watching a scary movie?

|_______|_______|_______|_______|_______|_______|_______|
NEVER OCCASIONALLY OFTEN

27. Do you ever avoid carnival or fairground rides because they are too scary?

|_______|_______|_______|_______|_______|_______|_______|
NEVER OCCASIONALLY OFTEN

28. How frequently do you watch tv soap operas or docu-dramas?

| _______ | _______ | _______ | _______ | _______ | _______ | _______ |
NEVER OCCASIONALLY OFTEN

29. Do you ever become so involved in doing something that you lose all track of time?

| _______ | _______ | _______ | _______ | _______ | _______ | _______ |
NEVER OCCASIONALLY OFTEN

Appendix B

PRESENCE QUESTIONNAIRE
Version 2.0, Bob Witmer & Michael J. Singer

Characterize your experience in the virtual environment, by marking an "X" in the appropriate box of the 7-point scale, in accordance with the question content and descriptive labels. Please consider the entire scale when making your responses, as the intermediate levels may apply. Answer the questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer. ANSWER ALL QUESTIONS WITH REGARD TO THE VIRTUAL ENVIRONMENT.

1. How much were you able to control events?

|_____|_____|_____|_____|_____|_____|_____|

NOT AT ALL — SOMEWHAT — COMPLETELY

2. How responsive was the environment to actions that you initiated (or performed)?

|_____|_____|_____|_____|_____|_____|_____|

NOT RESPONSIVE — MODERATELY RESPONSIVE — COMPLETELY RESPONSIVE

3. How natural did your interactions with the environment seem?

|_____|_____|_____|_____|_____|_____|_____|

EXTREMELY ARTIFICIAL — BORDERLINE — COMPLETELY NATURAL

4. How completely were <u>all</u> of your senses engaged?

|_____|_____|_____|_____|_____|_____|_____|

NOT ENGAGED — MILDLY ENGAGED — COMPLETELY ENGAGED

5. How much did the visual aspects of the environment involve you?

|_____|_____|_____|_____|_____|_____|_____|

NOT AT ALL — SOMEWHAT — COMPLETELY

6. How much did the auditory aspects of the environment involve you?

|_______|_______|_______|_______|_______|_______|_______|
NOT AT ALL SOMEWHAT COMPLETELY

7. How natural was the mechanism which controlled movement through the environment?

|_______|_______|_______|_______|_______|_______|_______|
EXTREMELY ARTIFICIAL BORDERLINE COMPLETELY NATURAL

8. How aware were you of events occurring in the real world around you?

|_______|_______|_______|_______|_______|_______|_______|
NOT AWARE AT ALL MILDLY AWARE VERY AWARE

9. How aware were you of your display and control devices?

|_______|_______|_______|_______|_______|_______|_______|
NOT AWARE AT ALL MILDLY AWARE VERY AWARE

10. How compelling was your sense of objects moving through space?

|_______|_______|_______|_______|_______|_______|_______|
NOT AT ALL MODERATELY COMPELLING VERY COMPELLING

11. How inconsistent or disconnected was the information coming from your various senses?

|_______|_______|_______|_______|_______|_______|_______|
NOT AT ALL INCONSISTENT SOMEWHAT INCONSISTENT VERY INCONSISTENT

12. How much did your experiences in the virtual environment seem consistent with your real world experiences?

|_______|_______|_______|_______|_______|_______|_______|
NOT CONSISTENT MODERATELY CONSISTENT VERY CONSISTENT

13. Were you able to anticipate what would happen next in response to the actions that you performed?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL — SOMEWHAT — COMPLETELY

14. How completely were you able to actively survey or search the environment using vision?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL — SOMEWHAT — COMPLETELY

15. How well could you identify sounds?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL — SOMEWHAT — COMPLETELY

16. How well could you localize sounds?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL — SOMEWHAT — COMPLETELY

17. How well could you actively survey or search the virtual environment using touch?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL — SOMEWHAT — COMPLETELY

18. How compelling was your sense of moving around inside the virtual environment?

|_____|_____|_____|_____|_____|_____|_____|
NOT COMPELLING — MODERATELY COMPELLING — VERY COMPELLING

19. How closely were you able to examine objects?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL — PRETTY CLOSELY — VERY CLOSELY

20. How well could you examine objects from multiple viewpoints?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL — SOMEWHAT — EXTENSIVELY

21. How well could you move or manipulate objects in the virtual environment?

|_______|_______|_______|_______|_______|_______|_______|

NOT AT ALL — SOMEWHAT — EXTENSIVELY

22. To what degree did you feel confused or disoriented at the beginning of breaks or at the end of the experimental session?

|_______|_______|_______|_______|_______|_______|_______|

NOT AT ALL — MILDLY DISORIENTED — VERY DISORIENTED

23. How involved were you in the virtual environment experience?

|_______|_______|_______|_______|_______|_______|_______|

NOT INVOLVED — MILDLY INVOLVED — COMPLETELY ENGROSSED

24. How distracting was the control mechanism?

|_______|_______|_______|_______|_______|_______|_______|

NOT AT ALL — MILDLY DISTRACTING — VERY DISTRACTING

25. How much delay did you experience between your actions and expected outcomes?

|_______|_______|_______|_______|_______|_______|_______|

NO DELAYS — MODERATE DELAYS — LONG DELAYS

26. How quickly did you adjust to the virtual environment experience?

|_______|_______|_______|_______|_______|_______|_______|

NOT AT ALL — SLOWLY — LESS THAN ONE MINUTE

27. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?

|_______|_______|_______|_______|_______|_______|_______|

NOT PROFICIENT — REASONABLY PROFICIENT — VERY PROFICIENT

28. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?

NOT AT ALL			INTERFERED SOMEWHAT			PREVENTED PERFORMANCE

29. How much did the control devices interfere with the performance of assigned tasks or with other activities?

NOT AT ALL			INTERFERED SOMEWHAT			INTERFERED GREATLY

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?

NOT AT ALL			SOMEWHAT			COMPLETELY

31. Did you learn new techniques that enabled you to improve your performance?

NO TECHNIQUES LEARNED			LEARNED SOME TECHNIQUES			LEARNED MANY TECHNIQUES

32. Were you involved in the experimental task to the extent that you lost track of time?

NOT AT ALL			SOMEWHAT			COMPLETELY