Social Presence in Multi-User Virtual Environments: A Review and Measurement Framework for Organizational Research

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ABSTRACT
As computer-mediated work continues to evolve, and online interactions between individuals become more immersive and socially nuanced, the experiences of individuals within virtual environments will no doubt be a recurrent topic of organizational research. Presence, or the subjective experience of “being” in an environment, has been suggested by researchers in multiple disciplines to be an important factor in the effective utilization of virtual worlds. This paper reviews the relevant literature on social presence and presents a framework through which this construct can reliably and validly be measured. The goal of this paper is to propose a conceptually- and statistically-sound strategy for how to define and measure presence for purposes of testing hypotheses in organizational behavior research.

Quite naturally, as computers have become more sophisticated, so have the virtual environments within which individuals are able to interact. For instance, many of the earliest socially-oriented virtual environments were text-based, referred to as multi-user dungeons (MUDs; Leslie, 1993). Over time, such environments have evolved to include not only text-based information, but visual and auditory stimuli as well as avatar embodiment. Exemplars of current-day virtual environments are the multi-player online games World of Warcraft (Mortensen, 2006) and Second Life (Atkinson, 2008; Berente, Hansen, Pike, & Bateman, 2008). A growing organizational trend in the use of technology as a communicative medium is the mounting popularity of multi-user virtual environments (MUVEs) such as Second Life, which can
allow multiple individuals who may or may not be geographically distributed to interact and strive towards collaborative goals via customized avatars in a user-created virtual world. For organizations in Second Life, this virtual world very often takes the form of a 3D office with boardrooms and workspaces that has been established by the organization for its employees to complete job tasks in the MUVE.

The use of virtual environments by organizations is not a new development; in fact, organizations have utilized virtual environments for a variety of purposes over the past decade. For example, crisis situations have been simulated in virtual outer space environments as part of the training NASA conducts for astronauts, and Boeing created full-size interactive 3D models of aircraft chassis for designers and engineers (Cox, 1999). Other organizations have used virtual environments as a way to market products to consumers, such as Nike’s marketing of shoes through the virtual world There (Clark, 2003). In the slightly more distant past, as can be seen in Takahashi (1998), MUVEs had been prevented from seeing widespread implementation due to the limitations of Internet connections and computer processors. In modern-day virtual environments such as Second Life, the obstacles to actualizing MUVEs for internal organizational use have been overcome as technology becomes increasingly sophisticated and high-speed Internet connections are more commonplace (Williams, Yee, & Caplan, 2008). As an increasing number of employees are turning to work arrangements such as telecommuting (e.g., Gajendran & Harrison, 2007), which have in large part been enabled by advances in computer-mediated communication technologies, more organizations are finding utility in using MUVEs for purposes such as holding meetings in virtual offices and for personnel recruitment (Steel, 2006). For those organizations who already use some form of synchronous computer-mediated communication, a MUVE like Second Life can provide “a single solution for content delivery and communications including chat, email, text messaging, audio and video streaming, slide presentations, images and voice” (Atkinson, 2008, p. 17). In addition, the swiftly-rising popularity of virtual environments (e.g., Williams et al., 2008) has prompted several major corporations to invest resources in crafting a corporate identity in MUVEs—even a recent congressional hearing was officially mirrored in Second Life with avatars (Duranske, 2008).
The goal of this paper is to arrive at an approach to measuring social presence in emerging computer-mediated communication technologies, focusing particularly on the use of MUVEs by organizations. A MUVE can be broadly defined as a three-dimensional, computer-based simulation of an environment that may or may not mimic a real, physical place; the subjective experience of “being” in that virtual environment while physically situated in another environment can be broadly defined as the experience of presence (Witmer & Singer, 1998; Wrench & Punyanunt-Carter, 2007). The available frameworks for considering the influence of social presence in computer-mediated environments are found in various disciplines such as education (Nelson & Ketelhut, 2007), human-computer interaction (Nash et al., 2000; Sas & O’Hare, 2001), computer and information science (Bainbridge, 2007), and clinical therapy (Moore, Cheng, McGrath, and Powell, 2005). To date, no available framework exists that appropriates the construct of social presence for use in organizational research. Thus, this paper will integrate prior research on social presence from a range of disciplines in the pursuit of applying existing knowledge to the study of computer-supported work, emphasizing the potential role of immersive 3D MUVEs such as Second Life.

Multi-User Virtual Environments

While there are many kinds of virtual environments, MUVEs and massively-multiplayer online games have exploded in popularity over the past several years (Li, Papagiannidis & Bourlakis, 2008); of this general type of virtual environment, Second Life appears to be capturing the attention of both researchers and organizations. In Second Life, users interact through avatars, or “digital models that may look or behave like the humans they represent... often rendered dynamically, in real time, to reflect at least some user behavior or movements” (Bailenson, Yee, Blascovich, & Guadagno, 2008, p. 78). Many organizations have started using Second Life to supplement various organizational functions such as conducting virtual job interviews (Athavaley, 2007) and marketing products to consumers (Sidel, 2008; Veiga, 2007). As evidence of the interest in the expansion of MUVEs such as Second Life, $345 million was invested in the first half of 2008 in nearly 40 companies whose operations are directly related to virtual worlds, according to an article in the Wall Street Journal (Duranske, 2008). The popularity of MUVEs has been attributed in large part to the fact that both the sensory richness
of most MUVEs and the use of avatars yield conditions which are conducive to the experience of social presence. As stated by Bente, Rüggenberg, Krämer, and Eschenburg (2008), “the social-communicative potential of avatars... provide[s] channels for the transmission of nonverbal cues, such as gestures, postures, movements, and facial expressions” (p. 288). Accordingly, Bente et al. demonstrated in a study that compared text, audio, video, and avatar social interaction that the use of avatars generates comparable levels of presence to video-conferencing. Therefore, avatars may be able to provide virtual experiences analogous to those in a high-fidelity communication medium.

Social presence in virtual contexts is an important construct for organizations to consider, as suggested by empirical research that has linked presence to various cognitive task outcomes (e.g., Nash, Edwards, Thompson, & Barfield, 2000) as well as general performance outcomes (Wrench & Punyanunt-Carter, 2007), particularly when a MUVE enables interaction with others (Nicovich, Boller, & Cornwell, 2005). Thus, as MUVEs continue to be used by an increasing number of organizations, the construct of social presence could prove highly relevant to research questions that would be of interest to those studying human behavior in the field of industrial and organizational psychology. Next, a definition of social presence will be condensed from the extant literature, followed by a review of measurement approaches to the construct and suggestions for measuring presence in organizational research.

**Defining Social Presence in Virtual Environments**

Short, Williams, and Christie (1976) originally defined social presence as both (a) “the degree of salience of the other person in the interaction” and (b) “the consequent salience of the interpersonal relationships” (p. 65). Over time, researchers exploring the construct of social presence in the context of computer-mediated communication have focused on the first half of Short et al.’s definition, examining questions related to the “psychological experience of the user while using a medium” (Abeele, Roe, & Pandelaere, 2007, p. 216). Accordingly, the line of inquiry relevant to the current paper focuses on the interactional salience in a virtual environment rather than the interpersonal relationships that may be forged there.

Building on Short et al.’s (1976) conceptualization of social presence, Sheridan’s (1992) definition of presence as it applies to technology-mediated contexts encompassed the idea that
presence occurs when an individual is extending their control of events from a physical reality to either another physical reality (through telepresence) or a fabricated reality (virtual presence). Yet, Sheridan’s definition does not patently engage the psychological antecedents of presence, and the research canon collected around Sheridan’s definition emphasizes the technological characteristics that appear to predict presence, making the assumption that the medium directly induces presence (Jurnet, Beciu, & Maldonado, 2005). Such a conceptualization does not recognize that there may be person-centered variables that are involved in the phenomenon of presence (Botella, Baños, & Alcañiz, 2003). Perhaps unsurprisingly, a review of different taxonomies of presence by Lee (2004) demonstrated a lack of agreement that exists in the literature as to how to best define presence. Further, Biocca, Burgoon, Harms, and Stoner (2001) noted that social presence is often poorly defined in psychological investigations of the construct.

As discussed by Wrench and Punyanunt-Carter (2007), social presence theory in general concerns the relative ability of different media formats to shape social interactions through various restrictions of nonverbal communication. For a MUVE such as Second Life, research on presence could serve to illuminate the possible applications for organizations as an array of nonverbal social norms are perpetuated in MUVEs (Yee, Bailenson, Urbanek, Chang, & Merget, 2007). Moreover, avatars such as those used in Second Life permit the communication of nonverbal cues (Bente et al., 2008). As organizations seeking to implement MUVEs in their operations may be particularly concerned with how people experience interactions, rather than how realistic the virtual environment looks, the definition of presence given by Witmer and Singer (1998) provides an inductive foundation for the discussion of presence as it is relevant to social interactions in a MUVE. Witmer and Singer’s (1998) definition of what constitutes presence contains four facets: (1) control over and behavioral impact on the virtual environment by the individual; (2) the breadth and richness of sensory stimuli in the virtual environment; (3) the experience of immersion in the virtual environment and the concurrent isolation to outside distractions; and, (4) the consistency between the virtual environment and the real world, or more simply, the social “realism” of the virtual environment. However, before discussing a means with which to assess presence based on the above definition, it is
instrumental to review the operational definitions of social presence as they appear in existing research.

**Operationalizing Social Presence in Virtual Environments**

Regardless of how presence is conceptualized, i.e., whether adopting the first or second component of Short et al.’s (1976) definition as given above, it is undeniably a multi-faceted construct comprised of many levels and various dimensions (Biocca & Delaney, 1995). However, just as there has not been relative agreement on the definition of social presence (e.g., Bailenson, Swinth, Hoyt, Persky, Dimov, & Blascovich, 2005), neither has there been a unifying approach to its measurement (Kuschel, Freyberger, Buss, & Färber, 2007). Following are several examples of the attempts to operationalize and measure social presence as it pertains to research in virtual environments.

Presence has been measured most often through the use of self-report questionnaires, though relatively few studies have provided adequate evidence for the appropriateness of these instruments. Russo (2001) compared ratings of presence across 6 scenarios designed to emulate high- and low-presence interaction conditions. Although this study did demonstrate substantive differences across these conditions, it did not provide evidence for the reliability or construct validity of the items used to assess presence. Further, the sample of raters only included 14 individuals, so it is possible that the results reported by Russo may be significantly contaminated by sampling error. Biocca, Harms, and Gregg (2001) sought to create a measure of presence that could be used for psychological research. However, while the authors did make an attempt to base their scale development on a clearly-defined and multidimensional conceptualization of social presence, their validation sample only contained 76 individuals, which likely did not provide adequate statistical power for exploratory factor analysis (EFA). Despite these and other efforts to create questionnaires to assess presence, such studies often fail to conduct proper scale validation analyses and demonstrate reliability and validity evidence as suggested by psychometric best-practices (e.g., Hinkin, 1998; MacKenzie, Podsakoff, & Jarvis, 2005; Nunnally & Bernstein, 1994). For example, even in scale development studies where EFA was employed, either the authors used principal components analysis (which is not appropriate for psychometric scales as it does not conceptually yield factors that reflect latent
constructs; c.f., Fabrigar, Wegener, MacCallum, & Strahan, 1999), conducted no confirmatory factor analysis as an a priori test of the factor structure of a measure, did not demonstrate convergent and discriminant validity evidence, or used sample sizes below Hinkin’s (1998) recommended cutoff for EFA of at least 200 individuals\(^1\) (e.g., Abeele et al., 2007; Gerhard, Moore, & Hobbs, 2004; Kuschel, Freyberger, Buss, & Färber, 2007). Further, the applications of EFA seen in such studies may be subject to question, as factor analysis is frequently misunderstood and misused by researchers (Fabrigar et al., 1999). For example, when the factor analysis conducted by Abeele et al. (2007) extracted two factors rather than the three factors that were expected from the pool of items, the researchers forced a three-factor solution to the data instead of revising their interpretation of the factor structure of their presence measure.

Noting the limitations inherent in the method of self-report measures (e.g., Spector, 1994), Meehan, Insko, Whitton, and Brooks (2001) and Slater, Guger, Edlinger, Leeb, Pfurtscheller, Antley et al. (2006) sought to measure presence using physiological markers. The underlying premise of these authors’ approach to measuring presence centers on the notion that when an individual is in a virtual scenario, the extent to which their experience evokes responses similar to their responses in a parallel physical environment should be reflected in difference scores of variables such as heart rate, skin conductance, and skin temperature between the two media. The smaller the difference scores for physiological reactions, the greater the inferred level of experienced presence. Other researchers have taken a behavior-based approach to assessing presence, which will be described later.

As evident in the prior attempts to measure social presence described above, the existing literature suffers from a lack of a well-validated instrument with which to assess this construct. Before discussing a more psychometrically and statistically rigorous approach to measuring presence that could serve the needs of organizational behavior researchers and practitioners, however, it is instructive to review the definitional nature of social presence as a variable that can vary between individuals.

\(^{1}\) It should be noted that there is not unanimous agreement as to the appropriate sample size for applications of factor analysis; for instance, Tabacknick & Fidell (2007) generally recommend a sample size of at least 300 individuals.
Social Presence as an Individual Difference

As previously mentioned, much of the extant literature on social presence in virtual environments has focused on technological characteristics at the exclusion of the influence of person-centered characteristics. If presence is to be defined as a psychological experience, which is recognized even in patently biological approaches to presence (e.g., Meehan et al., 2001), it follows that the subjective perception of presence necessitates the recognition of social presence as an individual difference. Said another way, different individuals in the same virtual environment may experience different levels of social presence independent of the technological characteristics of the medium. Accordingly, there have been some preliminary studies which have investigated the role of individual differences in social presence.

In a study that used virtual environment simulations of test anxiety scenarios, Jurnet et al. (2005) showed that individuals high in introversion and test anxiety experienced higher levels of social presence under the same virtual conditions. Another study by Stepparava, Harb, Russo, Zorzi, and Rizzi (2007) demonstrated that individuals using Second Life who were higher in the need for control reported less presence, which in turn negatively impacted affective reactions to the virtual environment. Results such as these clearly indicate that presence can differ as a function of the user, and any assessment of social presence must be based on an understanding of the construct that allows for variance between individuals.

Consideration of the role of individual differences in experiences of social presence can provide insight into the relative likelihood that an array of variables with interactive relationships influences presence across users. For this reason, it can be argued that a majority of the existing studies of presence in other disciplines do not include sample sizes large enough to detect these kinds of effects; in other words, if the study of social presence acknowledges individual differences, larger samples than those commonly found in many of the studies cited in this paper are required to test hypotheses with adequate statistical power. Therefore, the study of presence in MUVEs using improved measurement instruments and study design is not only of value to organizational research, but is generally in the interests of the study of presence as a multi-disciplinary line of inquiry.

Measuring Social Presence in Organizational Contexts
As discussed earlier in this paper, there have been several methods employed in the measurement of social presence. Nevertheless, the construct validity problems encountered in nearly all of the available self-report measures of presence prohibit the immediate inclusion of the presence construct in the formation of organizational research hypotheses. Thus, we now present suggestions for the development of a sound psychometric approach to measuring this variable, making use of the available theoretical work on social presence as a foundation.

Despite the empirical appeal of using objective physiological measurements similar to Meehan et al. (2001), it should again be stressed that presence is defined as a psychological phenomenon. As noted by Heeter (1992), the intention of measuring presence is to shed light on how a virtual environment convinces users that they are present in the virtual environment, and not merely to assess how well a virtual environment imitates the real world. Thus, physiological response is not a necessary condition for the subjective experience of presence, particularly as it may apply to the domain of organizational behavior. In some scenarios, such as a crisis training that is conducted via a MUVE, the training goal may be for individuals in the virtual environment not to respond biologically, particularly if the training scenario requires significant cognitive effort that may be disrupted by high levels of physiological arousal. In this example, desensitizing an individual to sensory inputs may be the outcome intended to be transferred to the real, physical world. In short, while potentially relevant for some training applications, physiological indicators of social presence are not immediately applicable to research concerning the ways in which a modern worker interacting in a virtual office may experience social presence.

Behavioral measures of social presence may be gathered with relative ease in Second Life research, since this environment facilitates the collection of a wide range of behavioral data at both individual and group levels (Yee & Bailenson, in press). For instance, the activity of avatars can be monitored to gather data about behaviors known to be related to immersion, such as lip animation (Verwey & Blake, 2005), group size (Eng, Mintz, & Verschure, 2005; Lowry, Roberts, Romano, Cheney, & Hightower, 2006), and the duration/direction of gazes between avatars (Bente, Eschenburg & Aelker, 2007; Bente et al., 2008). Further, if conversations between avatars can be recorded, the verbal exchanges between individuals can be analyzed
for affective content (Batliner, Steidl, Hacker, & Nöth, 2008; D’Mello, Craig, Witherspoon, McDaniel, & Graesser, 2008), or the use of figurative language (Delfino & Manca, 2007). Another notable advantage of behavioral data is that it circumvents the problems commonly associated with self-report measures, such as social desirability bias, by providing relatively objective data concerning avatar and, by extension, human behavior.

However, self-report measures of social presence can still prove useful as they ostensibly reflect the subjective psychological experience of presence, such that it would be difficult to make the case that behavioral indicators of social presence are more conceptually valid than a user’s self-reports, especially when a subjective measure suggests the individual did not feel immersed in the virtual environment. As stated by Sheridan (1992), “subjective report is the essential basic measurement” of presence (p. 121). Presence can depend on the ability of an individual to focus their attention on the set of sensory stimuli enabled by a virtual environment (Witmer & Singer, 1998). Thus, assessing presence surely involves asking users to reflect on their cognitive experience of a virtual environment. Schubert, Friedmann, and Regenbrecht (2001) developed a measure of presence designed to encompass such cognitive characteristics. Their scale was developed to assess three facets of presence: (a) the ability to move realistically in a virtual environment, (b) the congruence of sensory input in a virtual environment, and (c) subjective perceptions of realism. However, the items were validated in German translations, and no corresponding validation work has been done for the English-language versions of the items (see http://www.igroup.org/pq/ipq/). In addition, several of the items in the measure represent the construct of presence as a dependent variable better suited to research questions in cognitive or human factors psychology that deal with more molecular sensory concerns. The pre-established measure that appears to have the most promise for application in organizational research is Witmer, Jerome, and Singer’s (2005) 29- and 19-item versions of the Presence Questionnaire (PQ). (The 29-item PQ is presented in Appendix A.) This measure is consistent with the definition of presence by Witmer and Singer (1998) described previously. As such, Witmer et al.’s conceptualization of presence and complementary scale development provides a theory-based measure that can be used in MUVE research to quantify aspects of social presence that represent users’ subjective experience of immersion. However,
it should be noted that Witmer et al. (2005) did not provide complete validity evidence for the PQ consistent with the psychometric standards of organizational behavior research (Hinkin, 1998); for instance, only principal components analysis was used to determine the factor structure of the items. Moreover, Witmer et al. reported an alpha coefficient of .91, which in the absence of more comprehensive factor analytic evidence does not provide any information as to the dimensionality of the measure (Schmitt, 1996), and could be adversely influenced by the total number of items in the scale (Cortina, 1993). While this scale provides a conceptually useful measure of presence, future scale validation work is still needed to demonstrate the construct validity and psychometric rigor of Witmer et al.’s four-factor measure before it can be confidently employed in research settings typical of industrial and organizational psychology.

In sum, neither the behavioral nor self-report approaches to measuring presence are without interpretive obstacles, though each method has its own distinct advantages as noted. In a comparison of these two approaches, Bailenson, Aharoni, Beall, Guadagno, Dimov, and Blascovich (2004) assessed presence using both behavioral and subjective measures. They sought to explicitly compare self-reports of presence with behavioral responses to other embodied avatars, and their findings showed that differences in nonverbal behavior in a virtual environment, measured as interpersonal distance, did not correspond with subjective appraisals of presence. However, as social presence is not posited to be a unidimensional construct, the lack of convergence between behavioral and self-report measures of presence could be thought to reflect different aspects of the construct domain. Until better construct validity evidence for measuring presence is available, both approaches should be utilized in tandem to explore the role of social presence in the nomological network of virtual behavior.

In conclusion, the suggested approach to measuring presence for purposes of organizational research is the use of both behavioral and self-report measures of presence in studies with sample sizes large enough to permit factor analysis and hypothesis tests to be conducted. The measure of presence developed by Witmer et al. (2005) as described above could be administered to employees who use MUVEs and compared with behavioral data recorded by the computer software hosting the virtual platform. As noted by Yee and Bailenson (in press) and Williams et al. (2008), MUVEs can provide the unique opportunity to collect
detailed data on the behaviors of avatars—to ignore this rich source of data in favor of self-report measures may lead to misguided conclusions about how individuals use MUVEs.

Conversely, utilizing only behavioral measures at the expense of self-report questionnaires might fail to capture all aspects of social presence, such as assessments of psychological fidelity (or “realism”) and perceived control over actions in the virtual environment.

Suggestions for Future Research on Emerging Technologies

Though this paper cited several examples of research relevant to MUVEs, the comparative amount of research on this medium across disciplines remains limited, in spite of the millions of individuals who currently use MUVEs (Berente et al., 2008; Williams et al., 2008). In addition, despite the generally optimistic outlook in emerging research on the business opportunities that MUVEs can offer (e.g., Li et al., 2008), there remains some skepticism on the part of organizational leaders (Berente et al., 2008). However, it should be noted that the same sample of executives surveyed by Berente et al. assumed that the users of Second Life are young and technology-savvy—Williams et al. demonstrated that this is a faulty assumption, and the demographic characteristics of the average MUVE user in Williams et al.’s sample did not conform to other expectations as well (for example: older female players spent the most time in MUVEs on average compared to other gender/age categorical distinctions). So, the skepticism noted above may be partially misguided. More research is needed on MUVEs to elucidate how people are adapting virtual environments to support their work tasks, as well as to provide more accurate data regarding the characteristics of the population of MUVE users.

For practitioners in industrial and organizational psychology, MUVEs may offer a potential solution to many of the problems frequently associated with geographically-distributed virtual teams, such as higher levels of affective conflict compared to face-to-face teams (Hinds & Bailey, 2003). If MUVEs provide a means through which team members can have richer interactions in terms of the available sensory and social information, thereby providing conditions in which social presence should be experienced, organizations may be able to reap the benefits of virtual teams, such as the ability to bring experts together (e.g., Kirkman, Rosen, Gibson, Tesluk, & McPherson, 2002), while mitigating the negative consequences of virtual teamwork. In short, the social presence afforded by a MUVE may allow geographically-
distributed teams to compensate for the paucity of nonverbal cues in text-based or voice communication by using avatars to interact in a virtual space.

Obviously, the study of presence in organizations can be extended beyond MUVEs such as Second Life to include other technologies intended to support computer-mediated cooperative work. A recent article in the *New York Times* about Internet phenomena such as Twitter (Thompson, 2008, September 5), which allows individuals to “micro-blog” to one another in a manner similar to an online news ticker, hints at the possible changes occurring in computer-mediated communication that could impact the experience most people have of presence in socially-oriented computer-based environments. By permitting heightened social awareness of other peoples’ activities, an online social networking application such as Twitter can help coordinate organizational efforts. For instance, NASA used Twitter to disseminate information about the Mars Phoenix lander (Chang, 2008, May 31), and the Los Angeles Fire Department sends updates to ‘subscribers’ to the micro-blog feed about its activities (see [http://twitter.com/LAFD](http://twitter.com/LAFD)). As the technical limitations of MUVEs become increasingly relaxed with time, it is foreseeable that such social awareness features will be incorporated into 3D virtual offices in the near future. Bødker and Christiansen (2006) discussed several benefits of social awareness technology, and suggested that the type of information provided by social awareness software applications may be a reasonable substitute for the ability to passively observe another person’s behavior simply by being in their proximity. As computer-mediated communication continues to evolve, and online interactions between individuals become more immersive, social presence will no doubt be a recurrent topic of research as organizations move into the virtual age.
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Appendix A

Witmer, Jerome, & Singer’s (2005) 29-item Presence Questionnaire (PQ Version 3)

Version 3 of the PQ uses a seven-point Likert-type scale, although response choices differ slightly for each item stem (e.g., for item 2, 1 = “not responsive,” 7 = “very responsive;” for item 7, 1 = “not compelling,” 7 = “very compelling”). The 29 items are divided into four components as follows:

**Involvement**

1. How much were you 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 much did the visual aspects of the environment involve you?
5. How natural was the mechanism which controlled movement through the environment?
6. How compelling was your sense of objects moving through space?
7. How much did your experiences in the virtual environment seem consistent with your real world experiences?
8. How completely were you able to actively survey or search the environment using vision?
9. How compelling was your sense of moving around inside the virtual environment?
10. How well could you move or manipulate objects in the virtual environment?
11. How involved were you in the virtual environment experience?
12. How easy was it to identify objects through physical interaction, like touching an object, walking over a surface, or bumping into a wall or object?

**Sensory Fidelity**

13. How much did the auditory aspects of the environment involve you?
14. How well could you identify sounds?
15. How well could you localize sounds?
16. How well could you actively survey or search the virtual environment using touch?
17. How closely were you able to examine objects?
18. How well could you examine objects from multiple viewpoints?
Adaptation/Immersion

19. Were you able to anticipate what would happen next in response to the actions that you performed?
20. How quickly did you adjust to the virtual environment experience?
21. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?
22. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?
23. How completely were your senses engaged in this experience?
24. Were there moments during the virtual environment experience when you felt completely focused on the task or environment?
25. How easily did you adjust to the control devices used to interact with the virtual environment?
26. Was the information provided through different senses in the virtual environment (e.g., vision, hearing, touch) consistent?

Interface Quality

27. How much delay did you experience between your actions and expected outcomes?
28. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?
29. How much did the control devices interfere with the performance of assigned tasks or with other activities?