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Measuring Presence: A Guide to Current Measurement Approaches

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Abstract: This compendium constitutes a comprehensive overview of presence measures described in the literature so far. It contains both subjective and objective approaches to presence measurement. The theoretical basis of measures is described, along with research in which they have been applied, and other relevant literature.

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1. Introduction

Systematic research into the causes and effects of presence began in the early 1990s, and is currently picking up speed. However, a commonly accepted paradigm for its assessment has yet to emerge. One of the problems hindering the operationalisation of presence is a lack of consensus about its conceptualisation. Various definitions of presence have been introduced by scholars from diverse backgrounds. Similarly, there are different approaches to its measurement. In this regard, presence research is not an exception in the field of psychological inquiry. No single approach to the measurement of *any* psychological construct is universally accepted. Although standardised measures may come into existence, it remains likely that theorists studying the same construct may still select different types of behaviour to define that construct operationally. This is not necessarily a bad thing – the use of a variety of different measures can provide valuable complementary perspectives and converging evidence, thus collectively overcoming weaknesses that any single measure will invariably have.
This compendium aims to give an overview of current presence measures, which have been used or proposed to date. We will also try to give some preliminary indication of their relevance and value for presence research.

1.1 Structure of the Compendium

Lombard and Ditton (1997) identified six conceptualisations of presence: social richness, realism, transportation, immersion, social actor within medium, and medium within social actor. These conceptualisations can be grouped into two broad categories: physical and social. Physical presence refers to the sense of being physically located somewhere, whereas social presence refers to the feeling of being together (and communicating) with someone (IJsselsteijn, De Ridder, Freeman, and Avons, 2000). Most measures address either physical or social presence, although there are also several measures that try to address both. In the compendium we make a distinction between physical and social presence. The measured concept will be mentioned in the "description" part of each measure.
Two main approaches can be distinguished in presence research, resulting in two general categories of measures: subjective measures and objective corroborative measures. When using subjective measures, a participant is asked for a conscious judgement of his/her psychological state/response in relation to the mediated environment. The objective approach to presence measurement attempts to measure user responses that are produced automatically and without conscious deliberation, but are still sensibly correlated with measurable properties of the medium and/or the content (IJsselsteijn, 2004).
Subjective and objective measures will be discussed in separate sections of the compendium. Subjective measures include presence questionnaires, continuous measurement, qualitative measures, psychophysical measures, and subjective corroborative measures (e.g. subjective assessments of memory, attention, etc.). Objective corroborative measures include physiological measures, neural correlates, behavioural measures, and task performance measures.
Although the separate sections may suggest a clear distinction between subjective and objective measures, this is not the case. A continuum of presence measures going from objective to subjective would be a better approximation of the truth; however for the sake of structure we have tried to divide the measures into separate categories and subcategories. In some cases it was very difficult to draw the line. For example, measures such as the gravity-referenced eye level (GREL), described in the subjective corroborative measures section, may seem quite objective. The same goes for several memory- and attention-related measures discussed in the subjective corroborative section; they could be regarded as performance measures that should be listed in the objective measures section. Our main criterion for calling these measures subjective is that even though the participant is not asked for a judgment, s/he can consciously influence the measurement, whereas this is not possible in objective measures.
Each measure is described in three subsections: description, research, and sources. The description part discusses the theoretical basis of the measure, if such a basis is reported in the

literature. It also describes the measure itself and how it should be applied. In the research part, the most relevant studies in which the measure was used are discussed, along with their results. If possible, the research is used to draw preliminary conclusions about sensitivity, reliability, and validity. Finally, the primary source papers are listed, along with other literature which is relevant to the measure. If the measure is related to other measures discussed in the compendium, this is indicated under the heading "See also".
Appendix A contains the individual items of the various presence questionnaires that are publicly available – either through publications in journals or proceedings, or through the Internet. Appendix B is a list of measurement tools (e.g. psychophysiological tools, video observation tools, postural trackers, etc.) that have been (or could be) used to measure various human responses as indicators of presence.
Although we aim to be comprehensive, it is possible that we have missed existing presence measures. Additionally, several well-established presence measures (e.g. Witmer and Singer's Presence Questionnaire, Slater-Usoh-Steed Questionnaire, ITC-Sense of Presence Inventory) have been used in a large number of studies, the reporting of which is beyond the scope of the current document. Moreover, presence research is an advancing field which will undoubtedly develop additional measurement tools in the future. In order to accommodate for such changes and additions, we have provided a more flexible online version of this compendium at www.presence-research.org. Suggestions to improve or complete this version are most welcome, and can be emailed to w.a.ijsselsteijn@tue.nl.

1.2 Criteria for Presence Measures

Several criteria to which a good measure of presence should adhere have been identified in literature (IJsselsteijn, 2004; Hendrix and Barfield, 1996). These are reliability, validity, sensitivity, robustness, non-intrusiveness, and convenience. More information on the basic psychometrical properties of tests can be found in Cronbach (1990).

Reliability: the measure should be consistent and stable over time, meaning that it should give comparable results if administered under comparable conditions. There are several ways to estimate reliability:

- Inter-rater reliability: the degree to which different observers agree in their assessment. Inter-rater reliability can be calculated as the percentage of cases in which the observers give the same rating (for nominal measurement) or the correlation between ratings (for ordinal, interval, or ratio measurement)
- Test-retest reliability: the stability of a measure over time. Test-retest reliability can be calculated as the correlation between scores gathered at different occasions. Researchers should make sure that it can be reasonably assumed that the measured construct itself has not changed between these occasions.
- Parallel-forms: the consistency of similar measures. Parallel forms can be created by generating a large set of items addressing the same concept and randomly dividing them into two sets, administering them, and calculating the correlation. A related approach is to divide an existing measurement tool into two halves randomly, and calculate the correlation between the two scores. This is called split-half reliability.
- Internal consistency reliability: the extent to which the items of a measure address the same underlying trait or characteristic. There are different ways of estimating internal consistency: Cronbach's alpha, (average) inter-item correlation, (average) item-total correlation, and split-half reliability.

Ideally, reliability should be assessed in several ways in order to draw firm conclusions about a measurement instrument. In reality, however, this is often not possible. Internal consistency is the most widely used form of reliability, because it can be assessed using only one measurement instrument, on one occasion, in one population.

Validity: the measure should address the intended construct. There are many different approaches to validity, the most important of which are discussed here.

- Face validity: the extent to which a measure appears to address the intended construct. This approach is based on subjective judgment, preferably of several experts.
- Content validity: the instrument is checked against the relevant content domain for the construct, to see whether the instrument is compatible with theories and addressess all relevant dimensions of the construct. For this approach, it is necessary that theories about and clear definitions of the construct and its dimensions exist.
- Criterion-related and construct validity: comparing the measure to some other measure or criterion. Different forms of criterion-related validity are predictive validity (the extent to which a theoretically relevant criterion can be predicted), concurrent validity (the extent to which the measure discriminates between groups who differ on a theoretically relevant aspect), convergent validity (the degree to which the measure correlates with measures of theoretically related constructs), and discriminant validity (the degree to which a measure is different from measures of constructs to which it is not theoretically similar).

Face validity and content validity are typically established in the construction phase of a measurement instrument. Criterion-related validity can only be established through research. It is a more objective and therefore more convincing indication of validity.

Sensitivity: the measure should be able to distinguish between different levels of presence with a reasonable level of detail. If different levels of presence are expected based on different media, different content or different individual characteristics, the measure should reflect this difference.

Robustness: the measure should be applicable across a variety of different media platforms, varying in form, content, and context-of-use.

Non-intrusiveness: the measure should not interfere with the construct that is being measured.

Convenience: the measure should preferably be easy to learn, easy to administer, low-cost, and portable.

The three most important criteria, reliability, validity, and sensitivity, will be discussed for each measure described in the compendium.

2. Subjective Measures

Sheridan (1992) has argued that presence is a subjective sensation or mental manifestation, which should primarily be assessed using subjective methods. Subjective measures can be grouped into four sub-categories: presence questionnaires (which is by far the largest category), continuous assessment, qualitative methods, psychophysical measures, and subjective corroborative measures.

2.1 Presence Questionnaires

Post-test questionnaires are the most frequently used measure of presence. Many different questionnaires have been developed. These vary widely in scope and appearance, depending on the author's conceptualisation of presence and their context of application. Some studies have used only one general item addressing presence, while others have tried to develop questionnaires reflecting the multidimensional structure of presence presumed by the authors. Lessiter, Freeman, Keogh, and Davidoff (2001) have identified several criteria for presence questionnaires:

- Understanding of presence should not be assumed by directly asking respondents how present they feel.
- Questions should avoid addressing two issues in one question
- Response options should ideally be consistent across items
- Presence is likely to be a multidimensional construct; questionnaires should reflect this and tap a range of characteristics.
- Questions should not make reference to specific media system and content properties.
- A general presence measure should be piloted on participants of a range of media systems/contents.
- Questionnaires should be piloted with a sufficient number of subjects.

There are several advantages of questionnaires. They usually have high face validity, meaning that they appear to measure the intended concept. They are relatively cheap, and easy to administer, analyse and interpret. Because they are administered afterwards, they do not interrupt the experience. Several questionnaires have been shown in studies to be sensitive to different levels of presence. The design and experimental usage of questionnaires has often gone hand in hand with theoretical development. By performing factor or cluster analysis, it is possible to identify underlying dimensions of the measured construct.

A main disadvantage of questionnaires is that they are retrospective and therefore rely on participants' memories, which are an incomplete reflection of the experience, and prone to several biases. For example, it seems likely that user's judgments will be more influenced by events near the end of the experience (recency effect). Questionnaires are also sensitive to demand characteristics, i.e. the hints and cues in a research situation that may bias the participants' responses. For instance, Freeman, Avons, Pearson and IJsselsteijn (1999) have shown that simple post-test presence ratings are sensitive to the effect of unrelated prior training sessions.

This part of the compendium is divided into three subsections. We will start with questionnaires addressing physical presence, continue with questionnaires measuring both physical and social presence, and finally describe social presence questionnaires. Within these subsections, questionnaires are ordered alphabetically. If available, the questionnaire items are listed in Appendix A.

BARFIELD ET AL. QUESTIONNAIRE

Description

Concept: Physical presence.
Virtual presence and telepresence were termed by the authors as “ego-presence”: the sense of feeling present in a virtual or remote environment. The development of questions was guided by criteria for mental workload measures defined by Jex (1988).
The questionnaire contains a subscale measuring virtual presence consisting of two or three items accompanied by a ten point rating scale. Items address “the sense of being there”, “the sense of inclusion in the virtual world”, and “sense of presence in the virtual world”. Depending on the study and experimental conditions, items on interactivity and realism are included in the questionnaire. Two of the presence items are listed in Hendrix & Barfield (1996), and can be found in Appendix A.

Research

The three item version of the questionnaire was used in an experiment by Barfield & Weghorst (1993). Participants (n=86, between-subjects design) experienced one of three VEs differing in spatial landmarks and abstractness. Correlations of the individual presence items with other questionnaire items, such as display comfort, comfort with computers, being lost, and overall enjoyment, were reported. The three presence items were found to be highly intercorrelated. All three items were found to significantly predict overall enjoyment.
The two item version of the questionnaire was used in an experiment (n=12, within-subjects design) by Hendrix & Barfield (1996), comprising three sub-studies investigating the effects of monoscopic versus stereoscopic displays, head tracking (present/absent), and geometric field of view (10/50/90º). In each sub-study, subjects were asked to explore two or three VEs and consequently fill out the questionnaire about each VE. The results showed significant positive effects of all manipulated variables. A significant positive correlation was found between presence and realism. The two presence items produced consistent results. Subjects were also consistent when answering the same question across different studies using similar VEs.

Sensitivity: The questionnaire discriminated between different conditions.
Reliability: An intercorrelation was found between the three items, and there was consistency across items and studies.
Validity: There was a correlation with realism and other related constructs, and the effects of the manipulation of variables (stereoscopy, head tracking, field of view) on the scores are as predicted by theory and previous findings in presence research.

Primary Sources

Barfield, W., & Weghorst, S. (1993). The sense of presence within virtual environments: A conceptual framework. In G. Salvendy & M. Smith (Eds), *Human-computer interaction: Applications and case studies* (pp.699-704). Amsterdam: Elsevier.

Hendrix, C., & Barfield, W. (1996). Presence within virtual environments as a function of visual display parameters. *Presence: Teleoperators and Virtual Environments, 5,* 274 - 289.

CHO ET AL. QUESTIONNAIRE

Description

Concept: Physical presence.
The questionnaire consists of 4 items relating to the:

1. Visual realism of objects
2. Ability to perceive locations of oneself and other objects
3. Visual realism of the overall environment
4. Feeling of being in the environment

The exact wording of items is not reported in the paper. Items are rated on a 0-100 scale.

Research
The questionnaire was used in a study investigating how three "where" variables (stereoscopy, user motion and object motion) and three "what" variables (object self motion, geometry, and texture) contribute to overall presence. The authors hypothesized that the "where" cues would contribute more to presence than the "what" cues. An undersea VE was created, in which each variable could be manipulated on two levels (high vs. low). Subjects (n= 32?(not clearly reported), within-subjects design) looked at 32 versions of this VE, 90 seconds for each version, in random order, and completed the presence questionnaire for each version. The results (ANOVA and Regression Analysis) showed that both "what" and "where" variables influenced perceived realism and presence, and there were also significant interactions.

Sensitivity: Not reported.
Reliability: Not reported.
Validity: The experimental results obtained with the questionnaire supported the authors' theory of presence.

Primary Source
Cho, D., Park, J., Kim, G., Hong, S., Han, S., & Lee, S. (2003). Dichotomy of presence elements: The where and what. *Proceedings of the IEEE Virtual Reality 2003*, 273-274.

DINH ET AL. QUESTIONNAIRE

Description
Concept: Physical presence.
The questionnaire consists of 14 items: one overall presence rating (0-100 scale) and 13 shorter items (scale is not reported) which were adapted from two existing presence questionnaires (Hendrix and Barfield,1996; Fontaine, 1992). The items are listed in Appendix A.

Research
In a study (n=322, between-subjects design with 18 participants per condition), the level of visual detail, olfactory stimulation, ambient auditory stimulation (high or low) and tactile stimulation (absent or present) were varied in a VE depicting an office. Dependent variables were presence, recall of spatial layout and recall of object location. Both the overall presence rating and the 13 items showed significant effects of auditory and tactile cues, a non-significant trend of olfactory cues and no effect of visual cues.

Sensitivity: The questionnaire discriminated between different conditions.
Reliability: Not reported.
Validity: Out of four factors which were hypothesized to be presence-enhancing, two significantly increased and one marginally increased the questionnaire scores.

Primary Source
Dinh, H. Q., Walker, N., Song, C., Kobayashi, A., & Hodges L.F. (1999). Evaluating the importance of multi-sensory input on memory and the sense of presence in virtual environments. *Proceedings of the IEEE Virtual Reality 1999*, 222-228.

GERHARD ET AL. QUESTIONNAIRE

Description
Concept: Physical presence.
This questionnaire was based on the work of Witmer and Singer (1998), who identified involvement and immersion as necessary conditions for experiencing presence in a VE. Gerhard, Moore, and Hobbs (2001) extended these with two measures to cover issues in multi-user VEs: awareness and communication.

The questionnaire contains 19 items on a seven point rating scale measuring immersion, communication, involvement, awareness, nature of the environment itself, and user interface. It also contains open questions to reveal attitudes, beliefs and experiences. The items are listed in Appendix A.

Research
The questionnaire was used in a study investigating the influence of the appearance of avatars on presence. Subjects (n=27, between-subjects design) performed a collaborative judgment task. Avatars were basic shapes, animated cartoon-style or animated humanoid. The results showed that animated cartoon-style and humanoid avatars gave rise to higher levels of presence than basic shape avatars. This was supported by user comments elicited by the open questions.

Sensitivity: The questionnaire scores discriminated between different conditions.
Reliability: Not reported.
Validity: Convergence between presence scores and qualitative data (user comments).

Primary Source
Gerhard, M., Moore, D., & Hobbs, D. (2001). Continuous presence in collaborative virtual environments: Towards the evaluation of a hybrid avatar-agent model for user representation. In A. de Antonio, R. Aylett, & D. Ballin (Eds.): *Proceedings of the International Conference on Intelligent Virtual Agents,* pp. 137-153, Madrid, Spain.

Other Literature
Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and Virtual Environments, 7,* 225-240.

IGROUP PRESENCE QUESTIONNAIRE (IPQ)

Description
Concept: Physical presence.
Schubert, Friedmann, & Regenbrecht (2000) have argued that presence develops from the construction of a spatial-functional mental model of the VE. Two cognitive processes contribute to this model: construction, or the representation of bodily actions as possible actions in the VE, and suppression of incompatible sensory input. It is hypothesized that the conscious sense of presence reflects these two components as spatial presence and involvement.
To construct the first version of the IPQ, 75 items from previously published questionnaires (including Witmer & Singer, Hendrix, Slater-Usoh-Steed), items from the authors' own past research and newly designed items were combined into one questionnaire. The final version of the IPQ consists of 14 items rated on a five point rating scale. The items are reported in Appendix A. Items and accompanying scale anchors can be downloaded at http://www.igroup.org/pq/ipq/.

Research
In a first study (n=246, between-subjects design), participants of all forms of VEs (users of VR or CAVE-like systems, desktop VR, players of 3D games and text-based VEs) were asked to complete the initial, 75-item version of the questionnaire, which was posted on the Internet. The participants were instructed to remember one of the last times they used a VE and to answer all the items with reference to that single episode only. Other participants completed the questionnaire after experiencing a VE by means of a HMD in a laboratory. Exploratory factor analysis revealed eight factors, three of which were identified as Presence Factors, These three factord were:

1. Spatial presence: the sense of being there in the VE
2. Involvement: attention to the real and the virtual environment
3. Realness: reality judgment of the VE

The other five factors were identified as Immersion and Interaction Factors.

In a second study (n=296) aiming to replicate the first, only items relating to Presence and Interaction factors were used. A factor structure was found which was quite similar to the one found in the first study. Confirmatory factor analysis was used for the item selection, resulting in five items in the Spatial Presence scale, four items in the Involvement scale, three items in the Realness scale, and one general item. Internal consistency over these items was α=.87

Sensitivity: Not reported.
Reliability: Internal consistency, α=.87
Validity: Data gathered with the questionnaire yielded a similar factor structure as was found in other studies.

Primary Source

Schubert, T., Friedmann, F., & Regenbrecht, H. (2001). The experience of presence: Factor analytic insights. *Presence: Teleoperators and Virtual Environments, 10,* 266-281.

ITC-SENSE OF PRESENCE INVENTORY (ITC-SOPI)

Description

Concept: Physical presence.
The development of the ITC-SOPI was guided by criteria for presence questionnaires identified by the authors:

- Understanding of presence should not be assumed by directly asking respondents how present they feel.
- Questions should avoid addressing 2 issues in 1 question
- Response options should ideally be consistent across items
- Presence is likely to be a multidimensional construct; questionnaires should reflect this and tap a range of characteristics.
- Questions should not make reference to specific media system and content properties.
- A general presence measure should be piloted on participants of a range of media systems/contents.
- Questionnaires should be piloted with a sufficient number of subjects.

Initially, 63 items were generated for content areas based on literature: sense of space, involvement, attention, distraction, control and manipulation (autonomy), realness, naturalness, perception of time, awareness of behavioural responses, sense of social interaction (parasocial and copresence), personal relevance, arousal, and negative effects.
The revised version of the ITC-SOPI contains 44 items: Sense of Physical Space (19 items), Engagement (13 items), Ecological Validity (five items), Negative Effects (six items). The items are not listed in the paper.

Research

The initial version of the ITC-SOPI was administered to participants (n=604, between-subjects design) following a mediated experience using either IMAX 3D, IMAX 2D, cinema, video shorts, GCSU, or a PC game.
Four factors were identified using Principal Axis Factoring: Sense of physical space, Engagement, Ecological validity, and Negative effects. Eight questions failed to load on any factor and were removed from the revised version. Eleven items were removed because they were inconsistent or reduced alpha. The revised ITC-SOPI had very good alpha values on all four factors (ranging between.76 and .94). All factors showed sensitivity to media form. Also, correlations between factors were computed. The first three scales all intercorrelated significantly. Negative Effects only correlated with Sense of Physical Space.

Sensitivity: Questionnaire scores discriminated between different conditions (media).
Reliability: Alpha values range between .76 and .94. Significant correlations were found between three of the four scales.
Validity: Content validity was pursued in the construction phase. Differences in questionnaire scores were found between different media.

Primary Source

Lessiter, J., Freeman, J., Keogh, E., Davidoff, J. (2001). A cross-media presence questionnaire: The ITC-Sense of Presence Inventory. *Presence: Teleoperators & Virtual Environments, 10*, 282-298.

KIM & BIOCCA QUESTIONNAIRE

Description

Concept: Physical presence.

Kim and Biocca (1997) compared telepresence to "being transported": a media user is phenomenally transferred to a mediated environment, resulting from low accessibility to the unmediated information and high accessibility to the mediated information. It is hypothesized that the sensation of presence is unstable; from moment to moment the user may feel present in the physical, virtual, or imaginary environment.

The questionnaire was based on Barfield and Weghorst, and Slater, Usoh and Steed. It contains eight items rated on a Likert scale. The items can be found in Appendix A.

Research

The questionnaire was developed in the context of a study (n=96, between-subjects design) investigating the effects of telepresence in a television viewing situation on memory and persuasion. Unmediated visual stimuli (active or suppressed) and viewing angle (low, medium, or high) were manipulated.

Exploratory factor analyses revealed that the eight items could be grouped into two factors, which were labelled "departure" and "arrival". The manipulation of unmediated visual stimuli and viewing angle did not have an effect on either departure or arrival.

Sensitivity: Not reported.

Reliability: Not reported.

Validity: Manipulations that were hypothesized to influence presence did not have an effect on the questionnaire scores.

Primary Source

Kim, T., & Biocca, F. (1997). Telepresence via television: Two dimensions of telepresence may have different connections to memory and persuasion. *Journal of Computer-Mediated Communication, 3* (2).

See also

Barfield et al. Questionnaire

Slater-Usoh-Steed Questionnaire (SUS)

KRAUSS ET AL. QUESTIONNAIRE

Description

Concept: Physical presence.

Krauss and his colleagues (1997) described presence as a multidimensional construct. In order to reflect this multidimensionality, items taken from various sources were combined into one questionnaire. Fourty-two items measuring presence were taken from existing questionnaires (PQ, IPQ, Kim & Biocca Questionnaire) or the authors' own work. The items are not listed in the paper.

Research

A study was performed in order to evaluate the questionnaire. Participants (n=165) completed the questionnaire online. They were asked to remember a typical 3D gaming session. Of the 55 items that were initially generated, 13 were removed because of low item-total correlations. Afterwards,

reliability of the scale was α=.85. Principal components analysis revealed three factors, which were labelled Spatial presence, Quality of the interface, and Emotional involvement.

Sensitivity: Not reported.
Reliability: Internal consistency α=.85.
Validity: Not reported.

Primary Source

Krauss, M., Scheuchenpflug, R., Piechulla, W., & Zimmer, A. (2001). Measurement of presence in virtual environments. In A. Zimmer, K. Lange, K.-H. Bäuml, R. Loose, R. Scheuchenpflug, O. Tucha, H. Schnell & R. Findl (Eds), *Experimentelle Psychologie.* Lengerich: Pabst Science Publishers.

See also

Presence Questionnaire (PQ)
Igroup Presence Questionnaire (IPQ)
Kim & Biocca Questionnaire

MURRAY ET AL. QUESTIONNAIRE

Description

Concept: Physical presence.
The approach to presence measurement taken by Murray, Arnold, & Thornton (2000) was based on Gilkey and Weisenberger's (1995) argument for the importance of sound for the sense of presence.
The questionnaire contains five items related to presence. The items focus on the influence of hearing loss on the sense of presence. Presence items were based on existing questionnaires such as the SUS, and on written accounts of participants of an earlier study. Other items in the questionnaire address the ability to hear others, balance, alertness, awareness, touch, movement, disorientation, conspicuousness, use of peripheral vision, unconnectedness, use of hand gestures, isolation, vision, hearing blood flowing, self-consciousness, and hearing breathing. Only the presence items are reported in the paper. These are listed in Appendix A.

Research

The questionnaire was used in a pilot study (n=10) in which participants wore earplugs while performing daily activities. The authors reported that participants had difficulties understanding what some of the items meant. The questionnaire results are not discussed in the paper.

Sensitivity: Not reported.
Reliability: Not reported.
Validity: Not reported.

Primary Source

Murray, C., Arnold, P., & Thornton, B. (2000). Presence accompanying induced hearing loss: Implications for immersive virtual environments. *Presence: Teleoperators and Virtual Environments, 9,* 137-148.

Other Literature

Gilkey, R. H., & Weisenberger, J. M. (1995). The sense of presence for the suddenly deafened adult. *Presence: Teleoperators and Virtual Environments,* 4, 357-363.

NICHOLS ET AL. QUESTIONNAIRE

Description

Concept: Physical presence.
The questionnaire contains nine items, accompanied by seven point rating scales. The questionnaire contains three items taken from Slater et al. (1994), five items that are also related to other aspects of the virtual experience, and one item addressing exhilaration. The items are reported in Appendix A.

Research

An experiment (n=24, mixed design) was conducted using this questionnaire to compare alternative performance measures and investigate the influence of a headset and auditory simuli. Independent variables were display medium (headset vs. desktop, within subjects) and sensory information (visual vs. audio + visual, between subjects). Three presence measures were used: reflex response (to a "startle event"), background awareness (recall of background music) and the questionnaire. The VE used was an adaptation of a duck shoot fairground stall.
The results show that the three SUS items intercorrelated significantly. Two SUS items correlated with reflex response, and one correlated with background awareness. Of the other items, only one (about flatness of VE) correlated (negatively) with all three SUS items and with reflex response. Two SUS items were higher in the headset condition.

Sensitivity: Two of the SUS items distinguished between different conditions, not reported for other items.
Reliability: Intercorrelation between SUS items.
Validity: Correlation with reflex responses.

Primary Source

Nichols, S., Haldane, C., & Wilson , J. R. (2000). Measurement of presence and its consequences in virtual environments. *International Journal of Human Computer Studies, 52,* 471-491.

See also

Slater-Usoh-Steed Questionnaire (SUS)

OBJECT PRESENCE QUESTIONNAIRE (OPQ)

Description

Concept: Physical presence.
Stevens, Jerrams-Smith, Heathcote, and Callear (2002) proposed to adapt the definition of presence to be more appropriate for non-immersive displays. Object-presence was defined as "the subjective experience that a particular object exists in the user's environment, even when that object does not" (p. 82-83). They adapted the Witmer and Singer Presence Questionnaire to measure object-presence. The items are not listed in the paper.

Research

In an experiment aiming to assess the reliability and validity of this questionnaire, participants (n=16) carried out tasks with projection-augmented models, and completed the Immersive Tendencies Questionnaire (ITQ) and the Object Presence Questionnaire (OPQ).
Cronbach's alpha was calculated for the questionnaire, α=.84. Significant correlations were found between all subscales and the total score, except for the Haptic subscale. No correlation was found between the OPQ and the ITQ scores. Some significant correlations were found between OPQ and ITQ subscales, but only if the sample was split by gender.

Sensitivity: Not reported.
Reliability: Internal consistency α=.84.

Validity: OPQ total scores did not correlate with ITQ total scores.

Primary Source

Stevens, B., Jerrams-Smith, J., Heathcote, D., & Callear, D. (2002). Putting the virtual into reality: Assessing object-presence with projection-augmented models. *Presence: Teleoperators and Virtual Environments, 11,* 79-92.

See also

Presence Questionnaire (PQ)

PRESENCE QUESTIONNAIRE (PQ)

Description

Concept: Physical presence.

Witmer and Singer (1998) identified involvement and immersion as conditions for presence. They aimed to develop a measure of presence addressing factors that influence involvement and immersion. Main categories of such factors were derived from the work of Sheridan (1992) and Held & Durlach (1992):

- Control factors (degree, immediacy, anticipation, mode, and physical environment modifiability)
- Sensory factors (modality, environmental richness, multimodal presentation, consistency of multimodal information, the degree of movement perception, and active search)
- Distraction factors (isolation, selective attention, and interface awareness)
- Realism factors (scene realism, information consistent with the objective world, meaningfulness of the experience, separation, and anxiety/disorientation).

Thirty-two items were designed based on the above factors. The final version of the PQ contains 19 items, rated on a seven point rating scale with a midpoint anchor (e.g., 1= not compelling, 4 = moderately compelling, 7 = very compelling). The items can be found in Appendix A.

Research

The first version of the PQ was used in four experiments (n=152 in total). In two experiments, participants performed psychomotor tasks in a simple VE. In the other two experiments participants learned complex routes through a virtual office. Item-total correlations were calculated, most of which were significant. Internal consistency was calculated, α = .88, after reducing the number of items from 32 to 19.

Cluster analysis revealed three subscales: Involved/Control (11 items), Natural (three items), and Interface Quality (three items). PQ scores were correlated with measures for constructs associated with presence. PQ scores were found to be significantly correlated with Simulator Sickness Questionnaire scores across experiments. Significant correlations with performance of psychomotor tasks and spatial knowledge were found in some experiments, but not in others. No significant effect of natural interaction (head tracking) was found. A significant correlation was found with the Immersive Tendency Questionnaire.

Usoh, Catena, Arman, and Slater (2000) have argued that each presence questionnaire should be subject to a “reality test”: data obtained in a VE should be compared to data obtained in the real world. In such a study (n=20, between-subjects design), they tested the PQ. It did not distinguish between real and virtual experiences.

Youngblut and Perrin (2002) gave an extensive overview of research that has been conducted with the PQ. The PQ gave consistent results (in two or more studies) for the factors display field of view, head tracking, task-related experience, and gender. An experiment using the PQ and SUS questionnaire was conducted to investigate the relation between presence and task performance. Participants (n=40, between-subjects design) had to perform an aircraft maintenance procedure in a virtual world. The amount of practice was varied. An effect of practice was found only on the PQ Interface Quality subscale. The Involved/Control subscale correlated negatively with the number of errors. A significant correlation (r=.51) was found between the PQ and the SUS total scores, and also between all subscales. The authors

concluded that their data supported the argument that the PQ and the SUS measured the same construct, but there was not enough evidence to draw conclusions about their validity.

Sensitivity: The PQ discriminated between different conditions in several experiments (see Youngblut & Perrin, 2002).
Reliability: Internal consistency α=.88.
Validity: Inconclusive (see Youngblut & Perrin, 2002).

Primary Source

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and Virtual Environments, 7,* 225-240.

Other Literature

Held, R., & Durlach, N. I. (1992). Telepresence. *Presence:Teleoperators and Virtual Environments, 1,* 109-112.

Sheridan, T. (1992). Musings on telepresence and virtual presence. *Presence: Teleoperators and Virtual Environments, 1,* 120-126.

Slater, M. (1999). Measuring presence: A response to the Witmer and Singer presence questionnaire. *Presence: Teleoperators and Virtual Environments, 8,* 560-565.

Usoh, M., Catena, E., Arman, S., & Slater, M. (2000). Using presence questionnaires in reality. *Presence: Teleoperators and Virtual Environments, 9*, 497-503.

Youngblut, C., & Perrin, B. M. (2002). *Investigating the relationship between presence and performance in virtual environments.* Paper presented at IMAGE 2002 Conference, Arizona.

QUESTIONNAIRE ON PRESENCE AND REALISM

Description

Concept: Physical presence.
This questionnaire was used as part of a virtual task analysis tool for the creation and evaluation of virtual art exhibits. It contains ten items accompanied by a four point rating scale. The items were based on the work of Hendrix and Barfield (1996). The items are listed in Appendix A.

Research

Research using this questionnaire was not reported.

Primary Source

Parent, A. (1998). *A virtual environment task analysis workbook for the creation and evaluation of virtual art exhibits*. Technical Report NRC 41557 ERB-1056, National Research Council Canada.

See also

Barfield et al. Questionnaire

REALITY JUDGMENT AND PRESENCE QUESTIONNAIRE

Description

Concept: Physical presence.
The first version of this questionnaire contained 77 items based on existing work (Witmer & Singer, 1998) and literature. The following concepts were addressed:

- Reality Judgment (14 items)
- Presence (17 items)
- Emotional Involvement (14 items)
- Interaction (6 items)
- Control (4 items)
- Attention (4 items)
- Realism (7 items)
- Perceptual Congruence and Perceptual Continuity (3 items)
- Expectations (8 items)

The final version (derived from the long version containing 77 items) of the Reality Judgment and Presence Questionnaire contains 18 items in three dimensions:

1. Reality Judgment
2. Internal/External Correspondence
3. Attention/Absorption

Items are scored on a ten point rating scale. Both the 77 original items and the items retained after the factor analysis are listed in Appendix A.

Research

Participants (n=124, between-subjects design) were immersed in one of three different VEs, involving a claustrophobic scenario, a body image scenario or a spider scenario. The results of a factor analysis were used for item selection (see description). A significant correlation was found between Factor 1 and 2 (r=.33) and between Factor 1 and 3 (r=.25). Internal consistency was found to be α=.82.

Sensitivity : Not reported.
Reliability: Internal consistency α=.82.
Validity: Not reported.

Primary Source

Baños, R. M., Botella, C., Garcia-Palacios, A., Villa, H., Perpina, C., & Alcaniz, M. (2000). Presence and reality judgment in virtual environments: A unitary construct? *CyberPsychology and Behaviour, 3,* 327-335.

See also

Presence Questionnare (PQ)

SLATER-USOH-STEED QUESTIONNAIRE (SUS)

Description

Concept: Physical presence.
Slater, Usoh, and Steed (1994) proposed that both external and internal factors contribute to presence. They identified external factors based on existing research. These factors were quality and resolution of displays, consistency of environment, interactivity, realistic self-representation, and simple connection between actors and effects. Internal factors were identified based on a Neuro Linguistic Programming model. These factors were primary presentation system (visual, auditory or kinesthetic) and perceptual position (egogenic or exogenic). An empirical model was constructed that related sense of presence to these factors.
Partly based on Barfield & Weghorst, three presence indicators were identified:

1. Sense of being there
2. Extent to which the VE becomes more "real or present" than reality
3. Locality: the extent to which the VE is thought of as a place visited.

The original SUS questionnaire consisted of three items rated on a seven point rating scale. It has since been extended; the latest version contains six items. These items are listed in Appendix A. The overall score is calculated as the number of high (score six or seven) responses. This avoids the problem of averaging ordinal responses, and allows the use of logistic regression.

Research

The original, three item SUS was used in an experiment (n=24, between-subjects design) studying the influence of representation system, stacking of environments, gravity, virtual actors, and virtual cliff on presence (Slater et al, 1994). Based on a participants' responses to a questionnaire, they were scored for their visual (V), auditory (A) and kinesthetic (K), and perceptual position (P1). Participants experienced either two, four, or six different VEs. The VEs were either "stacked" requiring participants to put on a virtual HMD to get to the next environment, or not stacked meaning that participants could simply go through a door.

The results showed a positive relationship between presence (as measured by the SUS) and V and K, and a negative relationship between presence and A. Presence was positively associated with depth when the VEs were "stacked" using a virtual HMD, and negatively associated when participants went through a door. No other significant relationships were found.

The extended version of the SUS was used in two studies comparing different methods of locomotion (Slater et al., 1995; Usoh et al., 1999) (n=16, between-subjects design; n=33, between-subjects design). Real walking was compared to virtual walking-in-place and push-button-flying. Results showed that subjective presence was higher for virtual walkers than for flyers, and higher for real walkers than for virtual walkers, although this difference decreased when oculomotor discomfort was taken into account.

Usoh, Catena, Arman, and Slater (2000) have argued that each presence questionnaire should be subject to a "reality test": compare data obtained in a VE to data obtained in the real world. In such a reality test (n=20, between-subjects design), they found that only two SUS items showed significant differences.

Youngblut & Perrin (2002) extensively discussed research conducted with the SUS. The SUS-Questionnaire gave consistent results (in two or more studies) for immersive tendencies. An experiment was conducted to investigate the relationship between presence and task performance, using the PQ and SUS. Participants (n=40) performed an aircraft maintenance procedure in a virtual world, with varying amounts of practice. No effect of practice was found on SUS scores. SUS scores correlated negatively with the number of errors. A significant correlation (r=.51) was found between PQ and SUS total scores, and also between all subscales. The authors concluded that their data supported the argument that the PQ and the SUS measured the same construct, but there was not enough evidence to draw conclusions about their validity.

Sensitivity: The questionnaire distinguished between different conditions and individual differences in several experiments (see Youngblut and Perrin, 2002).
Reliability: Not reported.
Validity: Inconclusive (see Youngblut and Perrin, 2002).

Primary Sources

Slater, M., Usoh, M., & Steed, A. (1994). Depth of presence in virtual environments. *Presence: Teleoperators and Virtual Environments, 3,* 130-144.

Slater, M., Usoh, M., & Steed, A. (1995) Taking steps: The influence of a walking metaphor on presence in virtual reality. *ACM Transactions on Computer Human Interaction, 2(3),* 201-219.

Usoh, M. , Arthur, K., Whitton, M. C., Bastos, R., Steed, A., Slater, M., et al. (1999). Walking > walking-in-Place >flying in virtual environments. *Computer Graphics, Annual Conference Series: Proceedings of SIGGRAPH 1999*, 359–364.

Other Literature

Usoh, M., Catena, E., Arman, S. & Slater, M. (2000). Using presence questionnaires in reality. *Presence: Teleoperators and Virtual Environments, 9*, 497-503.

Youngblut, C., & Perrin, B. M. (2002). *Investigating the relationship between presence and performance in virtual environments.* Paper presented at the IMAGE 2002 Conference, Arizona.

SWEDISH VIEWER-USER PRESENCE QUESTIONNAIRE (SVUP)

Description

Concept: Physical presence.

The SVUP comprises 150 items covering various aspects of the VE experience. A publication about the construction of this questionnaire is in preparation.

In the studies described here, only 19 items were used, covering VE interaction, presence (four items), awareness of external factors, enjoyment, sound quality, and simulation sickness. These items are reported in Larsson, Västfjäll, and Kleiner, (2001a) and can be found in Appendix A.

Research

The SVUP was used in a study (Larsson et al., 2001a) investigating the hypothesis that actors feel more present in a VE than observers. Participants (n=32, between-subjects design) either actively performed tasks in a VE wearing a HMD, or merely observed another person performing these tasks on a projection screen. Results showed that actors reported higher degrees of presence, enjoyment and simulator sickness. Observers reported more distraction by external events.

A second paper (Larsson, Västfjäll, and Kleiner, 2001b) reported two experiments (n=40 in both cases, between-subjects design) which tested the hypotheses that 1) participants would experience more presence in a bimodal (auditory-visual) VE than in a unimodal (visual) VE, and 2) more accurate, congruent sound rendering would increase presence. The VE was a digital model of a church with singing as the audio stimulus.

The results showed that presence, enjoyment, and external awareness were rated higher in the bimodal condition than in the unimodal condition (experiment 1), and presence was rated higher in the condition with better sound rendering (experiment 2).

Sensitivity: The questionnaire distinguished between different conditions.

Reliability: Not reported.

Validity: The questionnaire results concur with the authors' theory of presence.

Primary Sources

Larsson, P., Västfjäll, D., & Kleiner, M. (2001a). The actor-observer effect in virtual reality presentations. *CyberPsychology and Behavior, 4,* 239-246.

Larsson, P., Västfjäll, D., & Kleiner, M. (2001b). *Do we really live in a silent world? The (mis)use of audio in virtual environments.* Paper presented at AVR II and CONVR 2001, Chalmers, Sweden.

LOMBARD & DITTON QUESTIONNAIRE

Description

Concept: Physical presence and Social presence.
The questionnaire was based on six dimensions of presence identified in earlier work by the same authors (Lombard & Ditton, 1997):

1. Social richness
2. Realism
3. Transportation
4. Immersion
5. Social actor within medium
6. Medium as social actor

The questionnaire addresses fiver presence dimensions (it is not clear which one was skipped) and "tendency to suspend disbelief". 103 items were drawn from existing questionnaires. The items are not listed in the paper.

Research

Participants (n=600, between-subjects design) completed the developed questionnaire in one of two conditions: high presence (high resolution, 3D, colour, multi-channel sound, etc.) and low presence (low resolution, 2D, black and white, single channel sound, etc.). At the time of this publication, the study was still in process. A preliminary factor analysis (n=307) of the high presence condition yielded seven factors: Immersion, Parasocial interaction, Parasocial relationships, Physiological responses, Social reality, Interpersonal social richness, and General social richness.

Sensitivity: Not reported.
Reliability: Not reported.
Validity: Not reported.

Primary Source

Lombard, M., Ditton, T. B., Crane, D., Davis, B., Gil-Egui, G., Horvath, K., et al. (2000). Measuring presence: A literature-based approach to the development of a standardized paper-and-pencil instrument. In W. IJsselsteijn, J. Freeman, & H. de Ridder (Eds). *Proceedings of the Third International Workshop on Presence*.

Other Literature

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication, 3*(2).

NOWAK & BIOCCA QUESTIONNAIRE

Description

Concept: Physical presence and Social presence (Co-presence).
The questionnaire contains 29 items in three scales:

1. Telepresence: five items taken from Lombard and Ditton (1999), rated on a seven point rating scale.
2. Copresence:
    a. Perceived other's copresence: 12 items rated on a five point rating scale. The items were derived from a combination of Burgoon and Hale's (1987) indicators for intimacy, involvement and immediacy.
    b. Self-reported copresence: six items rated on a five point rating scale. These are rephrased items from the perceived other's copresence scale.
3. Social Presence: six items taken from Short, Williams and Christie (1976), rated on a sliding scale.

A first version of the questionnaire contained 43 items (the item selection is not described). The 29 items of the final version are listed in Appendix A.

Research
The questionnaire was used in an experiment (n=134, between-subjects design) investigating the effects of agency and anthropomorphism. Participants engaged in a virtual meeting, and were either told they were interacting with a human (avatar condition) or a bot (agent condition). The representation of the other was highly anthropomorphic, low anthropomorphic or there was no image (control).
Internal consistency of the scales was α=.88, .90, .78, .82 respectively. No significant effects were found between agency and any presence scale. Higher levels of telepresence were reported for conditions showing an image compared to control condition; however, contrary to expectations, telepresence was higher for the low-anthropomorphic image than for the high-anthropomorphic image. Similar results were found for social presence and copresence.

Sensitivity: The questionnaire was sensitive to manipulation of anthropomorphism, though not in the expected direction.
Reliability: Internal consistency α=.88 (telepresence), α=.90 (perceived other's copresence), α=.78 (self-reported copresence), α=.82 (social presence).
Validity: Not reported.

Primary Source
Nowak, K.L., & Biocca, F. (2003). The effect of the agency and anthropomorphism on users' sense of telepresence, copresence, and social presence in virtual environments. *Presence: Teleoperators and Virtual Environments, 12*, 2-35.

Other Literature
Burgoon, J. K., & Hale, J. L. (1987). Validation and measurement of the fundamental themes of relational communication. *Communication Monographs, 54,* 19-41.

See also
Lombard & Ditton Questionnaire
Semantic Differential

SCHROEDER ET AL. QUESTIONNAIRE

Description
Concept: Physical presence and Social presence.
The questionnaire contains 11 items, addressing collaboration (three items), contribution to task (three items), presence (three items), and co-presence (two items). Items were based on earlier work by Slater et al. (2000) and Wideström et al. (2000). The items are listed in Appendix A.

Research
The questionnaire was used in a study (n=132, between-subjects design) comparing the user's experience while solving a puzzle in three different collaborative environments: IPT-to-IPT, IPT-to-desktop, or face-to-face (IPT: immersive projection technology). The results showed differences in scores for both presence and co-presence between participants using the different environments.

Sensitivity: The questionnaire discriminated between different collaborative environments.
Reliability: Not reported.
Validity: Not reported.

Primary Source

Schroeder, R., Steed, A., Axelsson, A-S., Heldal, I., Abelin, A., Wideström, et al. (2001). Collaborating in networked immersive spaces: As good as being there together? *Computer & Graphics, 25*, 781-788.

THIE & VAN WIJK QUESTIONNAIRE

Description

Concept: Physical presence and Social presence.
A Virtual Presence questionnaire was constructed from existing questionnaires. Items measuring Susceptibility for virtual presence and Virtual presence as a whole were taken from Psotka (1993), and items measuring Virtual social presence were taken from Short, Williams, and Christie (1976). The items are not listed in the paper.

Research

The questionnaire was used in an experiment (n=48, between-subjects design) testing the hypothesis that if virtual social presence cues increase, virtual presence will increase. Participants carried out a group decision task in a VE with either minimalised or maximized social presence cues. Other measures were comeback rate (participants were offered the choice of reading or re-entering the VE), task performance, and group polarization.
Results showed a significant correlation (r=.46) between social virtual presence and virtual presence. No differences in Social virtual presence or Virtual presence were found between the two conditions. The research findings of Psotka were not replicated (no significant correlation was found between virtual presence and susceptibility for virtual presence), and reliability of both Psotka's questionnaires was quite low (.67 and .45 respectively).

Sensitivity: The questionnaire scores did not discriminate between different conditions.
Reliability: Internal consistency is only reported for items taken from Psotka (α=.67 for susceptibility for virtual presence, α=.45 for virtual presence), findings from earlier work were not replicated .
Validity: Correlation between social virtual presence and virtual presence.

Primary Source

Thie, S., & Van Wijk, J., (1998). *A general theory on presence: Experimental evaluation of social virtual presence in a decision making task.* Paper presented at Presence in Shared Virtual Environments Workshop, University College London, 10 - 11 June 1998.

Other Literature

Psotka, J. M. Davison, S. & Lewis, S. A., (1993). Exploring immersion in virtual space. In R. Stuart & G. P. Panos (Eds.), Virtual Reality Systems tm, 1(2), 70-82.

Short, J., Williams, E., & Christie, B. (1976). *The social psychology of telecommunications*. London: John Wiley & Sons.

BAILENSON ET AL. QUESTIONNAIRE

Description

Concept: Social presence.
The questionnaire contains five items, accompanied by a seven point rating scale, measuring social presence. The items can be found in Appendix A.

Research

The questionnaire was used in an experiment investigating personal space. Participants (n=50, within-subjects design) were immersed in a virtual room in which a virtual male agent stood. In each trial they were asked to walk up to the agent and remember certain features and labels on the front and back of the agent's shirt. The position and orientation of participants were tracked. The photographic realism of the agent's face and the degree of mutual gaze between agent and participant were varied. After the experience was over, participants once more put on the HMD to rate the two different avatar types for social presence. A Likert-type scale (-3 to +3) was shown over the agent's head. Participants looked at the agent and the scale while the experimenter read out the questions. Internal consistency was α=.83. For women, a significant correlation was found between degree of gaze and social presence, but not for men. No effect of realism was found. The same pattern of results was found for interpersonal distance.

Sensitivity: Questionnaire scores discriminated between different conditions (degrees of gaze).
Reliability: Internal consistency α=.83.
Validity: The results obtained with the questionnaire were similar to an interpersonal distance measure. The correlation between the measures is not reported.

Primary Source

Bailenson, J.N., Blascovich, J., Beall, A.C., & Loomis, J.M. (2001). Equilibrium revisited: Mutual gaze and personal space in virtual environments. *Presence: Teleoperators and Virtual Environments, 10,* 583-598.

BASDOGAN ET AL. QUESTIONNAIRE

Description

Concept: Social presence.
This questionnaire consists of eight items rated on a seven poont rating scale. It aims to measure "the sense of being together". Items are reported in Appendix A. The overall score is constructed as the number of high (score six or seven) responses out of the eight items. This avoids the problem of averaging ordinal responses, and allows the use of logistic regression.

Research

The questionnaire was used in a study investigating the influence of haptic feedback on task performance and sense of togetherness of participants in a shared virtual environment (SVE). Participants (n=10, within-subjects design) carried out a collaborative task in a SVE with an expert. Haptic feedback was varied as a within-participants factor (only visual feedback or visual plus haptic feedback). A performance measure was based on time and errors. Results showed that haptic feedback increased both performance and the feeling of togetherness.

Sensitivity: The questionnaire distinguished between two conditions.
Reliability: Not reported.
Validity: Similar pattern in togetherness and performance scores. The correlation between the measures is not reported.

Primary Source

Basdogan, C., Ho, C., Srinivasan, M. A., & Slater, M. (2000). An experimental study on the role of touch in shared virtual environments. *ACM Transactions on Computer Human Interaction, 7*(4), 443-460.

CMC QUESTIONNAIRE / SOCIAL PRESENCE AND PRIVACY QUESTIONNAIRE (SPPQ)

Description

Concept: Social presence.

Tu (2002) defined social presence as the degree of feeling, perception, and reaction of being connected to another intellectual entity via Computer Mediated Communication. Three dimensions were distinguished:

1. Social context
2. Online communication
3. Interactivity

The questionnaire was based on a CMC attitude instrument (Steinfield, 1986) and an instrument measuring perceived privacy (Witmer, 1997). Content validation was conducted by asking five experts to perform an item-matching task.

Supposedly the same questionnaire is referred to as either CMC questionnaire (Tu, 2002b) or SPPQ (Tu, 2002a). The final version of the CMCQ/SPPQ contains 17 social presence items and 13 privacy items, rated on a five point rating scale. The items are not listed in either of the papers.

Research

In a construct validity study (Tu, 2002a), teachers (n=310) completed the questionnaire, and a factor analysis was performed on the resulting data. Five factors were extracted: social context, online communication, interactivity, system privacy, and feeling of privacy. Cronbach's alpha for the five factors ranged between .74 and .85. Three items were removed. A significant correlation was found between social presence and privacy. Significant intercorrelations were found between all factors.

A different study (Tu, 2002b) (n=43) was conducted comparing three different types of CMC (e-mail, BulletinBoard and real-time discussion). In addition to the CMC Questionnaire, qualitative measures were used (casual conversation, in-depth interview, direct observation, document analysis).

Factor analysis confirmed the five dimensions identified earlier (three social presence dimensions and two privacy dimensions). Together they accounted for 77% of all variance. All factors had high alpha values (ranging between .71 and .88). An ANOVA showed significant differences in social presence scores between the three systems; e-mail scored highest, followed by real-time discussion and BulletinBoard. As an explanation for these results, several problems with real-time discussion, which may degrade social presence, are discussed in the paper. These are overshadow effect, presence of assertive students and instructors, confusion because of many-to-many, multi-topic conversations, and problems with organization and facilitation.

Sensitivity: The questionnaire discriminated between different systems.

Reliability: High alpha values are reported for all factors, across two different studies; significant correlations were found between all factors.

Validity: Content validity was supported in the development process; factor analysis on date gathered two different studies yielded the same factor structure.

Primary Sources

Tu, C. (2002a). The measurement of social presence in an online learning environment. *International Journal on E-Learning 1*(2), 34-45.

Tu, C. (2002b). The impacts of text-based CMC on online social presence. *The Journal of Interactive Online Learning, 1*(2).

Other Literature

Steinfield, C. W. (1986). Computer-mediated communication in an organizational setting: Explaining task-related and socioemotional uses. In M. L. McLaughlin (Ed.). *Communiation yearbook 9* (pp. 777-804). Newbury Park: Sage.

Witmer, D. F. (1997). Risky business: Why people feel safe in sexually explicit on-line communication. *Journal of Computer-Mediated Communication, 2*(4).

GLOBALED QUESTIONNAIRE

Description

Concept: Social presence.

Gunawerda and Zittle (1997) set out to measure social presence in a CMC context from a group perspective. They based their questionnaire on the immediacy aspect of social presence as defined by Short, Williams, and Christie (1976).

The questionnaire contains 61 items on a five point rating scale, including the variables social presence (14 items), satisfaction (10 items), technical skills and CMC experience (three items), attitude towards CMC (two items), technical barriers (two items), active participation (one item), capability of mastering CMC (one item), equal opportunities (one item), and training (one item). The questionnaire items relating to social presence and satisfaction are listed in the paper. The 14 items relating to social presence can be found in Appendix A.

Research

The GlobalEd questionnaire was developed to evaluate a virtual conference. For validation purposes it also contained 17 semantic differential items taken from Short, Williams and Christie (1976). Participants (n=50) of the conference filled out the questionnaire.

Internal consistency of the social presence scale was α=.88. Strong positive correlations (ranging between .52 and .87) were found between the social presence scale and the semantic differential items, supporting validity. Social presence was found to be a strong predictor of user satisfaction.

Sensitivity: Not reported.
Reliability: Internal consistency α=.88.
Validity: High correlations with another measure for social presence (semantic differential).

Primary Source

Gunawerda, C.N., & Zittle, F.J. (1997). Social presence as a predictor of satisfaction within a computer-mediated conferencing environment. *The American Journal of Distance Education, 11*(3), 8-26.

Other Literature

Short, J., Williams, E., & Christie, B. (1976). *The social psychology of telecommunications*. London: John Wiley & Sons.

IPO SOCIAL PRESENCE QUESTIONNAIRE (IPO-SPQ)

Description

Concept: Social presence.

The IPO-SPQ combines 2 different methods for measuring social presence:

1. Osgood's semantic differential technique, as described by Short, Williams, and Christie (1976), which requires participants to rate media on a series of bipolar scales (e.g. impersonal – personal)
2. Attitude statements on which participants can agree or disagree.

The final version of the IPO-SPQ contains 17 items: five subjective attitude statements and 12 semantic differential items. All items are rated on a seven point rating scale. The items are not listed in the paper.

Research
The IPO-SPQ was used in an experiment in which participants (n=34, within-subjects design) used a system for sharing photos with only audio or audio and video. Internal consistency was calculated; three items were removed because of low item-total correlation. Analysis of the data using GLM showed a substantial effect of video for both measures. The data suggested that subjects needed an anchor point (such as a previous trial or training session) to be able to differentiate between different media conditions. Therefore, the authors concluded that a within-subjects comparison seems to be more sensitive to differences in perceived social presence.

Sensitivity: The questionnaire scores discriminated differences between conditions (audio/ audio+video).
Reliability: For the attitude statements, α = .72 and for the semantic differentials α = .90. The scales intercorrelated significantly, r=.58.
Validity: Adding of video, which is hypothesized to enhance presence, increased questionnaire scores. The authors indicate their intention to analyze video material from the experiment and use observed social responses as an objective corroborative measure of social presence.

Primary Source
De Greef, P., & IJsselsteijn, W. A. (2001). Social presence in a home tele-application. *CyberPsychology & Behavior, 4*, 307-316.

See also
Semantic Differential Technique

NETWORKED MINDS QUESTIONNAIRE

Description
Concept: Social presence.
The Networked Minds Questionnaire was based on the definition of social presence as "the moment-by-moment awareness of the co-presence of another sentient being accompanied by a sense of engagement with the other. It is an outcome of cognitive simulations of the other's cognitive, emotional, and behavioural dispositions" (p.2). Three dimensions of social presence were distilled from existing theories:

1. Co-presence
2. Psychological involvement
3. Behavioural engagement.

Over 80 items were created, 69 of which were retained after analysis for face and content validity. Based on factor analysis and internal consistency calculation (see Research) the number of items was reduced to 38 (mentioned in the text, but 40 items are listed in the paper). Items are rated on a seven point rating scale. The questionnaire consists of pairs of matched items to reflect both the participants' own feelings and the participants' perception of the feelings of their communication partners. E.g., the item "I often felt as if I was all alone" is matched by the item "I think the other individual often felt alone". The items of the final version are listed in Appendix A.

Research
The questionnaire was used in an experiment comparing face-to-face interaction with audio-video teleconferencing (n=76, within-subjects design). A purely verbal, non-emotional ranking task was chosen. A factor analysis was carried out on the obtained questionnaire scores. The identified factors were:

1. Co- presence: Isolation/Inclusion (2 items) and Mutual Awareness (6 items)
2. Psychological involvement: Mutual Attention (8 items), Empathy (6 items), Mutual Understanding (6 items)
3. Behavioural engagement: Behavioural Interaction (6 items), Mutual Assistance (4 items), Dependent Action (2 items)

The scores of all scales were higher in the face-to-face condition than in the mediated condition. ANOVA showed significant differences between the conditions in co-presence scales (as predicted), most but not all of the psychological involvement scales (as predicted), and one of the behavioural engagement scales (not predicted).

Sensitivity: Several subscales discriminated between different media (face-to-face vs. mediated).
Reliability: Internal consistency data are reported for each factor, ranging betweem .69 and .87.
Validity: Subscale scores mostly show differences as predicted by the authors based on the task and social presence theory.

Primary sources

Biocca, F., Harms, C., & Gregg, J. (2001). *The Networked Minds measure of social presence: Pilot test of the factor structure and concurrent validity.* In *Proceedings of 4th International Workshop on Presence*. Philadelphia, USA, 21-23 May, 2001.

Biocca, F. & Harms, C. (2002). Defining and measuring social presence: Contribution to the networked minds theory and measure. In F.R. Gouveia, & F. Biocca (Eds). *Proceedings of the 5th International Workshop on Presence,* 7-36.

Other Literature

Biocca, F., Harms, C., & Burgoon, J. (2004). Towards a more robust theory and measure of social presence: Review and suggested criteria. *Presence: Teleoperators and Virtual Environments, 12*, 456-480.

PARA-SOCIAL PRESENCE QUESTIONNAIRE

Description

Concept: Social presence.
The construct para-social presence was developed to capture the relational component between a web site and its customers. The web site was seen as a social actor.
The questionnaire was based on five sub-components of relational communication identified by Burgoon and Hale (1987): Immediacy/Intimacy, Sense of understanding, Positivity, Involvement, and Dominance. Each dimension is measured by six to eight items (a larger pool of items was refined using card sorting techniques). The items are listed in Appendix A.

Research

Research is currently being conducted to assess reliability and validity.

Primary Source

Kumar, N., & Benbasat, I. (2002). Para-social presence and communication capabilities of a website: A theoretical perspective. *e-Service Journal, 1*(3), 5-24.

Other Literature

Burgoon, J. K., & Hale, J. L. (1987). Validation and measurement of the fundamental themes of relational communication. *Communication Monographs, 54,* 19-41.

SEMANTIC DIFFERENTIAL TECHNIQUE

Description

Concept: Social presence.
The semantic differential technique described by Short, Williams, and Christie (1976) is one of the earliest questionnaires measuring social presence. It was based on Osgood's semantic differential technique (Osgood, Suci, and Tannenbaum, 1957). In the semantic differential technique, participants are asked to rate the communication media on a series of 24 seven point,

bipolar scales, including impersonal-personal, unsociable-sociable, insensitive-sensitive, and cold-warm. Not all items are listed in the book.

Research
Short et al. (1976) described two experiments using this questionnaire carried out by Champness. In the first experiment (n=72, within-subjects design), face-to-face, closed-circuit television and audio system were compared. Most of the scales (20 out of 24) discriminated between the audio condition and the two visual conditions. Four scales discriminated between the closed-circuit television and face-to-face. In a second experiment (n=90, between-subjects design), groups of three participants were distributed over two rooms; one pair in one room and one lone participant in the other. In the closed-circuit television condition, the pair saw a close-up image of their colleague, while the lone participant saw two small images of the other two. Factor analysis of the Semantic Differential scales revealed four factors, the first of which was Social Presence / Aesthetic Appeal. ANOVA showed that the medium was rated higher on this factor by subjects who saw the close-up image.
Christie performed two follow-up experiments comparing five different media (face-to-face, TV, 2 different speakerphones and multispeaker audio) were compared in a within-subjects design. Factor analysis revealed Social Presence as the first factor. Several significant differences between media were found for this factor.

Sensitivity: The questionnaire scores discriminated between different media and between different versions of one medium.
Reliability: Not reported.
Validity: Not reported.

Primary Source
Short, J., Williams, E., & Christie, B. (1976). *The social psychology of telecommunications*. London: John Wiley & Sons.

Other Literature
Osgood, C. E., Suci, G. J., & Tannenbaum, P. H. (1957). *The measurement of meaning.* Urbana*:* University of Illinois Press.

See also
IPO-SPQ

2.2 Continuous Assessment

Continuous assessment methods require participants to rate fluctuations in their sense of presence during the actual experience. Advantages of this method are that it overcomes recall problems or anchoring effects. It is sensitive to time-variant information, which cannot be assessed by post-test measures.
A disadvantage of the method is that, although it requires little effort and attention from the subject, it may interrupt the user experience. Also, the user can only rate one aspect of the experience at a time.

Description
Concept: Physical presence.
Subjects are asked to move a slider along a scale to indicate their perceived level of presence. A computer then samples the position of the slider at a constant rate.

Research
The method was used in two similar experiments in which participants (n=12, n=18, within-subjects design) watched a stereoscopic film three times, each time rating it for depth, naturalness of depth, or presence. Presence scores showed considerable variation over time. Changes in presence scores were associated with changes in the stimulus material, such as scene-cuts. Also, qualitative evidence was found suggesting that stereoscopic and motion parallax cues enhance the observer's sense of presence. This provides support for one of the determinants of presence hypothesized by Sheridan (1992), i.e. the extent of sensory information available to the observer.

Sensitivity: The measure was shown to be sensitive to differences in stimulus material.
Reliability: Similarity of results obtained in 2 different laboratories.
Validity: The obtained results are consistent with theoretical determinants of presence.

Primary Sources
IJsselsteijn, W.A., De Ridder, H., Hamberg, R., Bouwhuis, D., & Freeman, J. (1998). Perceived depth and the feeling of presence in 3DTV. *Displays, 18*, 207-214.

IJsselsteijn, W. A. (2004). *Presence in Depth*. Ph.D. Thesis. Eindhoven University of Technology.

2.3 Qualitative Measures

Qualitative research methods produce information which is not arrived at by any means of quantification, such as statistical procedures. Examples of qualitative methods are content analysis (e.g., of written text or thinking aloud protocols), interviews, and ethnographic approaches. Qualitative methods are most often used in exploratory research aimed at generating hypotheses.
Qualitative research typically results in very rich, detailed information, which helps to gain a deeper understanding of the user experience. In this sense, qualitative methods can be a valuable addition to quantitative measures. Another advantage is that qualitative methods do not shape and constrain participants' responses in the way that questionnaires do, but allow them to choose their own answers, using their own language and terminology (IJsselsteijn, 2004).
The abundance of information which qualitative methods usually produce is not only an advantage but also a drawback, because data-analysis tends to take a lot of time. Also, the central role of the researcher's interpretation in the data-analysis forms a threat to reliability. A final disadvantage is that it is often difficult to generalize findings.
Sensitivity, reliability, and validity are not discussed for most measures in this part of the compendium. Qualitative measures are primarily used for exploratory purposes; therefore these aspects can often not be determined or are not relevant. For some measures, such as content analysis, it is possible to take the level of agreement between different raters as an indication for reliability.

AUTOCONFRONTATION METHOD

Description

Concept: Physical presence or Social presence.
Retaux (2003) defined the feeling of "being in" a game as "performing, concentrating, being implicated, being touched, and changing of scenery". This definition was based on conducted interviews and online definition groups with users of virtual game environments. The "autoconfrontation method" was presented as a continuous, subjective measure of presence. When using the autoconfrontation method, the user is shown a video of the experience and is asked to explain his/her behaviour and feelings and rate feeling of presence on a nine point rating scale. Based on this report, the experimenter constructs a presence chronogram which shows variations in the presence experience over time.

Research

The technique was tested out in an experiment investigating the relationship between experience, task type and presence. Participants (n=15, within-subjects design) performed a total of 12 training games of five minutes each and two test games of five minutes each, distributed over two sessions (six training games and one test game per session). Afterwards, users viewed the videotape of the test game (lasting five minutes) and were asked to rate and verbalize their feelings of presence. Based on this report, the experimenter constructed a presence chronogram. No difference was found between presence scores in the two test games (this was expected because the authors hypothesized that as a player gets more experienced, he or she will experience more transparancy and therefore a higher level of rpesence). A significant difference was found between presence scores during two different activities: searching for equipment and fighting an enemy.

Primary Source

Retaux, X. (2003). Presence in the environment: theories, methodologies and applications to video games. *PsychNology Journal, 1(3)*, 284 - 310.

CONTENT ANALYSIS

Description

Concept: Social presence.

Rourke, Anderson, Garrison, and Archer (1999) identified 12 indicators of social presence in three categories based on previous research, literature, and analysis of transcripts:

1. Interactive responses: continuing a thread, quoting from other's messages, referring explicitly to each other's messages, asking questions, complimenting/expressing appreciation, expressing agreement.
2. Affective responses: expression of emotions, use of humor, self-disclosure.
3. Cohesive responses: vocatives, referring to a group using inclusive pronouns (e.g. we, us), phatics/salutations.

Transcripts of (online) communication were coded on the basis of a template. "Social presence density" was calculated by summing the raw number of instances then dividing them by the total number of words. The template contains the 12 indicators of social presence and is given in the paper, along with examples.

Research

The method was used for coding transcripts from two graduate courses (n=31, number of messages =134). Average interrater reliability was .91 - .95 (although much lower for latent indicators such as humor). The social presence density was higher in one transcript, which confirmed intuitive impressions.

Reliability: High average interrater reliability.

Primary Source

Rourke, L., Anderson, T. Garrison, D. R., & Archer, W. (1999). Assessing social presence in asynchronous, text-based computer conferencing. *Journal of Distance Education, 14*(3), 51-70.

ETHNOGRAPHIC OBSERVATION

Description

Concept: Physical presence.

Ethnographic research focuses on the exploration of sociocultural phenomena. In general, its aims are descriptive rather than analytic. It is a suitable tool for hypothesis generation. It does not consist of one method; instead, a combination of methods is used to study naturally occurring behaviour. Ethnographic methodology can be applied to presence research. Methods that have been used are open-ended questionnaires, unstructured interviews, and observation. The latter two can be used to gather data during the experience.

Research

McGreevy (1992) used ethnographic methods to study the sense of presence of planetary geologists (n=2, within-subjects design) while exploring a desert location. They performed similar tasks with and without a head-mounted video camera/display/recorder replacing natural vision. They were observed and interviewed (unstructured) during this experience, while performing "typical tasks". Resulting data were narrative descriptions and explanations, and information about gestures and performed actions. When wearing the HMD, the geologists commented on the poor resolution, the loss of context as a result of narrow field of view, poorer sense of depth perception, and several other factors complicating their tasks.

Primary Source

McGreevy, M. W. (1992). The presence of field geologists in Mars-like terrain. *Presence: Teleoperators and Virtual Environments, 1*, 375 - 403.

EXPERIENCE SAMPLING METHOD (ESM)

Description

Concept: Physical presence or Social presence.
Gaggioli, Bassi, and Delle Fave (2003) proposed to study the impact of VR on daily life and subjective experience from a theoretical perspective that emphasizes the active role of individuals in interacting with their natural and cultural environment. Cognitive, motivational, and affective components were seen as relevant to this experience.
The experience sampling method (ESM) constitutes repeated on-line assessment of the external situation and personal states of consciousness, as real events and situations occur. Participants carry a beeper, and fill out a form on receiving a signal. This form contains open-ended questions addressing topics such as place, activities, social context, thoughts, and goals. It also contains 0-12 rating scales regarding the three components of quality of experience: affect, activation, and cognitive efficiency. An Experience Fluctuation Model has been developed to analyze the results.

Research

ESM has not yet been used to study presence, but is suggested for investigating the multidimensional structure of presence, use of VR in daily life, and comparison across different media. An experiment is planned in which ESM results will be compared to ITC-SOPI data.

Primary Source

Gaggioli, A., Bassi, M., & Delle Fave, A. (2003). Quality of Experience in Virtual Environments. In G. Riva, F. Davide, & W.A. IJsselsteijn (Eds) *Being There: Concepts, Effects and Measurements of User Presence in Synthetic Environments.* Amsterdam: IOS Press.

FOCUS GROUP EXPLORATION

Description

Concept: Physical presence or Social Presence.
Focus group research involves organized discussion in small groups (four to eight individuals) in order to gain information about their opinions and experiences. Audio recordings are generally transcribed and coded manually, possibly with the aid of a software program. Focus groups are useful when "there is a gap between professionals and their target audiences and when investigating complex behaviours and motivations" (p. 531). Freeman and Avons (2000) described a discussion guideline containing questions and a standard set of prompts.

Research

A focus group study was conducted to elicit non-expert descriptions of 3DTV. Participants (n=25, divided over four groups, within-subjects design) were shown the same stimulus material on a normal and a stereoscopic TV. All groups reported "a sensation of being there" whilst watching 3DTV, without prompting, but the term presence was not used. Several comments were reported that link this sensation with physical responses (postural responses, the wish to interact). There was consensus among the groups that factors such as realism, naturalness and interest/involvement made them feel more present. There was some qualitative support for the multidimensional view of presence.

Reliability: the four different groups were consistent in their responses

Primary Source

Freeman, J. & Avons, S.E. (2000). Focus group exploration of presence through advanced broadcast services. *Proceedings of the SPIE, 3959,* 530-164.

FREE FORMAT SELF-REPORTS

Description

Concept: Physical presence or Social presence.
Participants are asked to give a retrospective, written description of an experience. These essays are then analyzed.

Research

In an exploratory pilot study into sense of place, Turner et al. (2003) asked participants (n=18) to provide a 150-350 word written description of a familiar place, "as if telling a friend about the experience". These descriptions were analyzed against the concept of place identity as described in the literature, and practical dimensions relevant to the particular project. Striking differences between individuals were observed in the overall richness of the descriptions. The visual modality was predominant in the descriptions. All three dimensions of place identity (physical setting, activities, meanings and affect) described in the literature were found in the descriptions.
In a second study (n=31) participants experienced either a virtual version of a botanical garden (27 participants) or the real environment (four participants). They were asked to describe the place to an interviewer, as if telling it to a friend.
Murray, Arnold, and Thornton, (2000) have used this approach in a study investigating the effect of hearing loss on the sense of presence. Participants (n=15) carried out everyday activities on their university campus while wearing earplugs. Afterwards, they were asked to provide a written account of the experience. The accounts contained many, varied descriptions of participant's feelings, whcih the authors interpreted as indicating a loss of the sense of presence (e.g., "like an astronaut in space").

Primary Sources

Turner, S., Turner, P., Caroll, F., O'Neill, S., Benyon, D., McCall, R., et al. (2003). *Re-creating the Botanics: Towards a sense of place in virtual environments.* Paper presented at the 3rd UK Environmental Psychology Conference, Aberdeen, 23-25 June 2003.

Murray, C., Arnold, P., & Thornton, B. (2000). Presence accompanying induced hearing loss: Implications for immersive virtual environments. *Presence: Teleoperators and Virtual Environments, 9,* 137-148.

INTERACTION ANALYSIS

Description

Concept: Physical presence.
Interaction analysis is a qualitative method for the systematic analysis of action, based on discourse analysis. Videotapes of participants' interaction with technology are recorded. Fragments which contain occurrences of the studied phenomenon (in this case presence)are extracted and coded. Single actions are analyzed, paying attention to order and context.

Research

Examples of various research projects were discussed by Spagnolli, Varotto, and Mantovani (2003). In total, 20 videotaped sessions of users immersed (by HMD) in a virtual library environment involving an agent were analyzed. The following questions were considered:

- What actions do participants envisage?
- What do virtual objects look like for participants?
- What norms regulate the organization of a VE?
- Which resources are imported in the VE?
- How rich is the environment in terms of projected activities?

Primary Source

Spagnolli, A., Varotto, D., & Mantovani, G. (2003). An ethnographic, action-based approach to human experience in virtual environments. *International Journal of Human-Computer Studies, 59,* 797-822.

INTERVIEW

Description

Concept: Physical presence or Social presence.

There are many different ways of interviewing; the semi-structured or unstructured approach appears to be most suitable for exploring presence, because it allows participants to express their personal experience, in their own words.

Research

This method was used by Murray, Arnold, and Thornton (2000) in order to investigate the influence of hearing loss on presence. Participants (n=6) wore earplugs while performing everyday activities such as shopping. Afterwards, a semi-structured interview was conducted. The interviews were transcribed, and significant themes were identified. Participants reported a heightened awareness of self, a feeling of remoteness, of being removed from the activities around them, a heightened environmental awareness, and a decreased feeling of social presence. They reported no doubts of actually being present in the environment.

Primary Source

Murray, C., Arnold, P., & Thornton, B. (2000). Presence accompanying induced hearing loss: Implications for immersive virtual environments. *Presence: Teleoperators and Virtual Environments, 9,* 137-148.

PRESENCE PROBE

Description

Concept: Physical presence.

This methodology is based on the view that a sense of place is an important aspect of presence. The approach is partly based on Relph's (1976) model of place, which defines three components of "place identity": physical setting, activities afforded by the place, and meanings attributed to the place. One of the goals of the presence probe was to be able to compare (benchmark) real and virtual environments. It was inspired by Gaver's (1999) cultural probes approach.

The presence probe consists of several sections:

1. "Visitors book" in which participants provide a short description of their experience of the visited place.
2. Participants are asked to sketch a map of the visited place
3. Three sets of three semantic differential items, combining Relph's conditions of place (physical features, activities afforded, affect engendered) with Osgood's axes of semantic differentials (good-bad, strong-weak, active-passive).
4. Participants are asked to pick a photograph that best exemplifies their experience, and to write down six words which best describe their experience of the place.

Research

The presence probe was tried out in a pilot study on three locations in Prague. Per location, 30-40 visitors of the locations were asked to complete the presence probe. The results suggested that participants had no difficulties in understanding the method. Rich, diverse responses were gathered, varying in level of detail. Examples of responses are given in the paper.

Primary Source

McCall, R., O'Neill, S., Carroll, F., & Benyon, D. (2004). *The Presence Probe*. Paper presented at the Workshop on Designing and Evaluating Virtual Reality Systems, University of Nottingham, UK.

REPERTORY GRID ANALYSIS

Description

Concept: Physical presence.

The repertory grid technique (Kelly, 1955, in Steed & McDonnell, 2003) is a method for exploring personal constructs. It was originally developed to explore constructs about interpersonal relationships in a clinical context (psychotherapy). It has since been applied in many other contexts. The underlying idea is that people represent their experiences by placing alternative constructions upon them. Steed and McDonnell (2003) have applied the approach in presence measurement.

A participant is presented with different experiences (e.g., VEs). Afterwards, personal constructs are elicited by comparing different combinations of three elements (experiences). Participants are asked to compare the items of a group and to discuss differences and similarities. Any distinction that is relevant to the participant becomes a construct. A grid is drawn up in which the elements form columns and the identified constructs form rows. Descriptions of the poles of each construct label both ends of a row. Participants then assign a rating to each construct for each experience. Elements and constructs can be clustered, revealing a pattern of personal meaning. Conversation with the participant is central to the technique.

Research

Two exploratory pilot trials were conducted using repertory grid analysis. In the first trial participants (n=3, within-subjects design) experienced six different environments: three experiences were immersive (HMD), three were not (desktop). Content and design also varied. Participants generated seven to eight constructs; there was similarity between the constructs generated by different participants. In the second trial, participants (n=5, within-subjects design) again experienced six different environments; however, this time all experiences were immersive and the environments were more similar to each other. The SUS questionnaire was completed for each environment. Although the results of both techniques (RGA and SUS) could not be compared, the constructs generated by the participants could be used to generate hypothesis about the causes of presence. The authors suggest that RGA could be used as a tool for constructing or refining questionnaires.

Primary Source

Steed, A., & McDonnell, J. (2003). Experiences with repertory grid analysis for investigating effectiveness of virtual environments. In *Proceedings of the 6th International Workshop on Presence.* Aalborg, Denmark, 6-8 October 2003.

THINKING ALOUD

Description

Concept: Physical presence.

The thinking aloud method requires participants to verbalize their thought processes, perceptions or feelings during an experience. These think-aloud protocols can be analyzed afterwards. The method is well-established in psychological research on problem solving, and is also used in usability testing.

Research

Turner, McGregor, Turner, and Carroll (2003) used the thinking aloud method in a study investigating presence and sense of place in a soundscape. A soundscape of a specific

environment (a computer centre) was created. Participants (n=40, between-subjects design) were assigned to one of four conditions:

1. physically present in the real environment,
2. 2. physically present in the real environment and thinking aloud,
3. 3. Blindfolded and exposed to the soundscape, and
4. 4. blindfolded and exposed to the soundscape and thinking aloud.

Participants in all conditions completed the SUS. The think-aloud protocols yielded rich and interesting qualitative date. However, scores on the SUS item relating to really being in the computer centre indicated that the speaking aloud task interfered with the feeling of being there.
In a different study (Turner et al., 2003), participants (n=31, between-subjects design) experienced either a virtual version of a botanical garden (n=27) or the real environment (n=4). They were asked to provide a running commentary as they explored the real/virtual environment. There were considerable differences in the richness and level of detail of the verbal reports. Participants in the virtual world commented on the absence of objects or sensations typical to the environment, and their restricted ability to perform actions. The real world stimulated much more reference to memory than the virtual world.

Primary Source

Turner, P., McGregor, I., Turner, S., & Carroll, F. (2003). Evaluating soundscapes as a means of creating a sense of place. In E. Brazil, & B. Shinn-Cunningham (Eds), *Proceedings of the 2003 International Conference on Auditory Display,* 148-151.

Turner, S., Turner, P., Caroll, F., O'Neill, S., Benyon, D., McCall, R., et al. (2003). *Re-creating the Botanics: towards a sense of place in virtual environments.* Paper presented at the 3rd UK Environmental Psychology Conference, Aberdeen, 23-25 June 2003.

2.4 Psychophysical Measures

Psychophysical methods require an observer to provide a subjective rating of the physical magnitude of a stimulus. This can be done by simply asking participants to assign a value to the degree of presence a stimulus induces (free-modulus magnitude estimation), by investigating the extent to which participants can discriminate between stimuli (paired comparison test), or asking participants to "translate" the intensity of their sensation of presence to a different modality (cross-modality matching).
Although only a limited number of studies in the field of presence have included psychophysical measures, at least two experiments have shown such measures to be sensitive to different levels of presence. In addition, these measures are relatively cheap, can be used unobtrusively and are easy to use.
Like all subjective methods, psychophysical measures are prone to bias. Also, what these methods will measure is heavily dependent on the experimenter's instructions, and on participants' own interpretation of what they should rate.

CROSS-MODALITY MATCHING (CMM)

Description
Concept: Physical presence.
Cross-modality matching (CMM) is a variation of magnitude estimation. It is based on the premise that a person can monotonically represent the experiences of one sensory modality through another modality by producing a "subjectively equal" representation using a measure of the second sensory modality. E.g., "make this light as bright as the strength of the presence you experienced in this virtual environment" (Welch, 1997). CMM is especially useful for the measurement of constructs that do not lend themselves easily to verbal scaling (IJsselsteijn, De Ridder, Freeman, & Avons, 2000).

Research
Not reported.

Primary source
Welch, R. B. (1997). The presence of aftereffects. In G. Salvendy, M. J. Smith, & R. J. Koubek (Eds). *Designs of computing systems: Cognitive considerations* (pp. 271-276). Amsterdam: Elsevier.

Other literature
IJsselsteijn, W. A., De Ridder, H., Freeman, J., & Avons, S. E. (2000). Presence: Concept, determinants and measurement. *Proceedings of the SPIE, 3959*, 520-529.

Sadowski, W., & Stanney, K. M. (2002). Measuring and managing presence in virtual environments. In K.M. Stanney (Ed.), *Handbook of virtual environments technology*. Mahwah, NJ: Lawrence Erlbaum Associates.

FREE-MODULUS MAGNITUDE ESTIMATION

Description
Concept: Physical presence.
Free-modulus magnitude estimation is based on the method magnitude estimation as described by Stevens (1971, in Snow & Williges, 1998). Subjects are asked to assign any value to a first stimulus, and then assign successive numbers accordingly to following stimuli. The geometric mean of judgments of several subjects can then be taken as the psychological scale value, thus producing data on a ratio scale.

Research
A series of three experiments (n=36, mixed design) was conducted using this method, across which 11 independent variables were varied: scene update rate, visual display resolution, field of view, sound, textures, head tracking, stereopsis, virtual personal risk, interactions, presence of a second user, and object detail. Participants carried out five tasks in a VE, wearing a HMD. After each trial, participants provided a free-modulus magnitude estimate of their level of perceived presence during the trial.
Field of view, sound, and head-tracking showed the largest (positive) effects on perceived presence. Other significant (positive) effects were those of visual display resolution, texture-mapping, stereopsis, and the presence of a second user.

Sensitivity: The method was sensitive to the effect of several environmental parameters.
Reliability: Not reported.
Validity: Factors which are hypothesized to enhance presence increased magnitude ratings.

Primary Source
Snow, M. P., & Williges, R. C. (1998). Empirical models based on free-modulus magnitude estimation of perceived presence in virtual environments. *Human Factors, 40*, 386-402.

PAIRED COMPARISON

Description
Concept: Physical presence.
Welch, Blackmon, Liu, Mellers, & Stark (1996) approached presence as telepresence, or the experience of being in the same distant physical location as the devices you are controlling. They hypothesized that maximal presence occurs when the user:

1. Feels immersed within the VE
2. Feels capable of moving about in it and manipulating content
3. Has an intense interest in the interactive task

To assess this, the method of paired comparison was used, which is well-established in psychological research. When using this method, subjects are exposed to pairs of VEs, and are asked to indicate for each pair which one produces the greater amount of presence. The size of the perceived difference has to be estimated by a number between one and 100.

Research
The method was used in two experiments investigating the effects of interactivity, pictorial realism, and delay of visual feedback on presence. Participants (n=24, n=20, within-subjects design) were exposed to pairs of environments (24 pairs in each experiment) and asked to indicate their feeling of being physically located in the environments by paired comparison. The task consisted of driving a virtual car. Factors varied within-subjects were interactivity (driver or passenger), pictorial realism (high/low) and delay of visual feedback (short/long). The results showed significant positive influences of all three factors.

Sensitivity: The method discriminated between different conditions.
Reliability: Not reported.
Validity: Factors which are hypothesized to enhance presence increased the ratings.

Primary Source
Welch, R. B., Blackmon, T. T., Liu, A., Mellers, B. A., & Stark, L. W. (1996). The effects of pictorial realism, delay of visual feedback, and observer interactivity on the subjective sense of presence. *Presence: Teleoperators and Virtual Environments, 5*, 263-273.

VIRTUAL REALITY TURING TEST

Description

Concept: Physical presence.

This is a variation on the paired comparison method, akin to the Turing test. It was based on signal detection theory. The idea is to set up a test in which the subject must make a series of observations under identical conditions, and determine his or her location based on the interaction. The subject is then asked whether s/he perceives that s/he is physically present in the specified environment. Presence is estimated by the ratio of correct identifications to incorrect identifications.

Schloerb (1995) suggested a set-up in which participants wear a head mounted display (HMD), which can either display a VE or filmed images from the real world. Participants are asked over many trials to indicate whether what they are seeing is real or virtual. The presence measure is based on the relative frequency of "yes" responses.

Research

Not reported.

Primary Source

Schloerb, D. W. (1995). A quantitative measure of telepresence. *Presence: Teleoperators and Virtual Environments 4,* 64-80.

2.5 Subjective Corroborative Measures

There are several subjective measures which do not directly assess presence, but provide information about mental processes that are presumably related to presence, such as attention, memory, and spatial cognition (IJsselsteijn, 2004). Such subjective corroborative indicators may support the validity of presence measures.

BREAKS IN PRESENCE (BIPS)

Description
Concept: Physical presence.
The BIPs method was developed with the goal to measure presence unobtrusively during the course of a VE experience. In order to do this, Slater and Steed (2000) made a link to Gestalt psychology. They hypothesized that there are two alternate gestalts: state V (virtual world) and state R (real world). Presence in the VE was defined as the extent to which interpretation V is favoured.
Users were asked to report transitions from V to R (from R to V is not possible). A probabilistic model was constructed to model these transitions. This model was then used to estimate the equilibrium probability (*p*) of being present in the VE. An additional post-experimental question was needed to discriminate between participants who were in the presence state for more than half the time and less than half the time.

Research
An experiment was carried out (Slater & Steed, 2000) to evaluate the measure (n=20, between-subjects design). The level of activity (low/high) and place (different from lab/same as lab) were varied. Participants entered a VE in which they had to move 3D chess pieces. During this experience they reported transitions from V to R. Afterwards they filled out a presence questionnaire, which contained five questions based on the SUS.
A significant correlation was found between *p* and the questionnaire. Participants reported both external (e.g. sensory information from the real world intruding) and internal (e.g. objects looking unnatural) reasons for BIPs.
Brogni, Slater, and Steed (2003) reported an additional study into the relationship between BIPs and self-reported questionnaire-based presence. In this case, they did not calculate *p* but took a simpler approach and merely counted the number of BIPs. Participants (n=60, between-subjects design) were distributed over six different virtual urban environments, which they experienced by means of a Cave-like system. The experience lasted four to five minutes; during this time participants were asked to report BIPs by pushing a button. After the experience, participants completed a four item version of the SUS. A significant regression of the number of BIPs on the subjective presence score was found. A significant negative correlation was found between the subjective presence score and the number of BIPs, meaning that more BIPs were associated with a lower subjective presence score.

Sensitivity: Not reported.
Reliability: Not reported.
Validity: Correlation with subjective presence items.

Primary Source
Slater, M., & Steed, A. (2000). A virtual presence counter. *Presence: Teleoperators and Virtual Environments, 9,* 413-434.

Other Literature
Brogni, A., Slater, M., and Steed, A. (2003). More breaks less presence. In *Proceedings of the 6th International Workshop on Presence.* Aalborg, Denmark, 6-8 October 2003.

DURATION ESTIMATION

Description

Concept: Physical presence.
Duration estimation, or the human ability to indicate how much time has elapsed, was proposed as a corroborative measure of presence. In previous literature, presence has been associated with both longer (Waterworth & Waterworth, 2001) and shorter (Lombard, 2000) experienced duration.
Subjects are asked to estimate the duration of the time interval they needed to complete tasks (in minutes and seconds). They are also asked to judge on a six point rating scale whether they think they completed the tasks in a short time.

Research

In an experiment exploring the relationship between duration estimation and presence, subjects (n=42, mixed design) navigated through a 3D maze using a route navigation system. Independent variables were type of information (map or text), which was varied between-subjects, and range of information (complete route, per subgoal, or per decision point), which was varied within-subjects. Dependent variables were the actual time taken to complete the task, duration estimation, participants' judgment whether they had completed the tasks in a short time (on a six point rating scale), and subjective presence, which was measured by four items on a six point rating scale.
A significant positive correlation was found between subjectively judged speed of task completion and sense of presence. No significant correlation was found between duration estimation and sense of presence.

Sensitivity: Not reported.
Reliability: Not reported.
Validity: The validity of subjectively judged speed of task completion was supported by its correlation with subjective presence scores. The validity of duration estimation was not supported.

Primary Source

IJsselsteijn, W., De Kort, Y., & Bierhoff, I. (2001). *Duration Estimation and Presence.* Paper presented at Presence 2001, Philadelphia, USA, 9-11 October 2001.

Other literature

Lombard, M. (1995). Direct responses to people on the screen: Television and personal space. *Communication Research, 22*, 288-324.

Waterworth, E. L., & Waterworth, J. A. (2001). Focus, locus and sensus: The 3 dimensions of virtual experience. *CyberPsychology and Behavior, 4,* 203-214.

SIMULATOR SICKNESS QUESTIONNAIRE (SSQ)

Description

Concept: Physical presence.
There are two alternative hypotheses about the relationship between presence and motion sickness:

1. A higher degree of presence provokes a greater degree of conflict between the visual and the proprioceptive senses, which leads to a higher degree of motion sickness.
2. Motion sickness may distract the user and lower the sense of presence.

The simulator sickness questionnaire (SSQ) is an extensively used protocol for measuring reported simulator sickness (Kennedy, Lane, Berbaum, & Lilienthal, 1993). Simulator sickness is divided into three components: nausea, oculomotor effects, and disorientation. The SSQ contains

16 items, each scored on a four point rating scale. Kennedy et al. (1993) give extensive instructions about the usage and scoring of the SSQ.

Research
Wilson, Nichols, and Haldane (1997) used the SSQ in two presence experiments. In the first experiment (n=20) subjects filled out the Witmer and Singer PQ and the SSQ after immersion in a VE wearing a HMD. Only the interface subscale of the PQ showed a significant negative correlation with SSQ scores. In the second experiment (n=24, between-subjects design), subjects participated in a "duck-shooting" VE using either HMD or desktop. Presence scores (items taken from several existing questionnaires) and SSQ scores were significantly higher in the HMD condition compared to the desktop condition, and a significant positive correlation was found between these measures in the HMD condition.

Sensitivity: The SSQ scores discriminated between different systems.
Reliability: Not reported .
Validity: Significant correlations between SSQ scores and presence scores were found, however, the correlation was positive in one study and negative in another.

Primary Source
Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *International Journal of Aviation Psychology*, *3*(3),203-220.

Other Literature
Wilson, J. R., Nichols, S. & Haldane, C. (1997). Presence and side-effects: Complementary or contradictory? In M.J. Smith, G. Salvendy, & R. J. Koubek (Eds). *Design of Computing Systems: Social and Ergonomic Considerations, Proceedings of the Seventh International Conference on Human-Computer Interaction, (HCI International '97)* (pp. 889-892). San Francisco, USA.

MEMORY CHARACTERISTIC QUESTIONNAIRE (MCQ)

Description
Concept: Physical presence.
Hoffman, Hullfish, and Houston (1995) used the approach of source monitoring in order to measure presence. Virtual reality monitoring is defined as "the decision process by which people distinguish between real, virtual, and imagined events, as represented in memory" (p. 9). It was proposed that real, virtual and imagined environments differ in quality (e.g., in the amount of cognitive effort they require). "These differences are preserved in memory, and can later serve as cues to where the memory originated" (p.17).
The Memory Characteristic Questionnaire (MCQ) was designed to assess this qualitative difference between experiences in memory. The questionnaire contains 21 items on a seven point rating scale, and includes metamemory judgments concerning presence, attention, coherence, field-of-view, and similarity among environments. The items are listed in Appendix A.

Research
The MCQ was used in an experiment comparing real, virtual, and imagined worlds (hullfish, 1996). Participants (n=16, within-subjects design) encountered 24 worlds (arrangements of shapes on a chess board) which could be real, virtual, or imagined. Afterwards, they completed a Virtual Reality monitoring test (recognition of encountered worlds) and the MCQ, in which they answered each item three times (for real, imagined and virtual worlds each). The results section discusses only one item of the MCQ, the one related to cognitive effort. Cognitive effort was highest for imagined worlds, lower for virtual worlds and lowest for real worlds. Results for other MCQ items are given in Appendix E and show several significant differences, e.g. for the items related to restrictedness, easy to view, easy to identify, and disorientation. For all items, the real

world scores were highest, followed by the virtual world scores, and the imagined world scores were lowest.

Sensitivity: several items discriminated between real, virtual, and imagined worlds
Reliability: not reported
Validity: not reported

Primary Sources

Hoffman, H. G., Hullfish, K. C., & Houston, S. J. (1995). Virtual reality monitoring. In *Proceedings of Virtual Reality Annual International Symposium*, 11-15 March 1995, Research Triangle Park, North Carolina. Los Alamitos: IEEE Computer Society Press.

Hullfish, K. C., (1996). Virtual reality monitoring: How real is virtual reality? Master's thesis, University of Washington, USA.

ATTENTION/AWARENESS

Description

Concept: Physical presence.
Darken, Bernatovich, Lawson, and Peterson (1999) argued that selective attention is an important component of presence. Their approach was based on Held and Durlach's (1992) notion of presence as an "alternate experience". In order to be present in an alternate world, attention must be focused there rather than on the real world.

Research

In an experiment by Darken et al. (1999), participants (n=70, between-subjects design) experienced a virtual world whilst a videotape ("Wallace and Gromit") was simultaneously shown. Independent variables were type of visual display (flatscreen, mini-CAVE or HMD), presence/absence of sound, and whether or not participants were primed to the presence of the dual task. Attention/engagement was measured through quizzes about the content of both the virtual and the real (videotape) world experiences. Subjects also completed the Witmer and Singer PQ. Attention scores of both the real and the virtual world experiences were highest in the mini-CAVE condition, lower in the flatscreen condition and lowest in the HMD condition. For the virtual world attention scores these differences were not significant, for the real world attention scores they were. Attention scores for the virtual world were higher in the condition where sound was present (as expected), but scores on real world attention were also higher in the sound condition. The authors suggested that the presence of sound allowed users to divide attention along a multi-modal axis. A significant relationship (regression analysis) was found between attention scores and PQ scores.
Nichols, Haldane, & Wilson (2000) measured background awareness by recall of background music. In their experiment (n=24, between-subjects design) using a VE representing a duck-shoot fairground stall, independent variables were system (HMD or desktop) and audition (full or none). Presence was measured subjectively by three items. There was a significant negative correlation between one presence item (visiting) and background awareness scores. No significant difference in awareness scores was found between the different conditions.

Sensitivity: One of Darken et al.'s (1999) measures (the real world attention score) distinguished between different systems. Nichols et al.'s measure did not discriminate between different conditions.
Reliability: Not reported.
Validity: Darken et al. (1999) found a significant correlation between their measure and PQ scores.

Sources

Darken, R. P., Bernatovich, D., Lawson, J., & Peterson, B. (1999). Quantitative measures of presence in virtual environments: The roles of attention and spatial comprehension. CyberPsychology and Behavior, 2, 337-347.

Nichols, S., Haldane, C., & Wilson , J. R. (2000). Measurement of presence and its consequences in virtual environments*. International Journal of Human Computer Studies, 52,* 471-491.

SPATIAL MEMORY

Description

Concept: Physical presence.

Similar to their attentional measures, Darken, Bernatovich, Lawson, & Peterson (1999) base this approach on Held and Durlach's (19992) notion of presence as an "alternate experience". If presence is the sense of being in another place, the amount of spatial information that is remembered from the VE can be used as a presence measure.

Research

Darken et al. (1999) used pointing, map building, and landmark selection spatial tests. Participants (n=40, between-subjects design) experienced a virtual world with a mini-CAVE system. The independent variable was sound. There were four different conditions: no sound, semantic information only, spatial information only, or both spatial and semantic information. Presence was measured using the PQ (Witmer & Singer, 1998). The presence of sound in any form was found to significantly increase PQ scores and landmark selection scores, but not the scores on other spatial tasks. No relationship was found between PQ scores and spatial comprehension.

Dinh, Walker, Song, Kobayashi, & Hodges (1999) used four spatial layout questions and five object location questions to assess spatial memory of a VE depicting an office (n=322, between-subjects design). The level of visual detail, olfactory stimulation, ambient auditory stimulation and tactile stimulation were varied as independent variables. No effects were found on the spatial layout scores. A significant positive effect of tactile cues and olfactory cues was found on object location scores.

Sensitivity: Two out of three spatial tests used by Darken et al.(1999) were sensitive to the presence of sound. An object location questionnaire used by Dinh. et al. (1999) was sensitive to tactile and olfactory cues.

Reliability: Not reported.

Validity: Inconclusive. In both studies, presence-enhancing factors influence some spatial measures, but not others.

Sources

Darken, R. P., Bernatovich, D., Lawson, J., & Peterson, B. (1999). Quantitative measures of presence in virtual environments: The roles of attention and spatial comprehension. CyberPsychology and Behavior, 2, 337-347.

Dinh, H. Q., Walker, N., Song, C., Kobayashi, A., & Hodges L.F. (1999). Evaluating the importance of multi-sensory input on memory and the sense of presence in virtual environments. *Proceedings of the IEEE Virtual Reality 1999*, 222-228.

SPATIAL MEMORY AWARENESS STATES

Description

Concept: Physical presence.
Mania, Troscianko, Hawkes, & Chalmers (2003) developed a methodology for assessing simulation fidelity of a VE based on human judgment of memory awareness states. Performance alone is was considered an imperfect reflection of the subjective experience that underlies performance in memory tasks. A distinction was drawn between different awareness states: "remembering", which is accompanied by a specific recollection of the source, and "knowing", which is a general sense not accompanied by such a recollection.
A questionnaire was designed to test memory recall of the positions and geometric shape of objects in the VE. A diagram of each wall in the room included numbered positions of objects. The questionnaire consists of 21 multiple choice questions; one for each object in the room. Every question is accompanied by three possible answers (box, sphere, pyramid), a confidence scale with five possible states (no confidence, low confidence, moderate confidence, confident, certain), and an awareness state report (remember, know, familiar, guess). Awareness state responses are taken to reflect the amount of visual mental imagery involved during retrieval.

Research

Participants (n=105, between-subjects design) were distributed over five conditions: real world, HMD mono head-tracked, HMD stereo head-tracked, HMD mono mouse, and desktop. In addition to the memory recall task, participants also completed the SUS presence questionnaire (Slater, Usoh, & Steed, 1994). The recall task was completed two times: immediately after the experiment and one week later.
There was a significant main effect of condition upon awareness state. Although the more naturalistic head-tracking interfaces (such as head-tracking) were expected to be associated with more correct responses compared to less naturalistic interfaces (such as mouse and desktop), this was not the case: the amount of correct responses in the "remember" state was higher for the HMD mono mouse condition than for both HMD tracking conditions. These responses correlated positively with confidence scores. The SUS results were not reported.

Sensitivity: The questionnaire scores discriminated between conditions, although not in the expected direction.
Reliability: Not reported.
Validity: Not reported.

Primary Source

Mania, K., Troscianko, T., Hawkes, R., & Chalmers, A. (2003). Fidelity metrics for virtual environment simulations based on spatial memory awareness states. *Presence: Teleoperators and Virtual Environments, 12,* 296-310.

GRAVITY-REFERENCED EYE LEVEL (GREL)

Description

Concept: Physical presence.
By manipulating the orientation of a VE, visual information is provided about spatial location, which is different from information provided by non-visual stimuli. Nemire, Jacoby, and Ellis (1994) proposed that the extent to which the visual information biases participants' estimates of spatial orientation can be used as a measure of simulation fidelity.
Participants are asked to estimate their eye level when viewing a pitched VE through a HMD. The GREL measure is calculated based on actual eye level and estimated eye level. The formula is described in the paper.

Research
Participants (n=12, mixed design) wore a HMD showing a virtual box. The orientation of the VE was manipulated by pitching it around the horizontal axis. Participants saw five different angles, with a varying optic structure of the visual stimuli: no grid, transverse partial grid, longitudinal partial grid, full grid. Participants, who had to remain motionless themselves, were asked to indicate their eye level. Data were compared to a similar experiment carried out in a real life physical environment.
Results showed that GREL was biased by the direction of the VE pitch. For simple or transverse partial grid conditions, this bias was greater in the physical environment than in the VE; for the longitudinal partial grid and full grid conditions the bias of the VE was not different from the bias of the physical environment.

Sensitivity: The GREL scores were affected by tilting angle.
Reliability: Not reported.
Validity: Not reported.

Primary Source
Nemire, K., Jacoby, R. H., & Ellis, S. R. (1994). Simulation fidelity of a virtual environment display. *Human Factors, 36*, 79-93.

SUBJECTIVE TILT ANGLE

Description
Concept: Physical presence.
The subjective tilt angle measure used by Hatada, Sakata, and Kusaka (1980) was based on the idea of "unification of display and observer space", which produces "a feeling of seamless continuity under which the observer is presented with the information contained in the displayed picture" (p. 564). Objective, visually obtained information influences the condition of the observer's subjective coordinate axis, which can be used as a measure of the sensation of reality. A subject is placed in front of a hemispherical glass-bead concave 180 degree screen, looking at it in a vertical position. The measurement procedure is as follows:

1. Without a picture being shown, a tilted line target is presented to which the observer adjusts his posture so that it appears to be vertical.
2. Still without a picture, the direction is determined at which the subject feels that the target line is vertical.
3. The subject is shown a tilted picture for 15 seconds.
4. The line target is shown again and it is determined at what tilt angle the observer feels the line is vertical.

These steps are repeated several times. The difference between the subjectively vertical tilt angles of step 2 and 4 is the effect induced by the picture.

Research
Earlier work has shown that the effects on the observer increase when the view angle is widened. View angle was found to have a similar effect on the "sense of reality", measured by a subjective seven step scale (no further explanation is given). The effect was also shown to be stronger when pictures contained pronounced perspective elements.

Sensitivity: Method distinguished between different viewing angles and differences in content.
Reliability: Not reported.
Validity: Similarity in results obtained by measuring subjective tilt angle and subjective sense of reality.

Primary Source
Hatada, T., Sakata, H., & Kusaka, H. (1980). Psychophysical analysis of the sensation of reality induced by a visual wide-field display. *SMPTE Journal*, 89, 560-569.

3. Objective Corroborative Measures

IJsselsteijn (2004) argues that “as the fidelity of the displayed environment increases, responses to that environment will be increasingly similar to responses we exhibit to the same objects, agents, or events in real environments”. This *response similarity* approach, rooted in the *behavioral realism* approach of Freeman, Avons, Meddis, Pearson, and IJsselsteijn (2000), forms the rationale behind a diverse set of objective corroborative indicators of presence such as physiological measures, behavioural measures, task performance measures, and neural correlates. These measures have mainly been used or suggested because they are not influenced by the participant’s subjective interpretation. Another advantage is that objective corroborative measures are relatively unobtrusive once the participant has gotten used to wearing the equipment (e.g., electrodes), because they address responses that are generated automatically. A problem of objective corroborative measures is that it not always clear what is being measured (a challenge to validity). Such measures can also be sensitive to factors that do not influence presence (IJsselsteijn, 2004). This is especially true for physiological measures; different stimuli can produce the same physiological response (Insko, 2003).

3.1 Psychophysiological Measures

Psychophysiological techniques address physiological processes such as heartbeat, blood flow, electrodermal processes, reactions of the eyes, and muscular responses. In line with the response similarity paradigm, it can be assumed that as the sense of presence in a VE increases, the physiological responses to the environment will become increasingly similar to those exhibited in a similar real environment (IJsselsteijn, 2004).
Apart from their objectivity, an advantage of physiological measures is that they are continuous, allowing for the assessment of time-varying characteristics of presence. As noted before, a disadvantage of physiological measures is that it can be difficult to determine what is being measured. Other difficulties are measurement noise and orienting effects (reactions to new stimuli) which may overwhelm effects of experimental manipulations, individual differences in physiological level (which can be controlled by establishing a baseline for each participant), and the fact that some physiological measures, such as skin temperature, change rather slowly (Insko, 2003). Finally, measurement equipment is expensive, and the wearing of sensors may interfere with participants’ experiences.

CARDIOVASCULAR MEASURES

Description
Cardiovascular measures are associated with heart rate and blood pressure. An electrocardiogram (ECG) is a graphic produced by an electrocardiograph, which records the electrical current in the heart in the form of a continuous graph. Cardiovascular activity is associated with emotional experience, hedonic valence, orienting response to novelty, and defensive responses (Dillon. Keogh, Freeman, & Davidoff, 2000).
Laarni, Ravaja, & Saari (2003) suggested that both automatic and controlled attention play an important role in presence, for which cardiac measures can be an indicator. Phasic heart rate deceleration was suggested as a measure of automatic attention, and respiratory sinus arrhythmia (a measure based on the influence of breathing on the heart rhythm) as a measure of controlled attention.

Research
Meehan, Insko, Whitton, & Brooks (2001) investigated physiological reactions, including heart rate (HR), in three experiments using a VE containing two non-stressful rooms and a stressful virtual pit room. The first study (n=10, within-subjects design) investigated the hypothesis that presence declines over multiple exposures on separate days. The second study (n=52, within-subjects design) investigated the hypothesis that passive haptics (the presence of a wooden

ledge) increases presence. The third study (n=33, within-subjects design) investigated the hypothesis that presence increases when frame rate increases. In all three studies, HR was significantly higher in the Pit Room (as compared to the other two rooms of the VE). Unlike the other psychophysiological measures used in the study, HR did not show an orienting effect. As anticipated, HR was significantly higher in the condition with the passive haptics. HR was found to correlate significantly with reported presence and reported behavioural presence as measured by a questionnaire. The authors concluded that HR is a promising between-subjects measure.
Dillon, Keogh, & Freeman (2002) investigated the effects of content and visual angle of the display on presence. In their study (n=24, mixed design), the content of a video clip (amusement, sadness, neutral) was varied within-subjects and the horizontal visual angle (21 or 42 degrees) was varied between-subjects. A significant effect of content was found on HR (there was a greater lowering of HR for Amusement and Sadness material than for Neutral material). No significant effect of angle on HR was found.
Slater, Brogni, & Steed (2003) investigated whether breaks in presence (BIPs) corresponded to changes in physiological state, such as HR. In an experiment which examined the effect of six different VE scenes on presence, subjects (n=60, between-subjects design) visited urban VEs inside a CAVE-like system, and were instructed to report BIPs by pressing a button. Heart Rate was measured during this experience. Mean HR was found to increase and reach a peak approximately 1 second before a BIP was signalled. Additional data were gathered to establish whether this was not merely a result of (the intention of) pressing the button, and this was confirmed.
In an experiment conducted by Wiederhold et al. (2001), participants (n=72) took part in a six minute VR airplane flight. Subjective measures included HR and a questionnaire on Presence and Realism (taken from Parent, 1998). HR showed significant negative correlations with both Presence and Realism.
Ravaja (2002) used respiratory sinus arrhythmia (RSA) as a measure for attention/engagement. In his experiment, participants (n=36, within-subjects design) saw financial news messages presented on a very small display, accompanied by either a static or a moving face. RSA scores were significantly lower in the moving face condition.

Sensitivity: Heart rate discriminated between stressful/non-stressful conditions and the absence/presence of passive haptics in Meehan's experiment, and between different types of content in the Dillon et al. study. RSA scores discriminated between static and moving interfaces in Ravaja's experiment.
Reliability: Not reported.
Validity: Correlations between HR and reported presence and reported behavioural presence in Meehan's experiment. Correspondence with reported BIPs (Slater et al.). Correlations between heart rate and subjective presence and realism (Wiederhold et al.).

Sources

Dillon, C., Keogh, E., Freeman, J., & Davidoff, J. (2000). Aroused and immersed: The psychophysiology of presence. In W. IJsselsteijn, J. Freeman, & H. de Ridder (Eds). *Proceedings of the Third International Workshop on Presence*.

Dillon, C., Keogh, E., & Freeman, J. (2002). 'It's been emotional': Affect, physiology and presence. In F.R. Gouveia, & F. Biocca (Eds). *Proceedings of the 5th International Workshop on Presence*.

Laarni, J., Ravaja, N. & Saari, T. (2003). Using eye tracking and psychophysiological methods to study spatial presence. In *Proceedings of the 6th International Workshop on Presence.* Aalborg, Denmark, 6-8 October 2003.

Meehan, M., Insko, B., Whitton, M., & Brooks, F. P. (2001). Physiological measures of presence in virtual environments. In *Proceedings of 4th International Workshop on Presence*. Philadelphia, USA, 21-23 May, 2001.

Ravaja, N. (2002). Presence-related influences of a small talking facial image on psychophysiological measures of emotion and attention. In F.R. Gouveia, & F. Biocca (Eds). *Proceedings of the 5th International Workshop on Presence*.

Slater, M., Brogni, A., & Steed, A. (2003). Physiological Responses to Breaks in Presence: A Pilot Study. In *Proceedings of the 6th International Workshop on Presence.* Aalborg, Denmark, 6-8 October 2003.

Wiederhold, B. K., Dong, P. J., Kaneda, M., Cabral, I., Lurie, Y., May, et al. (2001). An investigation into physiological responses in virtual environments: an objective measurement of presence. In G. Riva, & C. Calimberti, (Eds). *Towards cyberpsychology: Mind, cognition and society in the internet age.* Amsterdam: IOS Press.

SKIN MEASURES

Description

There are two psychophysiological measures related to the skin: skin temperature (ST) and skin conductance (SC). Measures of skin conductance, which is also referred to as electrodermal activity (EDA) or galvanic skin response (GSR), record changes in the electrical conductance of the skin, generally from the fingers or palms. SC is associated with emotional arousal, memory effects, and orienting response to novelty (Dillon et al., 2000).

Research

Meehan, Insko, Whitton, and Brooks (2001) used SC and ST in three experiments using a stressful VE including a virtual pit room (see section 'cardiovascular measures'). In all three studies, SC was significantly lower in the Pit Room as compared to the other two rooms of the VE. SC decreased significantly after the first exposure. SC was significantly higher in the condition with the passive haptics, whereas ST showed the opposite effect. SC was found to correlate significantly with reported presence and reported behavioural presence as measured by a questionnaire. No correlations with ST were found.

Dillon et al (2002) used SC in a study investigating the effects of content and visual angle of the display on presence (the study is described in the section on cardiovascular measures). Measures also included the SUS questionnaire (slater, Usoh, & Steed, 1994), and items relating to Engagement and Negative Effects taken from the ITC-SOPI questionnaire (Lessiter, Freeman, Keogh, & Davidoff, 2001). SC was generally (significance is not reported) higher in the Amusement category. A larger visual angle was associated with a lower negative SC deviation from baseline. This angle was also rated higher on the second SUS item.

Slater et al (2003) investigated the relationship between breaks in presence (BIPs) and physiological measures (see section 'cardiovascular measures'). Mean SC was found to increase and reach a peak approximately 1.8 seconds after a BIP was signalled. Additional data were gathered to make sure that this was not merely due to (the intention of) pressing the button. In a control group where anxiety was induced, SC showed a similar response, suggesting that a BIP may be a stress-inducing event.

In Wiederhold et al.'s (2001) study (see section 'cardiovascular measures'), ST showed significant correlations with both Presence and Realism questionnaire scores.

Sensitivity: The SC measures discriminated between stressful/non-stressful conditions and the absence/presence of passive haptics in Meehan's experiment, and between different content in Dillon et al. The sensitivity of ST was only supported by Wiederhold et al..

Reliability: Not reported.

Validity: Correlations were found between SC and both reported presence and reported behavioural presence (Meehan et al., 2001) and with SUS item 2 in Dillon et al. (2002). Correspondence to reported Breaks in Presence (Slater et al., 2003). Correlations between ST and subjective presence and realism (Wiederhold et al., 2001).

Sources

Dillon, C., Keogh, E., Freeman, J., & Davidoff, J. (2000). Aroused and immersed: The psychophysiology of presence. In W. IJsselsteijn, J. Freeman, & H. de Ridder (Eds). *Proceedings of the Third International Workshop on Presence*.

Dillon, C., Keogh, E., & Freeman, J. (2002). 'It's been emotional': Affect, physiology and presence. In F.R. Gouveia, & F. Biocca (Eds). *Proceedings of the 5th International Workshop on Presence*.

Meehan, M., Insko, B., Whitton, M., & Brooks, F. P. (2001). Physiological measures of presence in stressful virtual environments. In *Proceedings of 4th International Workshop on Presence*. Philadelphia, USA, 21-23 May, 2001.

Slater, M., Brogni, A., & Steed, A. (2003). Physiological Responses to Breaks in Presence: A Pilot Study. In *Proceedings of the 6th International Workshop on Presence.* Aalborg, Denmark, 6-8 October 2003.

Wiederhold, B. K., Dong, P. J., Kaneda, M., Cabral, I., Lurie, Y., May, et al. (2001). An investigation into physiological responses in virtual environments: an objective measurement of presence. In G. Riva, & C. Calimberti, (Eds). *Toward cyberpsychology: Mind, cognition and society in the internet age.* Amsterdam: IOS Press.

OCULAR MEASURES

Description

There are many psychophysiological measures associated with the eyes. Two have been suggested for presence research: eye tracking and pupil response. Eye tracking measures can be divided into two categories: spatial and temporal (Goldberg & Kotval, 1999). Spatial measures are, for example, amplitude of saccades and scanpath length. Temporal measures include fixation duration, fixation number, and scanpath duration.

Laarni, Ravaja, & Saari (2003) discussed the use of eye tracking measures for presence research. Three methods suitable for researching spatial presence were identified:

1. The degree to which the user's attention is distracted away from the mediated experience
2. The aspects of the mediated information looked at by the user and the order in which different areas of media stimuli were processed
3. Attention strategy (focused attention or distributed attention).

Pupilometry is the study of how a pupil reacts to different emotions and stimuli. Whereas facial expressions can be inhibited, the dilation and contraction of the pupils is an involuntary response not controllable by cognitive means. Huang & Alessi (1999) suggested that this approach could be used in presence research.

Research

Not reported. Laarni et al. (2003) proposed that eye tracking should be combined with other continuous measures such as phasic heart rate deceleration (as a measure of automatic attention) and respiratory sinus arrhythmia (as a measure of controlled attention).

Sources

Laarni, J., Ravaja, N. & Saari, T. (2003). Using eye tracking and psychophysiological methods to study spatial presence. In *Proceedings of the 6th International Workshop on Presence.* Aalborg, Denmark, 6-8 October 2003.

Huang, M., & Alessi, N. (1999). Presence as an emotional experience. In J. D Westwood, H. M. Hoffman, R. A. Robb, & D. Stredney, (Eds). *Medicine meets virtual reality: The convergence of physical and informational technologies options for a new era in healthcare.* Amsterdam: IOS Press.

Goldberg, J.H., & Kotval, X.P. (1999). Computer interface evaluation using eye movements: Methods and constructs. *International Journal of Industrial Ergonomics, 24,* 631-645.

FACIAL ELECTROMYOGRAPHY (EMG)

Description

Facial EMG is recorded by surface electrodes placed on the skin of the face. The potential difference measured at the electrode can be used as an indication of emotion.

Research

Facial EMG was used in an experiment by Ravaja (2002) (see section 'cardiovascular measures'). Participants viewed financial news messages presented on a very small display, accompanied by either a static or a moving face. EMG scores were higher in the moving face condition, as were subjectively rated emotional reactions and arousal.

Sensitivity: EMG discriminated between different conditions.
Reliability: Not reported.
Validity: Similar results of subjective emotional measures.

Source

Ravaja, N. (2002). Presence-related influences of a small talking facial image on psychophysiological measures of emotion and attention. In F.R. Gouveia, & F. Biocca (Eds). *Proceedings of the 5th International Workshop on Presence*.

3.2 Neural Correlates

Psychophysiological techniques aimed at studying brain processes and activity are addressed in this section. Such measures seem promising, because they yield "hard", objective data which are in no way influenced by interpretation on the part of the participant. However, the interpretation of such data is extremely difficult, because so little is known about the neural processes that are involved in the complex experience of presence. IJsselsteijn (2004) discusses several paradigms which could contribute towards an unambiguous operationalisation of presence in order to meaningfully interpret brain patterns. In addition to these problems of interpretation, brain imaging equipment is generally expensive and extremely intrusive. Body movements are restrained, and especially fMRI equipment tends to produce a lot of noise.

ELECTROENCEPHALOGRAM (EEG)

Description

An electroencephalograph is a device which amplifies and records electrical activity from the scalp using a number of small electrodes which are temporarily adhered to the scalp. EEG is usually described in terms of frequency bands: delta (less than 4 Hz), theta (4-8 Hz), alpha (8-12 Hz), beta (13-30Hz), and gamma (greater than 30Hz).
EEG has been suggested as a means to study presence from a cognitive (Pugnetti, Mendozzi, Barberi, Rose, & Attree, 1996) or emotional (Huang et al., 1999) perspective. Schlögl, Slater, & Pfurtscheller (2002) discussed properties, advantages and disadvantages of EEG. Advantages are that it is non-invasive, has a high time-resolution and can be used in almost any environment. Disadvantages are the poor signal to noise ratio and inter- and intra-trial variability. They suggest that adaptive autoregressive (AAR) parameters can be used to continuously classify the EEG spectrum. This might be useful in presence research. More specifically, they suggest that EEG could be used to complement the "breaks in presence" technique.

Research

Pugnetti, Mendozzi, Barberi, Rose, and Attree (1996) have used EEG and auditory evoked potentials (EP) to study cognitive tasks carried out in a VE (n=10). An inverse relationship was found between EEG alpha amplitude and performance measures (time, errors).
Strickland and Chartier (1997) investigated whether it is possible to obtain valid brain activity readings when subjects are wearing a headset, and whether there are differences in brain activity in similar virtual and real environments. Participants (n=14, within-subjects design) performed a set of tasks both with and without a HMD. Tasks were sitting with eyes closed, sitting with eyes open looking straight ahead, tracking the movement of a hand, and looking around. No artefact differences were found in Alpha, Theta, or Beta1 frequencies. Beta2 showed muscle artefacts caused by the weight of the helmet. Delta frequencies also showed artefacts, possible due to poor headset visual quality. The authors conclude that there was no interference of the helmet. The results showed that there were indeed differences between real and virtual image processing, but variations were more affected by subject and task than by brain area.

Sources

Huang, M., & Alessi, N. (1999). Presence as an emotional experience. In J. D Westwood, H. M. Hoffman, R. A., Robb, & D. Stredney, (Eds). *Medicine meets virtual reality: The convergence of physical and informational technologies options for a new era in healthcare.* Amsterdam: IOS Press.

Pugnetti, L., Mendozzi, L., Barberi, E., Rose, F. D., & Attree, E. A. (1996). Nervous system correlates of virtual reality experience. In P. M. Sharkey (Ed.). *Proceedings of the 1st European Conference on Disability, Virtual Reality & Associated Technologies*. Maidenhead, UK, 8-10 July 1996.

Schlögl, A., Slater, M., & Pfurtscheller, G. (2002). Presence Research and EEG. In F.R. Gouveia, & F. Biocca (Eds). *Proceedings of the 5th International Workshop on Presence*.

Strickland, D., & Chartier, D. (1997). EEG measurements in a virtual reality headset. *Presence: Teleoperators and Virtual Environments, 6,* 581-589.

FUNCTIONAL MAGNETIC RESONANCE IMAGING (FMRI)

Description

Functional magnetic resonance imaging (fMRI) is a technique which detects changes in the blood flow to the brain; using magnetic fields to provide images of the areas of the brain that are activated during a cognitive task. Thus, brain activity patterns associated with various types of mental activities can be studied.

Research

Studies using fMRI as a presence measure have not yet been reported.
Hoffman, Richards, Coda, Richards, and Sharar (2003) investigated whether participants can experience presence during an fMRI scan. In their study, participants (n=7, within-subjects design) were exposed to a VE depicting a winter landscape in which they could throw snowballs. During this experience they were in an fMRI scan. There were two conditions: a high-presence condition in which view was unobstructed, and a low-presence condition in which a white cross obstructed part of the view. Subjective presence was measured by one question. All subjects reported higher presence in the high-presence condition (mean rating was 7.0 in high presence condition, 4.1 in low-presence condition, 10 point scale). The fMRI results were not reported in the paper, because the authors were fearful of misinterpretation.

Primary Source

Hoffman, H.G., Richards, T., Coda, B., Richards, A., & Sharar, S.R. (2003). The illusion of presence in immersive virtual reality during an fMRI brain scan. *CyberPsychology & Behavior, 6,* 127-131.

3.3 Behavioural Measures

Like physiological measures, behavioural measures are based on the idea that the more a participant feels present in a virtual environment, the more similar his/her responses to stimuli will be to those s/he would exhibit in a similar real environment (IJsselsteijn, 2004). Therefore, it has been proposed that naturalistic behaviours such as startle responses, postural sway, and conditioned social responses can be used as indicators of presence.
An advantage of behavioural measures is that they are relatively free from bias, because they are generally not under users' conscious control, nor do they require specific instructions from the experimenter. They occur spontaneously, and therefore do not disrupt the experience. Also, they can be continuous measures of presence.
A problem of behavioural measures is that they are prone to bias originating from the experimenter, who observes and interprets the behaviour. This risk can be minimized by having independent observers score the behaviour according to a predefined categorization scheme, from which the inter-rater reliability can be calculated (IJsselsteijn, 2004). Also, the data-analysis can be time-intensive and difficult to interpret. Finally, behavioural measures are have limited generalizability; most behavioural measures are only applicable to a specific environment or content.

FACIAL EXPRESSION

Description
Observation of facial expression can be used to study the emotional components of presence (Huang et al., 1999). Facial expression can either be scored by human observers, or automatically recognized by means of pattern analysis. There are several methods to aid manual scoring; the most commonly used are the Facial Action Coding System (FACS) and the Maximally Discriminative Affect Coding System (MAX) (Ekman, 1985).

Research
Facial expression has been suggested for presence research by Huang and Alessi (1999)., but has not yet been used.

Sources
Ekman, P. (1982). Methods for measuring facial action. In K. Scherer and P. Ekman (Eds). *Handbook of methods in nonverbal behavior research* (pp. 45-135). Cambridge: Cambridge University Press.

Huang, M., & Alessi, N. (1999). Presence as an emotional experience. In J. D Westwood, H. M. Hoffman, R. A. Robb, & D. Stredney, (Eds). *Medicine meets virtual reality: The convergence of physical and informational technologies options for a new era in healthcare.* Amsterdam: IOS Press.

NULLING

Description
Prothero and Parker (2003) hypothesized that presence is "an illusion of position and orientation". According to the rest frame hypothesis, a particular reference frame, the "rest frame", is selected as the comparator for spatial judgments. The sense of presence in an environment is thought to reflect the degree to which that environment influences the selected rest frame. Presence is accordingly measured as the degree to which virtual cues overwhelm real cues.
In "nulling", this approach is used by asking subjects to determine the point at which two stimuli counterbalance each other.

Research
Participants (n=12, within-subjects design) wore a HMD providing visual self-motion while sitting in a rotating chair providing conflicting inertial self-motion cues. In each of two sessions, participants saw two visual conditions consisting of meaningful vs. non-meaningful (random pixels) material. Presence was measured by a visual-inertial crossover measure and a subjective presence rating (one item accompanied by a seven point rating scale). The crossover measure was based on participants signalling their perception of the left/right extremes of chair motion by switching a toggle.
As predicted, inertial crossover velocity was higher for the meaningful visual condition. For subjective presence, the difference was in the same direction but not significant. No significant correlation was found between the measures. A larger correlation, approaching significance ($r=.38$, $p<.07$) was found between the (differences between) visual conditions for both measures.

Sensitivity: The measure distinguished between different conditions.
Reliability: Not reported.
Validity: A moderate correlation with subjective presence measure.

Primary Source
Prothero, J., & Parker, D. (2003). A unified approach to presence and motion sickness. In L. Hettinger & M. Haas (Eds). *Virtual and adaptive environments: Applications, implications, and performance issues* (pp. 47-66). Mahwah, NJ: Lawrence Erlbaum Associates.

Other Literature
Prothero, J., Parker, D., Furness, T. A., & Wells, M. (1995). Towards a robust, quantitative measure of presence. In *Proceedings of the Conference on Experimental Analysis and Measurement of Situational Awareness*, pp. 359-366.

POSTURAL RESPONSES

Description
The behavioural realism approach, introduced by Freeman, Avons, Meddis, Pearson, and IJsselsteijn (2000), was based on the principle that the more similar a display becomes to the environment it represents, the more observers will respond in the same way that they would respond to the environment itself.
Postural responses have been proposed as a presence measure. One advantage is that they are not mediated by high level cognitive processes, so they are unlikely to affect concurrent subjective evaluation. A second advantage is that they have the capacity to produce differential levels of response.
Postural responses occur under the illusion of observer motion, or vection. It has been argued that measures of vection and presence should be related (Freeman et al., 2000; Ohmi, 1998); if a user experiences vection in an environment, s/he is more likely to feel present in that environment.

Research
Hoshino, Takahashi, Oyamada, Ohmi, and Yoshizawa (1997) measured body sway and subjective physiological discomfort while viewing 3D video images of a boat with a rolling background (n=8, within-subjects design). Independent variables were rolling frequency (5 levels) and the system (3 levels: HMD, 70 inch 3D display, or TV). Body sway was measured using the "Quick Mag" motion analysing system, which takes videos of a marker put on the head of the subject. Results showed that body sway was highest for a HMD, lower for 3D display, and lowest for TV. The same pattern was found for the physiological discomfort scores.
In this same experiment, but reported in a later publication (Ohmi, 1998), body sway was measured while participants watched real-world non-stereo video clips taken from a moving car or train. Body sway was found to be proportional and in the same direction as centrifugal acceleration induced by the stimulus material.

Freeman et al. (2000) investigated the effects of stimuli displaying left and right turns in rapid forward motion. In their study (n=24, within-subjects design), participants viewed videos either taken from inside a racing car traversing a curved track (moving stimulus) or taken from the side (still stimulus). Stimuli were presented both monoscopically and stereoscopically. A Flock of Birds magnetic position tracker placed at the back of the neck was used to measure participants' x, y, and z positions. After each stimulus, participants rated their presence, involvement, vection, and simulator sickness on continuous scales.
Results showed a strong correlation between postural movements in both viewing conditions; observers moved in the same direction as the car. There was significantly more movement for moving than for still stimuli, in both viewing conditions. The increase in motion was larger for stereoscopic than for monoscopic viewing conditions, an effect that just failed to reach significance. Subjective presence, involvement, and simulator sickness ratings were higher for stereoscopic presentation and moving stimuli. Subjective vection ratings were higher for moving stimuli, but there was no effect of stereoscopic presentation. No correlation was found between postural movement and subjective presence ratings.
A replication of this study was conducted by IJsselsteijn, De Ridder, Freeman, Avons, and Bouwhuis (2001) using a larger display. By comparing the results to those of Freeman et al. (2000), the effect of screen size was studied. Effects of stereoscopic presentation and motion were comparable to the previous study. Results showed a significant effect of screen size on the subjective sense of presence, but only for the moving stimulus. No significant difference in postural responses was found between Freeman et al. (2000) and IJsselsteijn et al. (2001).

Sources

Freeman, J., Avons, S., Meddis, R., Pearson, D., & IJsselsteijn, W. (2000). Using behavioural realism to estimate presence: A study of the utility of postural responses to motion stimuli. *Presence: Teleoperators and Virtual Environments, 9,* 149-164.

Hoshino, M., Takahashi, M., Oyamada, K., Ohmi, M., & Yoshizawa, T. (1997). Body sway induced by 3D images. In *Proceedings of the SPIE, 3012*, 400-407.

IJsselsteijn, W., De Ridder, H., Freeman, J. F., Avons, S. E., & Bouwhuis, D. (2001). Effects of stereoscopic presentation, image motion, and screen size on subjective and objective corroborative measures of presence. *Presence: Teleoperators and Virtual Environments*, *10,* 298-311.

POINTING (CONFLICTING CUES)

Description

Slater, Usoh, and Chrysanthou (1995) used a presence measure based on conflicting real and virtual cues. Participants were asked to point towards a radio, which was present both in the real and the virtual world. The position of the real radio was changed after participants entered the VE, so the sound came from a different location. The idea is that a high degree of presence will lead participants to point towards the virtual rather than the real radio.

Research

In an experiment investigating the influence of shadows on sense of presence in a VE, participants (n=8, within-subjects design) were asked to select the spear closest to the wall out of five. Each participant took part in five trials, in one to four of which (this varied per participant) shadows were displayed. Measures included subjective presence, measured by six items, and the objective pointing measure. Results showed a positive relationship between the number of trials with shadows and both subjective and objective presence measures (but only for visually dominant participants). Objective and subjective presence were significantly positively correlated.

Sensitivity: A correlation between condition (presence of shadows) and the pointing measure.
Reliability: Not reported.

Validity: A significant correlation between the pointing measure and a subjective presence measure (SUS questionnaire).

Primary Source

Slater, M., Usoh, M., Chrysanthou, Y. (1995). The influence of dynamic shadows on presence in immersive virtual environments. In M. Goebel (Ed.). *Proceedings of the 2nd Eurographics Workshop on Virtual Reality.* Monte Carlo, Monaco, January 1995.

REFLEX RESPONSES

Description

Held and Durlach (1991) first proposed to use reflex responses as a measure for presence. Loomis (1992) suggested reflex responses as a method for discriminating between presence (the experience of being in a VE) and distal attribution (the experience of being in touch with a VE). Loomis argued that the observer will only show reflex responses to stimuli if s/he experiences them as "real".

Research

Nichols, Haldane, and Wilson (2000) (n=24) explored reflex responses to a startle event (see section 'Nichols et al. Questionnaire') as a measure for presence. Three categories of reactions were identified: no reaction, verbal report, and physical reaction. There was a positive correlation between three subjective presence items (being there, visiting the virtual world, forgetting real world) and the reflex response score. Reflex response was greater in the HMD condition than in the desktop condition. The reflex response was greater in the auditory condition than in the silent condition.

Sensitivity: The measure discriminated between different systems.
Reliability: Not reported.
Validity: Correlation with subjective presence as measured by questionnaire (three out of five items). Factors that were hypothesized to enhance presence increased the reflex response.

Primary Source

Nichols, S., Haldane, C., & Wilson , J. R. (2000) Measurement of presence and its consequences in virtual environments. *International Journal of Human Computer Studies, 52,* 471-491.

Other Literature

Held, R., & Durlach, N.I. (1991). Telepresence, time delay, and adaptation. In S.R. Ellis (Ed.), *Pictorial communication in virtual and real environments*. New York: Taylor and Francis.

Loomis, J. M. (1992). Presence and distal attribution: Phenomenology, determinants, and assessment. In *Proceedings of the SPIE, 1666,* 590-594.

SOCIAL RESPONSES

Description

Sheridan (1992) first suggested using socially conditioned responses to virtual social encounters, such as grasping for an object that is handed over, shaking hands, or utterances, as indicators of social presence. IJsselsteijn, De Ridder, Freeman, and Avons, (2000) also propose a broad range of social behaviours such as facial expressions, gestures, body and head movements, eye contact, vocal cues, turn-taking behaviour, use of space, and verbal expressions.

Research

Bailenson (2001, 2003) and his colleagues carried out several experiments that explored interpersonal distance in virtual environments. In one experiment, (see section 'Bailenson et al.

Questionnaire') participants were immersed in a virtual room in which a virtual male agent stood. In each trial they were asked to walk up to the agent and remember certain features and labels on the front and back of the agent's shirt. Position and orientation of participants were tracked. Photographic realism of the agent's face and the degree of gaze from the agent to the participant were varied. The results showed that participants maintained more space around agents than around nonhuman-like objects. Female participants maintained more interpersonal distance between themselves and agents who engaged them in eye contact. There was no effect of realism.
Two later experiments (n=80, between-subjects design) replicated and extended these results. Some participants were led to believe that the agents were avatars, controlled by real people, whereas others were told that they were bots. It was found that participants maintained personal space bubbles around virtual humans that were similar in size and shape to bubbles maintained around real humans. Participants gave an avatar more personal space than an agent, unless the agent displayed realistic gaze behaviour. Participants showed more avoidance of approaching virtual humans when they thought they were controlled by a computer.

Sensitivity: The measure discriminated between different conditions (avatar vs. agent, gaze behaviour).
Reliability: Not reported.
Validity: Not reported.

Sources

Bailenson, J.N., Blascovich, J., Beall, A.C., & Loomis, J.M. (2001). Equilibrium revisited: Mutual gaze and personal space in virtual environments. *Presence: Teleoperators and Virtual Environments, 10,* 583-598.

Bailenson, J.N., Blascovich, J., Beall, A.C., & Loomis, J.M., (2003). Interpersonal distance in immersive virtual environments. *Personality and Social Psychology Bulletin, 29,* 1-15.

IJsselsteijn, W. A., De Ridder, H., Freeman, J., & Avons, S. E. (2000). Presence: Concept, determinants and measurement. *Proceedings of the SPIE, 3959*, 520-529.

Sheridan, T. (1992). Musings on telepresence and virtual presence. *Presence: Teleoperators and Virtual Environments, 1,* 120-126.

3.4 Task Performance Measures

It has been suggested that task performance measures can be used as objective corroborative indicators of presence (Barfield & Weghorst, 1993). Though it is generally assumed that higher levels of presence are associated with better task performance, the exact relationship between presence and task performance remains unclear. There is no firm evidence indicating a causal link between the two constructs. It seems plausible that several characteristics of a VE will similarly influence presence and task performance (IJsselsteijn, 2004). Also, characteristics of the user, such as ability and motivation, will influence task performance (Heeter, 2001). Task performance measures are only applicable in media environments where there is a clear task that should be performed.
Many studies associating presence to task performance have been conducted. Only a few of them are described here, since it is our aim to review measures rather than draw a conclusion on the relationship between presence and task performance.

COMPLETION TIME AND ERROR RATE

Description
The time taken to complete a task and the number of errors made in that task are the most classic ways of measuring task performance.

Research
Basdogan, Ho, Srinivasan, and Slater (2000) investigated the influence of haptic feedback on task performance and sense of togetherness of participants in a shared virtual environment (see section 'Basdogan et al. Questionnaire'). They calculated a task performance score based on the time taken to complete the task and the ratio of time spent in the error-free condition. The results showed that haptic feedback increased both the task performance score and the subjective feeling of togetherness. Correlation between the measures is not reported.

Sensitivity: The performance score discriminated between two conditions.
Reliability: Not reported.
Validity: A similar pattern in performance scores and subjective feeling of togetherness.

Primary Source
Basdogan, C., Ho, C., Srinivasan, M. A., & Slater, M. (2000). An experimental study on the role of touch in shared virtual environments. *ACM Transactions on Computer Human Interaction, 7(4)*, 443-460.

NUMBER OF ACTIONS

Description
Instead of measuring the time taken to complete a task, it is also possible to count the number of actions or steps that is needed to complete a task.

Research
Slater, Linakis, Usoh, & Kooper (1996) used performance measures in a study (n=24, mixed design) in which participants played the game tri-dimensional chess. Participants were either immersed in the environment by means of a HMD (egocentric view), or viewed it on a TV (exogentric view). The environment was either realistic, or plain. The complexity of the game was slightly varied, requiring either seven or nine moves. Performance was measured as the number of correct moves (out of seven or nine) that the subject made. Also, the SUS questionnaire was administered after the experience.
Results showed that performance was positively associated with egocentric immersion in comparison with the exocentric screen based viewpoint. Also, performance was positively associated with a more realistic environment compared with an empty environment. Subjective

presence was significantly higher for the egocentric compared to exocentric condition, but realism did not have a significant effect on subjective presence.

Sensitivity: the performance score discriminated between different conditions
Reliability: not reported
Validity: partly similar pattern in performance scores and SUS scores.

Primary Source

Slater, M., Linakis, V., Usoh, M., & Kooper, R., (1996). Immersion, presence, and performance in virtual environments: An experiment with tri-dimensional chess. In M. Green (Ed), *ACM Virtual Reality Software and Technology* (pp. 163-172), 1-4 July 1996.

SECONDARY TASK PERFORMANCE

Description

Performance on a secondary task can serve as a measure for the amount of effort and attention allocated to the primary task. The more effort is dedicated to the primary task, the more performance on the secondary task will decrease. A similar argument can be made in the case of presence: if more attention is allocated to the mediated environment, performance on a secondary task will decrease. Reaction times or error rates can be used as secondary task performance measures (IJsselsteijn, 2004).

Research

Research using direct secondary task performance measures has not been reported. Nichols, Haldane, adn Wilson (2000) used a secondary task paradigm, in which they measured background awareness by recall of background music (see section 'attention/awareness'). No difference was found between awareness scores in the different conditions.

Sensitivity: The performance score did not discriminate between different conditions.
Reliability: Not reported.
Validity: Not reported.

Primary Source

Nichols, S., Haldane, C., & Wilson , J. R. (2000) Measurement of presence and its consequences in virtual environments. *International Journal of Human Computer Studies, 52,* 471-491.

TRANSFER

Description

Performance can be measured by the degree to which a skill which is learned or practised in a VE is transferred to a real-world situation.

Research

Youngblut & Perrin (2002) pursued this approach in a study (n=40, between-subjects design) in which participants practiced an aircraft maintenance task in a VE, either for a long or a short time. Afterwards, training transfer was measured as the time taken to complete the task on a physical mock-up and the number of errors made. They also completed the PQ and the SUS.
The results showed no effect of practice time on any of the performance measures. Neither of the presence questionnaire scores showed a correlation with time taken, but both showed a significant negative correlation with the number of errors.

Sensitivity: The performance scores did not discriminate between different conditions.
Reliability: Not reported.
Validity: The number of errors was correlated with subjective presence measures (PQ and SUS). Validity of the time measure is not supported.

Primary Source

Youngblut, C., & Perrin, B. M. (2002). *Investigating the relationship between presence and performance in virtual environments.* Paper presented at the IMAGE 2002 Conference, Arizona.

References

Bailenson, J.N., Blascovich, J., Beall, A.C., & Loomis, J.M. (2001). Equilibrium revisited: Mutual gaze and personal space in virtual environments. *Presence: Teleoperators and Virtual Environments, 10,* 583-598.

Bailenson, J.N., Blascovich, J., Beall, A.C., & Loomis, J.M., (2003). Interpersonal distance in immersive virtual environments. *Personality and Social Psychology Bulletin, 29,* 1-15.

Barfield, W., & Weghorst, S. (1993). The sense of presence within virtual environments: A conceptual framework. In G. Salvendy, & M. Smith (Eds). *Human-computer interaction: Applications and case studies* (pp. 699-704). Amsterdam: Elsevier.

Basdogan, C., Ho, C., Srinivasan, M. A., & Slater, M. (2000) An experimental study on the role of touch in shared virtual environments. *ACM Transactions on Computer Human Interaction, 7(4)*, 443-460.

Baños, R. M., Botella, C., Garcia-PalaciosA., Villa, H., Perpina, C., & Alcaniz, M. (2000). Presence and reality judgment in virtual environments: A unitary construct? *CyberPsychology and Behavior, 3,* 327-335.

Barfield, W., & Weghorst, S. (1993). The sense of presence within virtual environments: A conceptual framework. In G. Salvendy & M. Smith (Eds). *Human-computer interaction: Applications and case studies* (pp.699-704). Amsterdam: Elsevier.

Biocca, F. & Harms, C. (2002). Defining and measuring social presence: Contribution to the networked minds theory and measure. In F.R. Gouveia, & F. Biocca (Eds). *Proceedings of the 5th International Workshop on Presence,* 7-36.

Biocca, F., Harms, C., & Burgoon, J. (2004). Toward a more robust theory and measure of social presence: Review and suggested criteria. *Presence: Teleoperators and Virtual Environments, 12*, 456-480.

Biocca, F., Harms, C., & Gregg, J. (2001) *The Networked Minds measure of social presence: Pilot test of the factor structure and concurrent validity.* In *Proceedings of 4th International Workshop on Presence*. Philadelphia, USA, 21-23 May, 2001.

Brogni, A., Slater, M., and Steed, A. (2003). More breaks less presence. In *Proceedings of the 6th International Workshop on Presence.* Aalborg, Denmark, 6-8 October 2003.

Burgoon, J. K., & Hale, J. L. (1987). Validation and measurement of the fundamental themes of relational communication. *Communication Monographs, 54,* 19-41.

Cho, D., Park, J., Kim, G., Hong, S., Han, S., & Lee, S. (2003). Dichotomy of presence elements: The where and what. Proceedings of the IEEE Virtual Reality 2003, 273-274.

Cronbach, L.J. (1990). *Essentials Of Psychological Testing (5th Edition).* New York: Harper Collins.

Darken, R. P., Bernatovich, D., Lawson, J., & Peterson, B. (1999). Quantitative measures of presence in virtual environments: The roles of attention and spatial comprehension. CyberPsychology *and Behavior, 2,* 337-347.

De Greef, P., & IJsselsteijn, W. A. (2001). Social presence in a home tele-application. *CyberPsychology & Behavior, 4*, 307-316.

Dinh, H. Q., Walker, N., Song, C., Kobayashi, A., & Hodges L.F. (1999). Evaluating the importance of multi-sensory input on memory and the sense of presence in virtual environments. *Proceedings of the IEEE Virtual Reality 1999*, 222-228.

Dillon, C., Keogh, E., & Freeman, J. (2002). 'It's been emotional': Affect, physiology and presence. In F.R. Gouveia, & F. Biocca (Eds). *Proceedings of the 5th International Workshop on Presence*.

Dillon, C., Keogh, E., Freeman, J., & Davidoff, J. (2000). Aroused and immersed: The psychophysiology of presence. In W. IJsselsteijn, J. Freeman, & H. de Ridder (Eds). *Proceedings of the Third International Workshop on Presence*.

Ekman, P. (1982). Methods for measuring facial action. In K. Scherer and P. Ekman (Eds). Handbook of methods in nonverbal behavior research (pp. 45-135). Cambridge: Cambridge University Press.

Freeman, J., & Avons, S.E. (2000). Focus group exploration of presence through advanced broadcast services. *Proceedings of the SPIE, 3959,* 530-164.

Freeman, J., Avons, S., Meddis, R., Pearson, D., & IJsselsteijn, W. (2000). Using behavioural realism to estimate presence: A study of the utility of postural responses to motion stimuli. *Presence: Teleoperators and Virtual Environments, 9,* 149-164.

Freeman, J., Avons, S., Pearson, D., & IJsselsteijn, W. (1999). Effects of sensory information and prior experience on direct subjective ratings of presence. *Presence: Teleoperators and Virtual Environments, 8,* 149-164.

Gaggioli, A., Bassi, M., & Delle Fave, A. (2003). Quality of Experience in Virtual Environments. In G. Riva, F. Davide, & W.A. IJsselsteijn (Eds). *Being there: Concepts, effects and measurements of user presence in synthetic environments* (pp 121-135). Amsterdam: IOS Press.

Gerhard, M., Moore, D., & Hobbs, D. (2001). Continuous presence in collaborative virtual environments: Towards the evaluation of a hybrid avatar-agent model for user representation. In A. de Antonio, R. Aylett, & D. Ballin (Eds.): *Proceedings of the International Conference on Intelligent Virtual Agents,* pp. 137-153, Madrid, Spain.

Gilkey, R. H., & Weisenberger, J. M. (1995). The sense of presence for the suddenly deafened adult. *Presence: Teleoperators and Virtual Environments,* 4, 357-363.

Goldberg, J.H., & Kotval, X.P. (1999). Computer interface evaluation using eye movements: Methods and constructs. *International Journal of Industrial Ergonomics, 24,* 631-645.

Gunawardena, C.N., & Zittle, F.J. (1997). Social presence as a predictor of satisfaction within a computer-mediated conferencing environment. *The American Journal of Distance Education, 11*(3), 8-26.

Hatada, T., Sakata, H., & Kusaka, H. (1980). Psychophysical analysis of the sensation of reality induced by a visual wide-field display. *SMPTE Journal*, 89, 560-569.

Heeter, C. (2001). Reflections on real presence by a virtual person. In *Proceedings of 4th International Workshop on Presence*. Philadelphia, USA, 21-23 May, 2001.

Held, R., & Durlach, N.I. (1991). Telepresence, time delay, and adaptation. In S.R. Ellis (Ed.), *Pictorial communication in virtual and real environments*. New York: Taylor and Francis.

Held, R., & Durlach, N. I. (1992). Telepresence. *Presence:Teleoperators and Virtual Environments, 1,* 109-112.

Hendrix, C., & Barfield, W. (1996). Presence within virtual environments as a function of visual display parameters. *Presence: Teleoperators and Virtual Environments, 5,* 274 - 289.

Hoffman, H. G., Hullfish, K. C., & Houston, S. J. (1995). Virtual reality monitoring. In *Proceedings of Virtual Reality Annual International Symposium*, 11-15 March 1995, Research Triangle Park, North Carolina. Los Alamitos: IEEE Computer Society Press.

Hoffman, H.G., Richards, T., Coda, B., Richards, A., & Sharar, S.R. (2003). The illusion of presence in immersive virtual reality during and fMRI brain scan. *CyberPsychology & Behavior, 6,* 127-131.

HoshinoM., Takahashi, M., Oyamada, K., Ohmi, M., & Yoshizawa, T. (1997). Body sway induced by 3d images. In *Proceedings of the SPIE, 3012*, 400-407.

Huang, M., & Alessi, N. (1999). Presence as an emotional experience. In J. D Westwood, H. M. Hoffman, R. A. Robb, & D. Stredney, (Eds). *Medicine meets virtual reality: The convergence of physical and informational technologies options for a new era in healthcare.* Amsterdam: IOS Press.

Hullfish, K. C., (1996). *Virtual reality monitoring: How real is virtual reality?* Master's thesis, University of Washington, USA.

IJsselsteijn (2004). *Presence in Depth*. Ph.D. Thesis. Eindhoven University of Technology.

IJsselsteijn, W., de Kort, Y., & BierhoffI. (2001). Duration *Estimation and Presence.* Paper presented at Presence 2001, Philadelphia, USA, 9-11 October 2001.

IJsselsteijn, W. A., De Ridder, H., Freeman, J., & Avons, S. E. (2000). Presence: Concept, determinants and measurement. *Proceedings of the SPIE, 3959*, 520-529.

IJsselsteijn, W., De Ridder, H., Freeman, J. F., Avons, S. E., & Bouwhuis, D. (2001). Effects of stereoscopic presentation, image motion, and screen size on subjective and objective corroborative measures of presence. *Presence: Teleoperators and Virtual Environments*, *10,* 298-311.

IJsselsteijn, W. A., De Ridder, H., Hamberg, R., Bouwhuis, D., & Freeman, J. (1998). Perceived depth and the feeling of presence in 3DTV. *Displays, 18*, 207-214.

Insko, B. (2003). Measuring presence: Subjective, behavioral, and physiological methods. In G. Riva, F. Davide, & W. IJsselsteijn (Eds). *Being there: Concepts, effects, and measurement of user presence in synthetic environments* (pp. 109-119) Amsterdam: IOS Press.

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *International Journal of Aviation Psychology*, *3*(3),203-220.

Kim, T., & Biocca, F. (1997). Telepresence via television: Two dimensions of telepresence may have different connections to memory and persuasion. *Journal of Computer-Mediated Communication, 3 (2).*

Kumar, N., & Benbasat, I. (2002). Para-social presence and communication capabilities of a website: A theoretical perspective. *e-Service Journal, 1*(3), 5-24.

Laarni, J., Ravaja, N. & Saari, T. (2003). Using eye tracking and psychophysiological methods to study spatial presence. In *Proceedings of the 6th International Workshop on Presence.* Aalborg, Denmark, 6-8 October 2003.

Larsson, P., Västfjäll, D., & Kleiner, M. (2001a). The actor-observer effect in virtual reality presentations. *CyberPsychology and Behavior, 4,* 239-246.

Larsson, P., Västfjäll, D., & Kleiner, M. (2001b). *Do we really live in a silent world? The (mis)use of audio in virtual environments.* Paper presented at AVR II and CONVR 2001, Chalmers, Sweden.

Lessiter, J., Freeman, J., Keogh, E., Davidoff, J. (2001). A cross-media presence questionnaire: The ITC-Sense of Presence Inventory. *Presence: Teleoperators & Virtual Environments, 10*, 282-298.

Lombard, M. (1995). Direct responses to people on the screen: Television and personal space. *Communication Research, 22*, 288-324.

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer-mediated communication, 3*(2).

Lombard, M., Ditton, T. B., Crane, D., Davis, B., Gil-Egui, G., Horvath, K., et al. (2000). Measuring presence: A literature-based approach to the development of a standardized paper-and-pencil instrument. In W. IJsselsteijn, J. Freeman, & H. de Ridder (Eds). *Proceedings of the Third International Workshop on Presence*.

Loomis, J. M. (1992). Presence and distal attribution: Phenomenology, determinants, and assessment. In *Proceedings of the SPIE, 1666,* 590-594.

Mania, K., Troscianko, T., Hawkes, R., & Chalmers, A. (2003). Fidelity metrics for virtual environment simulations based on spatial memory awareness states. *Presence: Teleoperators and Virtual Environments, 12,* 296-310.

Meehan, M., Insko, B., Whitton, M., & Brooks, F. P. (2001). Physiological measures of presence in virtual environments. In *Proceedings of 4th International Workshop on Presence*. Philadelphia, USA, 21-23 May, 2001.

McCall, R., O'Neill, S., Carroll, F., & Benyon, D. (2004). *The Presence Probe*. Paper presented at the Workshop on Designing and Evaluating Virtual Reality Systems, University of Notthingham, UK.

McGreevy, M. W. (1992). The presence of field geologists in Mars-like terrain. *Presence: Teleoperators and Virtual Environments, 1*, 375 - 403.

Murray, C., Arnold, P., & Thornton, B. (2000). Presence accompanying induced hearing loss: Implications for immersive virtual environments. *Presence: Teleoperators and Virtual Environments, 9,* 137-148.

Nemire, K., Jacoby, R. H., & Ellis, S. R. (1994). Simulation fidelity of a virtual environment display. *Human Factors, 36*, 79-93.

Nichols, S., Haldane, C., & Wilson , J. R. (2000) Measurement of presence and its consequences in virtual environments. *International Journal of Human Computer Studies, 52,* 471-491.

Nowak, K.L., & Biocca, F. (2003). The effect of the agency and anthropomorphism on users' sense of telepresence, copresence, and social presence in virtual environments. *Presence: Teleoperators and Virtual Environments, 12*, 2-35.

Osgood, C. E., Suci, G. J., and Tannenbaum, P. H. (1957). *The measurement of meaning.* Urbana*:* University of Illinois Press.

Parent, A. (1998). *A virtual environment task analysis workbook for the creation and evaluation of virtual art exhibits*. Technical Report NRC 41557 ERB-1056, National Research Council Canada.

Prothero, J., & Parker, D. (2003). A unified approach to presence and motion sickness. In L. Hettinger & M. Haas (Eds). Virtual and adaptive environments: Applications, implications, and performance issues (pp. 47-66). Mahwah, NJ: Lawrence Erlbaum Associates.

Prothero, J., Parker, D., Furness, T. A., & Wells, M. (1995). Towards a robust, quantitative measure of presence. In Proceedings of Conference on Experimental Analysis and Measurement of Situational Awareness, pp. 359-366.

Psotka, J. M. Davison, S. & Lewis, S. A., (1993). Exploring immersion in virtual space. In R. Stuart & G. P. Panos (Eds.), Virtual Reality Systems tm, 1(2), 70-82.

Pugnetti, L., Mendozzi, L., Barberi, E., Rose, F. D., & Attree, E. A. (1996). Nervous system correlates of virtual reality experience. In P. M. Sharkey (Ed.). Proceedings of the 1st European Conference of Disability, Virtual Reality & Associated Technologies. Maidenhead, UK, 8-10 July 1996.

Ravaja, N. (2002). Presence-related influences of a small talking facial image on psychophysiological measures of emotion and attention. In F.R. Gouveia, & F. Biocca (Eds). *Proceedings of the 5th International Workshop on Presence*.

Retaux, X. (2003). Presence in the environment: theories, methodologies and applications to video games. *PsychNology Journal, 1(3)*, 284 - 310.

Rourke, L., Anderson, T. Garrison, D. R., & Archer, W. (1999). Assessing social presence in asynchronous, text-based computer conferencing. *Journal of Distance Education, 14*(3), 51-70.

Sadowski, W., & Stanney, K. M. (2002). Measuring and managing presence in virtual environments. In K.M. Stanney (Ed.), *Handbook of virtual environments technology*. Mahwah, NJ: Lawrence Erlbaum Associates.

Schloerb, D. W. (1995). A quantitative measure of telepresence. *Presence: Teleoperators and Virtual Environments 4,* 64-80.

Schlögl, A., Slater, M., & Pfurtscheller, G. (2002). Presence Research and EEG. In F.R. Gouveia, & F. Biocca (Eds). *Proceedings of the 5th International Workshop on Presence*.

Schroeder, R., Steed, A., Axelsson, A-S., Heldal, I., Abelin, A., Wideström, et al. (2001). Collaborating in networked immersive spaces: as good as being there together? *Computer & Graphics, 25*, 781-788.

Schubert, T., Friedmann, F., & Regenbrecht, H. (2001). The experience of presence: Factor analytic insights. *Presence: Teleoperators and Virtual Environments, 10,* 266-281.

Sheridan, T. (1992). Musings on telepresence and virtual presence. *Presence: Teleoperators and Virtual Environments, 1,* 120-126.

Short, J., Williams, E., & Christie, B. (1976). *The social psychology of telecommunications*. London: John Wiley & Sons.

Slater, M. (1999). Measuring presence: A response to the Witmer and Singer presence questionnaire. *Presence: Teleoperators and Virtual Environments, 8,* 560-565.

Slater, M., Brogni, A., & Steed, A. (2003). Physiological Responses to Breaks in Presence: A Pilot Study. In *Proceedings of the 6th International Workshop on Presence.* Aalborg, Denmark, 6-8 October 2003.

Slater, M., Linakis, V., Usoh, M., & Kooper, R., (1996). Immersion, presence, and performance in virtual environments: An experiment with tri-dimensional chess. In M. Green (Ed), ACM Virtual Reality Software and Technology (pp. 163-172), 1-4 July 1996.

Slater, M., & Steed, A. (2000). A virtual presence counter. *Presence: Teleoperators and Virtual Environments, 9,* 413-434.

Slater, M., Usoh, M., Chrysanthou, Y. (1995). The influence of dynamic shadows on presence in immersive virtual environments. In M. Goebel (Ed.). *Proceedings of the 2nd Eurographics Workshop on Virtual Reality.* Monte Carlo, Monaco, January 1995.

Slater, M., Usoh, M., & Steed, A. (1994). Depth of presence in virtual environments. *Presence: Teleoperators and Virtual Environments, 3,* 130-144.

Slater, M., Usoh, M., & Steed, A. (1995). Taking steps: The influence of a walking metaphor on presence in virtual reality. *ACM Transactions on Computer Human Interaction, 2(3),* 201-219.

Snow, M. P., & Williges, R. C. (1998). Empirical models based on free-modulus magnitude estimation of perceived presence in virtual environments. *Human Factors, 40*, 386-402.

Spagnolli, A., Varotto, D., & Mantovani, G. (2003). An ethnographic, action-based approach to human experience in virtual environments. *International Journal of Human-Computer Studies, 59,* 797-822.

Steed, A., & McDonnell, J. (2003). Experiences with repertory grid analysis for investigating effectiveness of virtual environments. In *Proceedings of the 6th International Workshop on Presence.* Aalborg, Denmark, 6-8 October 2003.

Steinfield, C. W. (1986). Computer-mediated communication in an organizational setting: Explaining task-related and socioemotional uses. In M. L. McLaughlin (Ed.). *Communiation yearbook 9* (pp. 777-804). Newbury Park: Sage.

Stevens, B., Jerrams-Smith, J., Heathcote, D., & Callear, D. (2002). Putting the virtual into reality: Assessing object-presence with projection-augmented models. *Presence: Teleoperators and Virtual Environments, 11,* 79-92.

Strickland, D., & Chartier, D. (1997). EEG measurements in a virtual reality headset. Presence: Teleoperators and Virtual Environments, 6, 581-589.

Thie, S., & Van Wijk, J., (1998). *A general theory on presence: Experimental evaluation of social virtual presence in a decision making task.* Paper presented at Presence in Shared Virtual Environments Workshop, University College London, 10 - 11 June 1998.

Tu, C. (2002a). The measurement of social presence in an online learning environment. *International Journal on E-Learning 1*(2), 34-45.

Tu, C. (2002b). The impacts of text-based CMC on online social presence. *The journal of interactive online learning, 1*(2)*.*

Turner, P., McGregor, I., Turner, S., & Carroll, F. (2003). Evaluating soundscapes as a means of creating a sense of place. In E. Brazil, & B. Shinn-Cunningham (Eds), Proceedings of the 2003 International Conference on Auditory Display, 148-151.

Turner, S., Turner, P., Caroll, F., O'Neill, S., Benyon, D., McCall, R., et al. (2003). *Re-creating the Botanics: towards a sense of place in virtual environments.* Paper presented at the 3rd UK Environmental Psychology Conference, Aberdeen, 23-25 June 2003.

Usoh, M. , Arthur, K., Whitton, M. C., Bastos, R., Steed, A., Slater, M., et al. (1999). Walking > Walking-in-Place >Flying, in Virtual Environments. *Computer Graphics, Annual Conference Series: Proceedings of SIGGRAPH 1999*, 359–364.

Usoh, M., Catena, E., Arman, S., & Slater, M. (2000). Using presence questionnaires in reality. *Presence: Teleoperators and Virtual Environments, 9*, 497-503.

Waterworth, E. L., & Waterworth, J. A. (2001). Focus, locus and sensus: The 3 dimensions of virtual experience. *CyberPsychology and Behavior, 4,* 203-214.

Welch, R. B. (1997). The presence of aftereffects. In G. Salvendy, M. J. Smith, & R. J. Koubek (Eds). *Designs of computing systems: Cognitive considerations* (pp. 271-276). Amsterdam: Elsevier.

Welch, R. B., Blackmon, T. T., Liu, A., Mellers, B. A., & Stark, L. W. (1996). The effects of pictorial realism, delay of visual feedback, and observer interactivity on the subjective sense of presence. *Presence: Teleoperators and Virtual Environments, 5*, 263-273.

Wiederhold, B. K., Dong, P. J., Kaneda, M., Cabral, I., Lurie, Y., May, et al. (2001). An investigation into physiological responses in virtual environments: an objective measurement of presence. In G. Riva, & C. Calimberti, (Eds). *Toward cyberpsychology: Mind, cognition and society in the internet age.* Amsterdam: IOS Press.

Wilson, J. R., Nichols, S. & Haldane, C. (1997). Presence and side-effects: Complementary or contradictory? In M.J. Smith, G. Salvendy, & R. J. Koubek (Eds). *Design of Computing Systems: Social and Ergonomic Considerations, Proceedings of the Seventh International Conference on Human-Computer Interaction, (HCI International '97)* (pp. 889-892). San Francisco, USA.

Witmer, D. F. (1997). Risky business: Why people feel safe in sexually explicit on-line communication. *Journal of Computer-Mediated Communication, 2*(4).

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and Virtual Environments, 7,* 225-240.

Youngblut, C., & Perrin, B. M. (2002). *Investigating the relationship between presence and performance in virtual environments.* Paper presented at the IMAGE 2002 Conference, Arizona.

Appendices

Appendix A: Questionnaire Items

BARFIELD ET AL. QUESTIONNAIRE

1. If your level in the real world is 100, and your level of presence is 1 if you have no presence, rate your level of presence in this virtual world.
2. How strong was your sense of presence, “being there”, in the virtual environment? (1-5 scale)

DINH ET AL. QUESTIONNAIRE

The rating question
If your level of presence in the real world is "100" and your level of presence is "1"' if you lack presence, rate your level of presence in this virtual world (presence is a "feeling of being there"). Enter a number 1-100.

The 13 other presence questions
Subjects were asked to rate each question on a 1-5scale where 1=poor, 2=fair, 3=good, 4=very good, and 5=excellent.

1. How strong was your sense of presence in the virtual environment?
2. How strong was your sense of "being there" in the virtual environment?
3. How strong was your sense of inclusion in the virtual environment?
4. How aware were you of the real world surroundings while moving through the virtual world (i.e., sounds, room temperature, other people, etc.)?
5. In general, how realistic did the virtual world appear to you?
6. How realistically were you moved through the virtual world?
7. With what degree of ease were you able to look around the virtual environment?
8. Do you feel that you could have reached into the virtual world and grasped an object?
9. What was your overall comfort level in this environment?
10. What was your overall enjoyment level in the virtual environment?

GERHARD ET AL. QUESTIONNAIRE

The subscale to which each item belongs is mentioned in parentheses after each question. These are: Immersion (IMM), Communication (COM), Involvement (INV), and Awareness (AW). The questionnaire also covered the
moderator variables relating to the nature of the environment itself (CVE) together with its user interface (INF) .

1. Besides you, how many persons were in the virtual gallery? (Qualitative)
2. How stimulating was the design of the virtual world? (CVE)
3. How natural was the mechanism, which controlled the actions of your avatar? (INF)
4. How responsive were the avatars of other participants to verbal communication that you initiated? (COM)
5. How natural did your communication with other participants seem? (COM)
6. How compelling was your sense of being present in a virtual world? (IMM)
7. How compelling was your sense of other participants being present? (IMM)
8. How credible were the avatars of other participants with respect to representing human beings? (AVA)
9. How aware were you of the existence of your own avatar? (AWN)
10. How easy was it to distinguish between the avatars of different participants? (AVA)
11. How easy was it to control your avatar? (INF)
12. How well could you concentrate on communication and the assigned task rather than on the mechanisms used to perform these? (INF)

13. Were you involved in communication and the experimental task to the extent that you lost track of time? (IVM)
14. To what extent did events occurring outside the virtual gallery distract from your experience in the virtual environment? (IVM)
15. I was immediately aware of the existence of other participants. (AWN)
16. I was an active participant in the meeting. (IVM)
17. I was aware of the actions of other participants. (AWN)
18. I enjoyed the virtual gallery experience. (IVM)
19. My senses were completely engaged during the experience. (IMM)
20. Was it difficult to find a unanimous decision within the group? Did you experience any other difficulties during the experiment? (Please explain.) (Qualitative)
21. Did you notice others using means of non-verbal communication, such as gestures? Do you consider them useful in this setting? (Please explain.) (Qualitative)
22. Do you think the deployment and appearance of avatars was significant for the virtual gallery experience? (Please explain your answer.) (Qualitative)
23. Do you have any other comments on this experiment? (Qualitative)

IGROUP PRESENCE QUESTIONNAIRE (IPQ)

1. How aware were you of the real world surrounding you while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?
2. How real did the virtual world seem to you?
3. I had a sense of acting in the virtual space, rather than operating something from outside.
4. How much did your experience in the virtual environment seem consistent with your real world experience?
5. How real did the virtual world seem to you?
6. I did not feel present in the virtual space.
7. I was not aware of my real environment.
8. In the computer generated world I had a sense of "being there".
9. Somehow I felt that the virtual world surrounded me.
10. I felt present in the virtual space.
11. I still paid attention to the real environment.
12. The virtual world seemed more realistic than the real world.
13. I felt like I was just perceiving pictures.
14. I was completely captivated by the virtual world.

Scale anchors vary for each question and can be downloaded at www.igroup.org/pq/ipq

KIM & BIOCCA QUESTIONNAIRE

1. When the broadcast ended, I felt like I came back to the "real world" after a journey. (Strongly Disagree -- Strongly Agree)
2. The television came to me and created a new world for me, and the world suddenly disappeared when the broadcast ended. (Strongly Disagree -- Strongly Agree)
3. During the broadcast, I felt I was in the world the television created. (Never -- Always)
4. During the broadcast, I NEVER forgot that I was in the middle of an experiment. (Never -- Always; Reversed Scale)
5. During the broadcast, my body was in the room, but my mind was inside the world created by television. (Never -- Always)
6. During the broadcast, the television-generated world was more real or present for me compared to the "real world." (Never -- Always)
7. The television-generated world seemed to me only "something I saw" rather than "somewhere I visited." (Never -- Always; Reversed Scale)
8. During the broadcast, my mind was in the room, not in the world created by television. (Never -- Always; Reversed Scale)

MURRAY ET AL. QUESTIONNAIRE

1. How was your feeling of being present in the real world affected by your hearing loss?
2. How was your feeling of being present amongst other people affected by your hearing loss?
3. How was your sense of personal existence affected by your hearing loss?
4. How was your feeling of being present in an active, changing environment affected by your hearing loss?
5. How was your ability to think about your own presence in the real world affected by your hearing loss?

All items were rated on a 5-point scale where 1= much lower, 2= lower, 3= normal, 4= higher, and 5= much higher.

NICHOLS ET AL. QUESTIONNAIRE

1. In the computer generated world I had the sense of "being there" (1. Not at all – 7. Very much).
2. During the game, how often did you think of the other person(s) in the room with you? (1. Not at all – 7. All the time).
3. How flat and missing in depth did the game appear? (1. Not at all – 7. Very much).
4. Do you think of the computer-generated world as... (1. Something that I saw – 7. Somewhere that I visited).
5. How much more enjoyable would it have been to use the game with no-one else in the room? (1. No more enjoyable – 7. A great deal more enjoyable).
6. How disturbing was the lag or delay between your movements of the controls and the response in the computer-generated world? (1. Didn't notice it – 7. Completely off-putting).
7. Whilst you used the game, music played in the background. How much attention did you pay to it? (1. None at all – 7. A great deal).
8. The computer-generated world became more real or present to me compared to the "real world" (1. At no time – 7. Almost all the time).
9. How exhilarated did you feel after the experience? (1. Felt normal - 7. Felt really exhilarated).

PRESENCE QUESTIONNAIRE (PQ)

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 completely were all of your senses engaged?
5. How much did the visual 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. How inconsistent or disconnected was the information coming from your various senses?
12. How much did your experiences in the virtual environment seem consistent with your real-world experiences?
13. 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. How well could you 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. How well could you examine objects from multiple viewpoints?
21. How well could you 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. How distracting was the control mechanism?
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. 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?
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?

This is the initial version of the questionnaire. Items 4, 8, 9, 11, 22, 24, 31, and 32 were dropped. Items 5, 6, 10, 18, 23, and 32 were included to address involvement in the VE

QUESTIONNAIRE ON PRESENCE AND REALISM

1. If one's level of presence in the real world is 100%, rate your level of presence in this virtual world.
2. How strong was your sense of presence?
3. Did you feel you could reach into the virtual environment and grasp an object?
4. How realistic did the virtual world appear?
5. How realistic were depth and volume?
6. How realistic were the virtual world's reactions to your actions?
7. When exploring the virtual space, did the objects appear too compressed or too magnified?
8. Did the virtual objects appear geometrically correct, did they seem to have the right size and distance in relation to yourself and other objects?

Overall, how would you rate the sense of presence generated by the environment?
Overall, how would you rate the degree of realism achieved by the virtual environment?

Items 1-8 are rated on a 4-point scale: 0 (none), 1 (2-50%), 2 (50-75%), 3 (75-100%). The two general items are rated on a 5-point scale (Very satisfactory – Moderately satisfactory – Neutral – Moderately unsatisfactory – Very unsatisfactory)

REALITY JUDGMENT AND PRESENCE QUESTIONNAIRE

1. How clear was what you saw in the virtual world?
2. To what extent was what you saw in the virtual world similar to reality?
3. To what extent could you predict or anticipate what you were going to see in the virtual world?
4. How clear were the sounds in the virtual world?
5. To what extent was what you heard in the virtual world similar to reality?

6. To what extent could you predict or anticipate what you were going to hear in the virtual world?
7. To what extent did you feel bodily sensations in the virtual world (heat, cold, etc.)?
8. To what extent could you predict or anticipate the bodily sensations you were going to feel in the virtual world?
9. To what extent did you feel you “were” physically in the virtual world?
10. To what extent were your perceptions in the virtual world (visual, somatic, etc) congruent?
11. In your opinion, how was the quality of the images in the virtual world?
12. To what extent did you experience things you were not expecting to happen in the virtual world?
13. To what extent did things in the virtual world have impact on you?
14. To what extent what you experienced in the virtual world fitted the information you had about what was going to happen?
15. To what extent what you experienced in the virtual world fitted your expectations about what could happen in a virtual world?
16. To what extent what you experience in the virtual world was a fiction?
17. To what extent did you feel you “went into” the virtual world?
18. To what extent did the experience seem real to you?
19. To what extent did you feel as a passive spectator in the virtual world?
20. To what extent did you feel as an active participant in the virtual world?
21. To what extent did the virtual world respond to your actions?
22. To what extent do you trust in the information computers offer you?
23. To what extent do you believe the computer (virtual reality system) could trick you?
24. To what extent were the voices or other perception from outside the virtual world congruent to what you were experiencing in the virtual world?
25. Do you believe other people similar to you could have an experience similar to yours in the virtual world?
26. Do you believe the virtual world was able to induce emotions?
27. To what extent did the virtual world make you feel emotions (anxiety, sadness, happiness, etc.)?
28. To what extent did you feel emotionally involved in the virtual experience?
29. To what extent did you wish to let yourself be carried by the virtual world?
30. To what extent did you feel like you “went into” the virtual world, and you almost forgot about the world outside?
31. To what extent did you find easy to manipulate the joystick, mouse, etc?
32. To what extent did your interactions with the virtual world seem natural to you, like in the real world?
33. To what extent was your experience in the virtual world a challenge to you?
34. To what extent were the objects present in the virtual world?
35. To what extent was the experimenter/therapist present in the experience?
36. To what extent could you interact with the virtual world?
37. How real did the virtual objects seem to you?
38. To what extent what you experienced in the virtual world was congruent to other experiences in the real world?
39. To what extent what you experienced in the virtual world was different to other experiences you had in the real world?
40. To what extent could you move around the virtual world?
41. To what extent did your movements in the virtual world seem natural to you?
42. To what extent did the mechanisms which controlled your movements in the virtual world seem natural to you?
43. To what extent did the mechanism which controlled your movements let you move in a natural way in the virtual world?
44. To what extent was there a delay between your actions and their effects in the virtual world?
45. To what extent was difficult to you to “go into” the virtual world?

46. To what extent was easy to you to get used to the virtual world?
47. To what extent did the experience imply a mental effort to you?
48. To what extent did you have to pay a lot of attention about what was going on in the virtual world?
49. To what extent did the experience make you learn anything?
50. To what extent did you feel you have initiative to do things in the virtual world?
51. To what extent did the actions and events in the virtual world have continuity, like in a movie?
52. To what extent did you feel you have control over the experience?
53. Do you believe you could finish the virtual experience at your will?
54. To what extent did your actions produce changes in the virtual world?
55. Did you assume/play a role while experiencing the virtual environment?
56. To what extent were you yourself while experience the virtual environment?
57. To what extent did you feel you had to play a role in the virtual world?
58. To what extent do you believe the virtual system had initiative?
59. To what extent could you accurately estimate the time you spent in the virtual world?
60. To what extent were the events in the virtual world congruent to your actions?
61. To what extent did you feel it was necessary to devote all your attention to what you were doing in the virtual world?
62. To what extent did you feel self-satisfaction while experiencing the virtual environment?
63. To what extent did the virtual experience seem satisfying/reinforcing to you?
64. To what extent did you get bored while experiencing the virtual world?
65. To what extent did you have a good time while experiencing the virtual world?
66. To what extent did you feel disappointed while experiencing the virtual world?
67. To what extent would you like to repeat the virtual experience?
68. To what extent did the virtual experience lack sensations?
69. To what extent did the virtual experience lack emotions?
70. To what extent did you forget you were in a room wearing a helmet?
71. To what extent did the virtual experience seem more like a computer game, an entertainment?
72. To what extent did the quality of the images in the virtual world influence how real the experience seemed to you?
73. To what extent did what you heard and the quality of the sound in the virtual world influence how real the experience seemed to you?
74. To what extent did the bodily sensations you felt in the virtual world influence how real the experience seemed to you?
75. To what extent did the bodily sensations influence how into the virtual world you went?
76. To what extent did the sounds influence how into the virtual world you went?
77. To what extent did the quality of the images influence how into the virtual world you went?

The final version of the questionnaire contains 18 items in 3 scales: Reality Judgment (items 2, 9, 11, 17, 18, 32, 37, 38), Internal/External Correspondence (items 21, 36, 40, 54, 56, 60), and Attention/Absorption (30, 48, 61, 70).

SLATER-USOH-STEED QUESTIONNAIRE (SUS)

1. Please rate your *sense of being in the* virtual environment, on a scale of 1 to 7, where 7 represents your *normal experience of being in a place.*
2. To what extent were there times during the experience when the virtual environment was the reality for you?
3. When you think back to the experience, do you think of the virtual environment more as *images that you saw* or more as *somewhere that you visited*?
4. During the time of the experience, which was the strongest on the whole, your sense of being in the virtual environment or of being elsewhere?

5. Consider your memory of being in the virtual environment. How similar in terms of the *structure of the memory* is this to the structure of the memory of other *places* you have been today? By 'structure of the memory' consider things like the extent to which you have a visual memory of the virtual environment, whether that memory is in colour, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such *structural* elements.
6. During the time of your experience, did you often think to yourself that you were actually in the virtual environment?

SWEDISH VIEWER-USER PRESENCE QUESTIONNAIRE (SVUP)

1. How natural was the interaction with the environment? (P)
2. To what extent were you able to identify sounds? (SQ)
3. To what extent were you able to localize sounds? (SQ)
4. To what extent were you aware of things happening around you, outside the Virtual Environment? (EA)
5. To what extent did you feel you were present in the Virtual Environment? (P)
6. To what extent did you feel disoriented or confused in the Virtual Environment? (Q)
7. How involved were you in the experience? (P)
8. To what extent did you think it was enjoyable to interact in the Virtual Environment? (E)
9. How much did the sound add to the perceived realism? (SQ)
10. To what extent did you focus your attention on the situation, rather than on other things? (EA)
11. To what extent did you think that the things you did and saw happened naturally and without much mental effort? (P)
12. To what extent did you find the Virtual Environment fascinating? (E)
13. I felt nauseous (S)
14. My eyes felt strained (S)
15. I had a headache (S)
16. I had problems concentrating (S)
17. I felt unpleasant (S)

E = enjoyment, SQ = sound quality, P = presence, EA = external awareness, S = simulator sickness.

NOWAK QUESTIONNAIRE

Items assessing perceived other's copresence:

1. My interaction partner was intensely involved in our interaction.
2. My interaction partner seemed to find our interaction stimulating.
3. My interaction partner communicated coldness rather than warmth.
4. My interaction partner created a sense of distance between us.
5. My interaction partner seemed detached during our interaction.
6. My interaction partner was unwilling to share personal information with me.
7. My interaction partner made our conversation seem intimate.
8. My interaction partner created a sense of distance between us (this item is identical to the fourth item of this scale, perhaps by mistake).
9. My interaction partner created a sense of closeness between us.
10. My interaction partner acted bored by our conversation.
11. My interaction partner was interested in talking to me.
12. My interaction partner showed enthusiasm while talking to me.

Items assessing self-reported copresence:

1. I did not want a deeper relationship with my interaction partner.

2. I wanted to maintain a sense of distance between us.
3. I was unwilling to share personal information with my interaction partner.
4. I wanted to make the conversation more intimate.
5. I tried to create a sense of closeness between us.
6. I was interested in talking to my interaction partner.

All items are rated on a 5-point scale where 1= Strongly disagree, 2= Disagree, 3= Neither agree nor disagree, 4= Agree , and 5= Strongly agree.

SCHROEDER ET AL. QUESTIONNAIRE

Items assessing collaboration:

1. To what extent did you experience that you and your partner collaborated?
2. Think of some previous time (before today) when you enjoyed collaborating with someone. To what extent did you enjoy collaborating with your partner in today's task?
3. To what extent would you, on another occasion, like to carry out a similar task with your partner?

Items assessing contribution to the task:

1. How would you estimate your and your partner's share in solving the task?
2. To what extent did you and your partner contribute to placing the cubes?
3. Who talked the most, you or your partner?

Items assessing presence:

1. To what extent did you have the experience of being in the same room as the cubes?
2. When you think back on the task, to what extent can you have the experience right now that you are moving around in the room where the cubes were?
3. To what extent did you experience the environment as a place you visited rather than something that you were looking at?

Items assessing copresence:

1. To what extent did you have a sense of being in the same room as your partner?
2. When you continue to think back on the task, to what extent do you have a sense that you are together with your partner in the same room?''.

All items are rated on a 5-point scale (1= to a very small extent, 5= to a very high extent).

BAILENSON ET AL. QUESTIONNAIRE

1. I perceive that I am in the presence of another person in the room with me.
2. I feel that the person is watching me and is aware of my presence.
3. The thought that the person is not a real person crosses my mind often.
4. The person appears to be sentient (conscious and alive) to me.
5. I perceive the person as being only a computerized image, not as a real person.

BASDOGAN ET AL. QUESTIONNAIRE

1. To what extent, if at all, did you have a sense of being with the other person?
2. To what extent were there times, if at all, during which the computer interface seemed to vanish, and you were directly working with the other person?
3. When you think back about your experience, do you remember this as more like just interacting with a computer or working with another person?
4. To what extent did you forget about the other person, and concentrate only on doing the task as if you were the only one involved?

5. To what extent were you and the other person in harmony during the course of the performance of the task?
6. Think about a previous time when you cooperatively worked together with another person in order to move or manipulate some real thing in the world (for example, shifting some boxes, lifting luggage, moving furniture, and so on). To what extent was your experience in working with the other person on this task today like that other real experience, with regard to your sense of doing something together?
7. During the time of the experience, did you often think to yourself that you were just manipulating some screen images with a pen-like device, or did you have a sense of being with another person?
8. Overall rate the degree to which you had a sense that there was another human being interacting with you, rather than just a machine?

GLOBALED QUESTIONNAIRE

1. Messages in GlobalEd were impersonal
2. CMC is an excellent medium for social interaction
3. I felt comfortable conversing through this text-based medium
4. I felt comfortable introducing myself on GlobalEd
5. The introduction enabled me to form a sense of online community
6. I felt comfortable participating in GlobalEd discussions
7. The moderators created a feeling of online community
8. The moderators facilitated discussions in the GlobalEd conference
9. Discussions using the medium of CMC tend to be more impersonal than face-to-face discussion
10. CMC discussions are more impersonal than audio conference discussions
11. CMC discussions are more impersonal than video teleconference discussions
12. I felt comfortable interacting with other participants in the conference
13. I felt that my point of view was acknowledged by other participants in GlobalEd
14. I was able to form distinct individual impressions of some GlobalEd participants even though we communicated only via a text-based medium.

These are only the items addressing social presence. In total, the questionnaire contains 61 items.

NETWORKED MINDS QUESTIONNAIRE

Items assessing co-presence:

Isolation/ Aloneness

1. I often felt as if I was all alone.
2. I think the other individual often felt alone.

Mutual Awareness

3. I hardly noticed another individual.
4. The other individual didn't notice me in the room.
5. I was often aware of others in the environment.
6. Others were often aware of me in the room.
7. I think the other individual often felt alone.
8. I often felt as if I was all alone.

Attentional Allocation

9. I sometimes pretended to pay attention to the other individual.
10. The other individual sometimes pretended to pay attention to me.
11. The other individual paid close attention to me
12. I paid close attention to the other individual.
13. My partner was easily distracted when other things were going on around us.
14. I was easily distracted when other things were going on around me.

15. The other individual tended to ignore me.
16. I tended to ignore the other individual.

Items assessing Psychological Involvement:
Empathy
1. When I was happy, the other was happy.
2. When the other was happy, I was happy.
3. The other individual was influenced by my moods.
4. I was influenced by my partner's moods.
5. The other's mood did NOT affect my mood/emotional-state.
6. My mood did NOT affect the other's mood/emotional-state.

Mutual Understanding
7. My opinions were clear to the other.
8. The opinions of the other were clear.
9. My thoughts were clear to my partner.
10. The other individual's thoughts were clear to me.
11. The other understood what I meant.
12. I understood what the other meant.

Items assessing Behavioral Engagement:
Behavioral Interdependence
1. My actions were dependent on the other's actions.
2. The other's actions were dependent on my actions.
3. My behavior was in direct response to the other's behavior.
4. The behavior of the other was I direct response to my behavior.
5. What the other did affected what I did.
6. What I did affected what the other did.

Mutual Assistance
7. My partner did not help me very much.
8. I did not help the other very much.
9. My partner worked with me to complete the task.
10. I worked with the other individual to complete the task.

Dependent Action
11. The other could not act without me.
12. I could not act without the other.

PARA-SOCIAL PRESENCE QUESTIONNAIRE

Items assessing Immediacy/Intimacy:
1. ABC.com created a sense of closeness with me.
2. I felt close to ABC.com.
3. ABC.com created a sense of distance.
4. I felt that ABC.com was aloof in its interactions with me.
5. I found ABC.com to be very detached from me.
6. ABC.com was very impersonal in its dealings with me.
7. I found ABC.com to be very detached in its interactions with me.

Items assessing Sense of Understanding:
1. ABC.com did not understand my needs.
2. ABC.com understood what I wanted.
3. ABC.com knows me well.
4. ABC.com understood my goals.
5. ABC.com understood what I was trying to do.
6. ABC.com had no clue as to what I really wanted.
7. ABC.com does not know my desires at all.

Items assessing Positivity (Items under development):

1. ABC.com is likeable.
2. ABC.com is pleasant.
3. ABC.com is unfriendly.
4. ABC.com is fun.
5. I have positive feelings about ABC.com.

Involvement

1. ABC.com keeps me totally absorbed in my interactions with it.
2. I was deeply involved in my interactions while shopping at ABC.com.
3. ABC.com holds my attention.
4. I was completely interested in what I was doing while browsing ABC.com.
5. ABC.com failed to keep me involved while I was shopping.
6. ABC.com excites my curiosity.
7. ABC.com aroused my imagination.

Items assessing Dominance:

1. ABC.com tried hard to persuade me.
2. I felt that ABC.com was very assertive.
3. ABC.com influenced me a great deal.
4. ABC.com influenced my decisions.
5. I felt that ABC.com was pushy.
6. I felt that ABC.com controlled the interaction.
7. ABC.com was aggressive in trying to influence me.
8. ABC.com was over-selling its products/services/ideas.

MEMORY CHARACTERISTIC QUESTIONNAIRE (MCQ)

1. My memories for (R,V,I) objects are: 1 = black & white; 7 = entirely color
2. My memories for (R,V,I) configurations are: 1 = very fuzzy; 7 = very sharp/clear
3. My view of (R,V,I) configurations seemed: 1 = unrestricted; 7 = restricted.
4. My memories for (R,V,I) events involve visual detail: 1 = none; 7 = a lot
5. For (R,V,I) events, I remember only the positions of objects (as opposed to the whole configuration). 1 = strongly disagree; 7 = strongly agree
6. During (R,V,I) events, the whole configuration was easy to view at one time. 1 = strongly disagree; 7 = strongly agree
7. My memories for (R,V,I) configurations seem: 1 = divided; 7 = whole
8. My memories for (R,V,I) configurations are: 1 = incomplete; 7 = complete
9. During the Identification Of Origin Test, I had to reconstruct the pieces of the (R,V,I) events from memory. 1 = strongly disagree; 7 = strongly agree
10. During (R,V,I) events, identifying the global shape of a configuration was: 1 = very difficult; 7 = very easy
11. I remember that the amount of concentration during (R,V,I) events was: 1 = none; 7 = a lot
12. I remember being distracted by the surroundings during (R,V,I) events: 1 = never; 7 = always
13. During the Identification Of Origin Test, my general level of confidence in the accuracy of my (R,V,I) answers was: 1 = just guessing; 7 = very sure
14. My memories for (R,V,I) events are: 1 = very weak; 7 = very strong
15. I remember feeling disoriented during (R,V,I) events. 1 = strongly disagree; 7 = strongly agree
16. My sense of "being there" for (R,V,I) events was: 1 = none; 7 = a lot
17. (R,V,I) events seemed more like: 1 = something that I saw; 7 = some place that I visited
18. During (R,V,I) events, I remember being a: 1 = spectator; 7 = participant
19. I remember being surrounded by objects during (R,V,I) events. 1 = strongly disagree; 7 = strongly agree

20. For (R,V,I) events, I was aware of my body. 1 = strongly disagree; 7 = strongly agree
21. How similar are your Real and Imagined memories? 1 = very different; 7 = very similar.
    How similar are your Real and Virtual memories? 1 = very different; 7 = very similar
    How similar are your Imagined and Virtual memories? 1 = very different; 7 = very similar

R = Real, V = Virtual, I = Imagined.

Appendix B: Measurement Tools and Resources

Psychophysiological

Astro-Med's
Equipment for psychophysiological and neural measurement. *http://www.grass-telefactor.com/*

Biofeedback Zone
Equipment for measuring cardiovascular and electrodermal responses.
http://store.biofeedbackzone.com/procomp.html

Biopac Systems
Amplifiers, electrodes, and software for EEG measurement. http://biopac.com/fr_prod.htm

Database of eye movement equipment
http://ibs.derby.ac.uk/emed/index.html

J+J Engineering
Equipment for measurement of EEG, EMG, and heart rate.
http://www.jjengineering.com/c2prod.htm

Lexicor Health Systems
Hardware and software for EEG measurement. http://www.lexicor.net/

Micromed
(Portable) EEG recorders. http://www.micromed-it.com

Psylab
Biological amplifiers and software for measuring Multiple EEG, ECG, EMG, startle blink, heart rate, peripheral pulse, skin conductance, respiration, temperature, and sexual response.
http://www.psylab.com

Postural responses & position

Ascension Technology
Magnetic position and orientation tracking. http://www.ascension-tech.com/products

Isense
Orientation and motion head-tracking, eye-tracking tools. http://www.isense.com/products/

Quick Mag
System for analyzing motion (Ouyo Keisoku Kenkyujo). No web resources.

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