

Measurement of presence in virtual environments

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Introduction

One major factor which determines the quality of an implementation of a virtual environment (VE) is the extent to which the simulation is able to induce a feeling of being in the virtual reality (Draper, Kaber & Usher, 1998). This illusion is commonly called **presence in VE**; Witmer and Singer (1998) provide as definition: „the subjective experience of being in one place or environment even when one is physically situated in another“ (p. 225), while other authors define presence as an illusion of position and orientation (Prothero, Parker, Furness & Wells, 1995). In this paper we describe the development of a questionnaire to measure this aspect of VE quality, which will be used to compare different implementations of a virtual driving simulator constructed by a major Italian car manufacturer (EU research project VIRtual, 1999-GRD-11030).

Examination of the literature reveals that presence is a multidimensional construct (Regenbrecht, Schubert & Friedmann, 1998). Witmer and Singer (1998) suggest the factors **selective attention**, **involvement** and **immersive response** as necessary in experiencing presence, based on theoretical considerations. Other authors explicitly include objective properties of the simulation as a factor, which led to some confusion and debate about the term immersion (Witmer & Singer, 1998; Slater, 1999). Lately, Schubert, Friedmann and Regenbrecht (1999, in press) empirically identified eight factors contributing to presence: **spatial presence**, **quality of immersion**, **involvement**, **drama**, **interface awareness**, **exploration** of VE, **predictability** and interaction, **realness**.

In addition, it has been suggested that the tendency to experience presence might depend on personal characteristics of the user; Witmer and Singer (1998) therefore added the factor **immersive tendency** (the personal tendency to be drawn into a book, novel or VE) to the problem of presence measurement.

While several other techniques to assess the quality of the subjective experience of presence have been suggested (qualitative interviews, psychophysiological measurement, behavioural measures, comparison to real task performance), a most straightforward way is to use self report measures collected by questionnaires (for a discussion of different methods see Prothero et al., 1995; Schubert et al., 1999; Slater, 1999). Standard procedure in questionnaire design asks for a collection of relevant items which are weeded out in an item analysis after getting responses to the items from a large sample of subjects (e.g. Krauth, 1995). Therefore we collected answers on a large set of items from persons with experience in VEs.



Method

Subjects

170 persons with experience in so called „first-person shooters“ participated in the study. In these games the player experiences 3-D-worlds from the viewpoint of a simulated person (his avatar), instead of from a camera perspective as in other games. These games are the most highly developed VEs readily available outside laboratories, and therefore formed a proper base of experience for our questionnaire.

96% of the participants were male, the mean age was 21.8 years (SD 6.42). Mean duration of experience with first-person-games was 4.9 years (SD 2.68).

Material

73 items related to the concept of presence were prepared. Sources were published questionnaires (Witmer & Singer, 1998; Schubert, Friedmann, Böhme & Kreß, 1996; Kim & Biocca, 1997) as well as own developments. Items were translated to German if necessary. In addition participants were asked to enter their age, gender, duration of experience with games and which games they knew. The items were presented online in a HTML-document tested for browser compliance.

(A German version of the questionnaire is available on request from the second author.)

Procedure

Subjects were recruited online, by advertising the survey in four specialised newsgroups and three forums of computer game publications. To motivate subjects for participation, a lottery between all participants was conducted with 10 computer games as prizes. Subjects could enter their email address to participate in the lottery, which did 86% of the participants. The announcement contained a hyperlink to the online questionnaire. Subjects were instructed to remember a typical game session with a 3-D-game and answer the items wrt. this session. As answers subjects rated each item on a seven point scale by selecting one of seven radiobuttons which were appropriately labelled. This took approximately 10 to 15 minutes (according to server logs).

Results

While some subjects tried to optimise their chances in the lottery, repeated entries could be detected and were excluded from analysis. In addition, questionnaires where more than 5 items had not been answered were also excluded. Otherwise the mean response to the item was entered in case of missing data, leaving a total of 165 complete data sets. Items measuring presence (55 of 73) are analysed separately from the items measuring immersive tendency (18 of 73).

Measurement of Presence:

As a general measure of presence a sum score of the (properly oriented) ratings was computed. After deleting 13 (of 55) items for low item-to-total correlation (correlations below 0.2 were not significant on a level of $\alpha = 0.01$), the scale's reliability is 0.85 (Cronbach's alpha). Items which were deleted are related to

- use of auditory and haptic cues in the simulation („How well could you identify/localise sounds“; „How well could you actively survey or search the virtual environment using touch“; item source: Witmer & Singer, 1998)
- control over the simulation's progress („How much were you able to control events“, item source: Witmer & Singer, 1998)
- learning to use the control mechanism (e.g. „How much did the control devices interfere with the performance of assigned tasks“; item source: Witmer & Singer, 1998)
- presence of other persons („I felt observed by the other persons in the room“; item source: Kim & Biocca, 1997)
- carry-over effects („After leaving the VE I showed behaviour which was appropriate only in the virtual reality“; item source: own development)

Principal components analysis of the items left in the questionnaire revealed 11 factors with eigenvalues larger than 1 (Kaiser, 1960), explaining 63% of total variance. Using the Scree-test (Catell, 1966) as criterion left three factors which were orthogonally rotated by the Varimax method. The first factor taps into the difference between physical and virtual localisation, and could therefore be called **spatial presence** in the sense of the definition (see also Schubert et al., in press). Highest loading item was „During the simulation my body was in the room, but my mind in the world created by the simulation“ (source: Kim & Biocca, 1997).

The second factor is related to the **quality of the interface**, i.e. problems with the interaction through the control elements or with the display; highest loading item was „How natural was the mechanism which controlled movement through the environment“ (source: Witmer & Singer, 1998). The third factor is determined by items asking for **emotional involvement** and aspects of drama, highest loading item „After having mastered tasks I felt relieved“ (source: own development).

Immersive tendencies:

Of the 18 items measuring the individual tendency to be drawn into other realities (e.g. novels, films) 6 were deleted. The resulting scale reliability is 0.78 (Cronbach's alpha). Items deleted were related to

- non-specific properties („How mentally alert do you feel at the present time“, „How physically fit do you feel today“, „How often do you play video games“; item source: Witmer & Singer 1998)
- directed attention („How good are you at blocking out external distractions when you are involved in something“; item source: Witmer & Singer 1998)

Factor analysis of the items remaining in the questionnaire revealed 4 (Kaiser's criterion) vs. 2 factors (Scree test). After Varimax rotation the first factor could be interpreted as tendency to get **emotionally involved**; highest loading item is „Have you ever gotten excited during a chase or fight scene on TV or in the movies“ (source: Witmer & Singer, 1998). The second factor could be called **degree of involvement**, with the highest loading item „Do you easily become deeply involved in movies or TV dramas“ (source: Witmer & Singer, 1998).

Discussion

Analysis of presence items:

During item analysis several items were deleted from the questionnaire. In most cases there are plausible explanations based on specific properties of the sample at hand: Current equipment does not provide haptic cues, so one would expect low variance on this item in the sample; items related to learning the use of control devices were probably not relevant in a sample of experienced players; items focussing on being observed in an experimental setting are obviously not relevant for the solitary player in front of his or her PC.

An explanation why items asking for control of events are excluded might be a misinterpretation by participants. During the game, unanticipated events (surprises like ambush fire, unanticipated moves of enemies) occur, which are difficult to deal with on a tactical or strategical level; in fact this constitutes the appeal of these games. It is possible that the opinion on this aspect of the games dominated the participants' answers, while the items were originally intended to focus on problems of interaction with simulated objects.

Analysis of items related to immersive tendency:

The items deleted from the sample were related to non-specific information and directed attention. While items asking for mental alertness (see above) seem to be irrelevant for the measurement of general immersive tendency, Witmer and Singer (1998) found rather high item-to-total correlations. In our sample these items do not contribute to the measurement of immersive tendency. The item asking how often the respondent played video games did not generate variance in the sample, probably due to an improper response anchor (highest rating corresponded to „playing every or every second day“). It is not so clear why items related to directed attention (blocking out distractions) were excluded; maybe this item was too general to generate variance.

The factor analyses of both measures must be viewed with caution. The sample is not really large enough to rely on the factors (165 subjects, 55 and 18 items), but in general the structure seems to mirror results identified by other authors with different methods (cluster analysis, Witmer & Singer, 1998; direct oblimin rotation, Schubert et al., in press). So the concept of presence seems to consist of a component related to differentiation of real and virtual space, interface quality and emotional involvement.

Otherwise, the study produced a reliable instrument for measurement of the subjective experience of presence and of the subject characteristic immersive tendency.

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