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Validating Presence by Relying on Recollection: Human Experience and Performance in the Mixed Reality System XIM

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Abstract

A fundamental issue in presence research is how we can quantify "presence". A standard approach has been to use questionnaires and self-report measures. However, it has been well established that human's capabilities to access and externalize their internal states is limited. Hence, we have investigated the question whether more objective measures can be devised that can corroborate subjective self-reports. In particular we have developed an objective and quantitative recollection task that assess the ability of human subjects to recollect the factual structure and organization of a mixed reality experience in a human accessible mixed reality space, the eXperience Induction Machine (XIM). In this experience – referred to as "Autodemo" – a virtual guide explains the key elements and properties of XIM. To evaluate the users' experience and the amount of factual information retained about the Autodemo, we used the ITC-SOPI questionnaire and a recall test design for the Autodemo. We found a positive correlation between one of the four ITC-SOPI factors and recall performance, and a positive correlation between subject's activity and recollection performance. Our results show that we can assess correlates of presence by focusing on other dependent measures such as those related to memory and performance. Additionally, our work shows how virtual and mixed reality systems provide new ways to address fundamental questions in psychology and cognitive science.

Keywords--- **Interactive Narrative, Mixed Reality, Recollection, Presence**

1. Introduction

Central to the conceptualization and design of a virtual and mixed reality environment (VMRE) is the issue of enriching the user experience and the augmentation of the users' sense of presence. As VMREs induce experiences in users that differ from other kinds of computer-mediated interactions, it is essential to systematically assess them from an empirical perspective. Thus far the subjective sense of immersion and presence in VMREs has mainly been assessed through self-description in the form of questionnaires [1, 2, 3]. It is unclear however to what extent the answers that the users provide actually reflect the dependent variable, in this case "presence", and it is well know that a self-report based approach towards human behavior and experience is error prone [17, 18]. It is essential to establish an independent validation of these self-reports, as some authors have done e.g. using real time physiology [4, 5, 6, 7]. In line with previous research, we want to asses whether the level of presence reported by a user correlates with an objective measures such as those that assess memory and recollection. We investigate this hypothesis using a VMRE called the eXperience Induction Machine (XIM) [8]. XIM provides an interface to a virtual world, the Persistent Virtual Community (PVC), where physically present humans can interact with remotely present users, fully synthetic characters, and the space which itself is an autonomous entity. In this experimental environment users are exposed to an interactive scenario, an "Autodemo", that in a standardized way explains to the user the components of XIM and their functional properties.

After the subjects were exposed to this Autodemo, they were asked to fill out a commonly used "presence" questionnaire, the ITC-SOPI [16], and a questionnaire that specifically targeted the user's recollection of the physical organization of XIM, its functional properties and the narrative content. This allowed us to evaluate the correlations between the level of presence reported by the users and their recall performance of information conveyed in the "Autodemo".

2. Methods

2.1 Infrastructure

The *eXperience Induction Machine* (XIM) is a room with a surface area of ~30m^2 equipped with a number of sensors and effectors (Figure 1) [8], and is a further development of the installation "Ada – the intelligent space" that was built for the Swiss national exhibition Expo02 [9]. XIM is a complete re-implementation of this precursor, and is, as opposed to Ada, embedded in the Persistent Virtual Community (PVC).

The core concept of the PVC is to develop a platform where entities of different degrees of virtuality – real users in the XIM, avatars i.e. alter egos of remote users, and fully synthetic characters controlled by neurobiologically grounded models – can meet and interact. The (PVC) serves as a platform to conduct experiments on presence, in particular social presence in mixed reality, and is being developed in the context of the PRESENCCIA project (www.presenccia.org [10]).

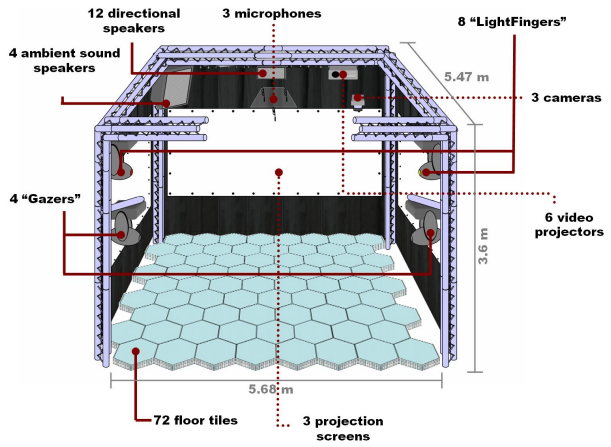

Figure 6 Technical infrastructure of the eXperience Induction Machine (XIM) indicating the main components. The space covers an area of 5.5x5.5m, and is equipped with the following devices: 3 cameras at the top of the rig provide a "bird's eye view", 3 microphones are placed in the center, 8 steerable theater lights ("LightFingers"), 4 steerable color cameras ("Gazers"), 16 speakers with the corresponding sound equipment. The space is surrounded by 3 projection screens (2.25m x 5m), and 6 video projectors are used for displaying content. The floor of the space consists of 72 custom built tiles, each of which can measure weight and display a color by means of a build in computer controlled RGB light source

The representation of a mixed reality world lies at the heart of the system, and is implemented using the game engine "Torque" (GarageGames, Inc., OR, USA). To track the position of individual users in XIM over an extended period of time, a "multi-modal tracking system" [11] integrates information from a number of devices such as the static cameras mounted in the ceiling, steerable cameras, and the pressure sensors in the floor. Music plays a central role in modulating the user experience. To deliver sonification that is flexible and can adapt to the status of the installation, we use the autonomous music composition system "Roboser" [12]. A complex installation such as XIM needs an "operating system" which integrates sensory information and controls the overall behavior of the system. This control of the system is realized by means of the large-scale neuronal systems simulator iqr [13].

2.2 Narrative structure of the Autodemo

The total duration of the Autodemo is 9min 30sec, and dived into four stages: "sleep", "welcome", "inside story", and "outside story". Participants to the Autodemo are led through the story by a virtual guide (Figure 2). This guide comprises a pre-recorded voice track (one of the authors) that delivers factual information about the installation, and an avatar that is an anthropomorphic representation of the space itself. By combining a humanoid shape and an an-organic texture, the avatar of the virtual guide is deliberately designed to be a hybrid representation.

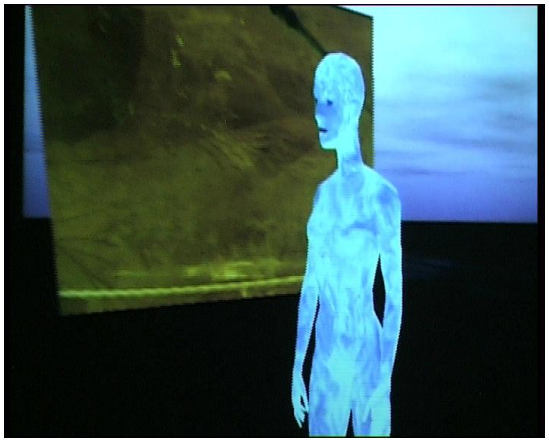

Figure 7 Depiction of the Avatar representing the virtual guide in the Autodemo

Up to the beginning of the "outside" part, the visitor is placed inside a black box, i.e. the walls of XIM are black. Before users enter, the space is *sleeping*. In this state the floor displays a blue wave animation, the LightFingers move slowly with blue lights, while Roboser is playing a sleep composition with a predominance of low frequencies. When users enter, the sleep stage ends with a brief welcome ceremony.

In the "*inside story*", the virtual guide appears, and, pointing at every instrument of the space, explains what they are and what their function is. The pointing movements are enhanced by matching pointing actions of the "LightFingers"

that illuminate the components of XIM that are being described by the guide. To encourage users to interact with the space, the "Energy" game is played. In this game the movement speed of the visitors is mapped onto the responses of the space in terms of the intensity of the sound and light compositions. "High energy" is rewarded by an animation on the floor, applause and a consonant sonification.

The sleep stage is followed by the "*outside story*". The purpose of this stage of the Autodemo is to convey to the users that XIM is embedded in the PVC, where each user in XIM is represented in the virtual space by an avatar. To give users an augmented sense of the spatiality of the virtual world, the entire space will move through the virtual world, either automated or controlled by the users. To demonstrate that a mixed reality space can also be used in a utilitarian way, users can trigger the displaying of video sequences. The outside story ends with the users playing a game of "football". The "football" game is a variation of the original "Pong" game, where opponents on both sides of the playing area are moving a paddle left and right or up and down to deflect a ball [14]. The major difference between Pong and the game played in XIM is that multiple players form a team, and that each player has an individual paddle. In XIM ball and paddle position are indicated by color patterns of the light emitting floor.

2.3 Questionnaires

The subjective experience of presence was evaluated in terms of media experience, while as a performance measure, we developed an Autodemo specific recall test. Media experience was assessed using the ITC-SOPI questionnaire (ITC-Sense of Presence Inventory – [16]) that measures four factors: the "Sense of Physical Space" (or spatial presence), "Engagement", "Ecological Validity" (e.g. content believability) and "Negative Effects" (e.g. dizziness). This questionnaire assesses users' media experiences after being exposed to media content by letting subjects evaluate 44 statements on a 5-point Likert scale (from 1 - "strongly disagree" to 5 - "strongly agree"). The answers to the questionnaire are combined to form a four factor scores per participant.

The XIM recall test assesses how well participants remember information presented about XIM and the PVC. Ten 3-alternative choice questions and two quantitative open questions ("how many…") address the information about the floor, the cameras, the audio system, the interactivity of XIM, PVC and the virtual guide. One of the questions about the virtual guide assesses the user's emotional evaluation asking whether the guide was perceived as happy, neutral or sad. Additionally subjects were asked to draw the locations of the different instruments of XIM into a cube, and to give an estimate of the duration of the Autodemo.

2.4 Subjects and procedure

Eighteen participants (6 female, 12 male, mean age 30±5) took part in the evaluation of Autodemo experience. All of them encountered the Autodemo for the first time. Questionnaires (first ITC-SOPI and then recall test) were administered immediately after the experience.

3. Results & Discussion

In the recall test participants on average answered 6 of 11 factual XIM questions correctly (SD = 2) (Figure 3). One

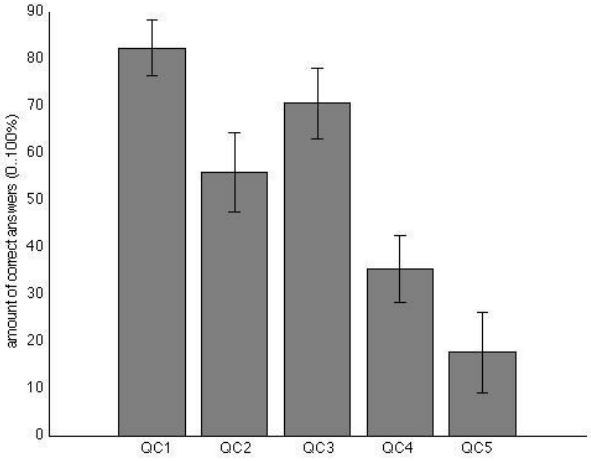

Figure 8 Percentage of correct answers to the recall test. The questions are grouped into thematic clusters (QC): QC1 - interaction; QC2 –Persistent Virtual Community; QC3 - sound system; QC4 - effectors; QC5 - quantitative information. Error bars indicate the standard error of mean

participant answered only one question correctly, and was, based on the assumption that he was effectively refusing to participate in the experiment, excluded from the data analysis.

The results show that the questions varied in difficulty with quantitative open questions being the most difficult ones. Questions on interaction and the sound system were answered with most accuracy, while the quantitative estimates on the duration of the experience and the number of instruments were mostly not answered correctly. From the answers, an individual recall performance score was computed for each participant.

Ratings of ITC-SOPI were combined into four factors and the mean ratings were: the Sense of Physical Space 2.8 (SE = 0.1), Engagement - 3.3 (SE = 0.1), Ecological Validity 2.3 (SE = 0.1), Negative Effects 1.7 (SE = 0.2) (Figure 4). The first three "positive presence-related" scales have been reported to be positively inter-correlated [16]. In our results only Engagement and Ecological Validity were positively correlated, ($r = 0.62$, $p < 0.01$).

We correlated the summed recall performance score with the ITC-SOPI factors and found a positive correlation between recall and Engagement: $r = 0.5$, $p < 0.05$. This correlation was mainly caused by recall questions related to the virtual guide and the interactive parts of the experience. Experience time perception and subject related data (age, gender) did not correlate with recall or ITC-SOPI ratings.

In the emotional evaluation of the avatar representing the virtual guide, 11 participants described this virtual character as neutral, 4 as positive and 2 as negative.

The results obtained by ITC-SOPI for the Autodemo experience in XIM differ from scores of other media experiences described and evaluated in [16]. For example, on the "Engagement" scale, the Autodemo appears to be more comparable to a cinema experience (M=3.3) than to a computer game (M=3.6) as reported in [16]. For the "Sense of Physical Space" our scores are very similar to IMAX 2D displays and computer game environments but are smaller than IMAX 3D scores (M=3.3). At the same time, some questions used to measure this factor may appear to be misleading for a mixed reality experience such as the Autodemo. To avoid such critique, it might be useful to design a dedicated questionnaire addressing taking into account the specifics of mixed reality installations. However, we see questionnaire-based evaluation of experience only as a subjective part of multilevel measurements encompassing user behavior, performance and physiological responses. Such measures are crucial for continuous assessment of user experience. For example, continuous assessment of the user's arousal state would corroborate our data on the recall test and help to identify the most engaging parts of Autodemo experience and validate its use as a psychological paradigm.

Previous research indicated that there might be a correlation between the users' sensation of presence and their performance in a memory task [15]. The difference between our study and [15] is that we have used a more objective evaluation procedure by allowing subjects to give quantitative responses and to actually draw positions in space.

Conclusions

So far the objective evaluation of "presence" has been elusive. This is not only because of the lack of proper operationalization of presence but also because of a lack of proper measurements techniques. To address this question we have assessed the correlation between subjective self-reports of presence, as measured by a standard presence questionnaire, and explicit measures of recollection, after being exposed to a standardized automatic presentation of a mixed reality space. By evaluating the users' subjective experience in the mixed reality space, we were able to identify a positive correlation between the presence engagement scale and factual recall. Our results indicated that information conveyed in the interactive parts of the Autodemo was better recalled than those that were conveyed at the moments that the subjects were passive. This confirms an earlier study where we have identified a correlation between activity level and experience among the 560000 visitors of the Ada installation [1]. We believe that the correlation between recall performance and the sense of presence identified here opens the avenue to the development of a measure of presence that is more robust, and less problematic than the use of questionnaires. This could e.g. be achieved by assessing what factual information a user has retained after the exposition to a virtual and/or mixed reality environment.

Additionally, the work on the temporal structure of the Autodemo, its interactive components and its subjective evaluation presented here, can yield better insights into the design of interactive mixed reality installations delivering high degrees of spatial presence and engagement.

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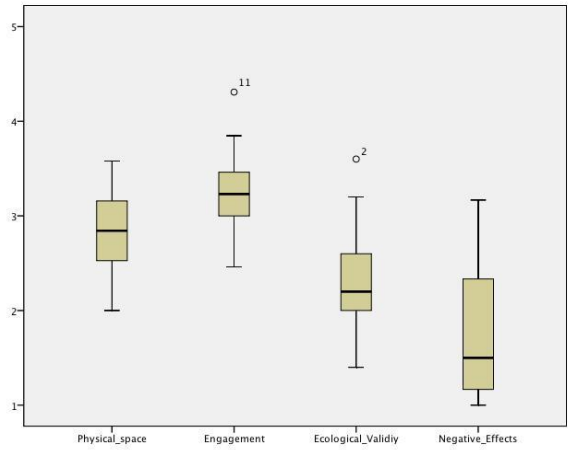

Figure 9 Boxplot of the four factors of the ITC-SOPI questionnaire (0..5 scale)

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