The Effects of Explicit and Implicit Interaction on User Experiences in a Mixed Reality Installation: The Synthetic Oracle

Sergi Bermúdez i Badia*
Aleksander Valjamae
Fabio Manzi
Ulysses Bernardet
Anna Mura
Laboratory for Synthetic Perceptive, Emotive and Cognitive Systems (SPECS)
Universitat Pompeu Fabra
Barcelona, Spain

Jônatas Manzolli
Interdisciplinary Nucleus for Sound Studies (NICS)
University of Campinas (UNICAMP)
Brazil

Paul F. M. J. Verschure
Laboratory for Synthetic Perceptive, Emotive and Cognitive Systems (SPECS)
Universitat Pompeu Fabra
Barcelona, Spain
and
Institució Catalana de Recerca i Estudis Avançats (ICREA)
Barcelona, Spain

Abstract

Virtual and mixed reality environments (VMRE) often imply full-body human-computer interaction scenarios. We used a public multimodal mixed reality installation, the Synthetic Oracle, and a between-groups design to study the effects of implicit (e.g., passively walking) or explicit (e.g., pointing) interaction modes on the users' emotional and engagement experiences, and we assessed it using questionnaires. Additionally, real-time arm motion data was used to categorize the user behavior and to provide interaction possibilities for the explicit interaction group. The results show that the online behavior classification corresponded well to the users' interaction mode. In addition, contrary to the explicit interaction, the engagement ratings from implicit users were positively correlated with a valence but were uncorrelated with arousal ratings. Interestingly, arousal levels were correlated with different behaviors displayed by the visitors depending on the interaction mode. Hence, this study confirms that the activity level and behavior of users modulates their experience, and that in turn, the interaction mode modulates their behavior. Thus, these results show the importance of the selected interaction mode when designing users' experiences in VMRE.

1 Introduction

One of the central tasks when designing a virtual and mixed reality environment (VMRE) is that of enriching the user experience and the augmentation of the sense of presence. VMREs integrate local and remote, and real and synthetic environments to induce experiences in users that can significantly differ from standard computer-mediated interactions (e.g., desktop or handheld devices). Therefore, it is essential to systematically evaluate and quantify these experiences from an empirical perspective. Moreover, it has been shown that the type of technology chosen to enable such interactions can have a great impact on the behavior and the personal experience of users (Benford, Greenhalgh, Reynard, Brown, & Koleva, 1998; Tang, Biocca, & Lim, 2004). In particular, the impact of the use of full body in-

Presence, *Vol. 18, No. 4, August 2009,* 277–285

*Correspondence to sergi.bermudez@upf.edu

teraction in VMRE experiences is not yet well understood, although many real-time systems have been developed to enable full body interaction within virtual reality environments.

One of the pioneering systems is the ALIVE system, which used a vision-based interface to interpret the actions of users to trigger specific behaviors in semi-autonomous virtual agents (Maes, Darrell, Blumberg, & Pentland, 1997). This system provided more complex and new experiences as opposed to traditional VR systems. Many vision based systems exploit full-body motion to interact with interactive environments (Tollmar, Demirdjian, & Darrell, 2003; Modler, Myatt, & Saup, 2003), and recently some research has been done to assess the affective content of gesture (Camurri, Mazzarino, Ricchetti, Timmers, & Volpe, 2004; Camurri, Volpe, De Poli, & Leman, 2005). However, very little research has been done on how to map the movements of users with various degrees of freedom to interaction commands in VMREs. More importantly, little is known about to what extent the mapping of gesture expression influences the experience of the user, and this is one of the central questions of this research.

VMREs allow various types of interaction scenarios, using both implicit and explicit cues provided by the user. During explicit interaction, users are aware that their actions or physiological states are changing particular parts of a surrounding environment (e.g., brain-computer interfaces for VR as described in Leeb et al., 2006). On the contrary, implicit interaction hides the relation between changing VMRE cues and users' behavioral or physiological changes. Many museum and interactive art exhibitions often use the implicit interaction approach where the user does not have a prior knowledge on the interaction type (e.g., walking, pointing). For example, in the large scale installation "Ada—The Intelligent Space" that was built for the Swiss national exhibition Expo02, visitors freely explored and discovered hidden interactions (Eng et al., 2006). It was found that active visitors perceived the interactive space differently than passive ones.

Our main experimental platform is an interactive multimodal space—the eXperience induction machine (XIM)—which is a successor of Ada. XIM is a general-purpose mixed-reality infrastructure equipped with a wide range of sensors and effectors that supports a broad range of studies in human-artifact interactions (Bernardet, Bermúdez i Badia, & Verschure, 2007). Our previous studies in XIM stressed the importance of the users' full-body interaction as a key component of immersive experience interaction (Inderbitzin, Wierenga, Valjamae, Bernardet, & Verschure, 2008; Bernardet et al., 2008). In particular, Inderbitzin et al. studied user behavior when playing a football game in which two teams of two players have to cooperate and compete in order to win. The results showed that winning and losing strategies can be discerned in specific behavioral patterns. This demonstrates that mixed reality systems such as XIM can provide new paradigms for the investigation of human social behavior and interaction.

Since type and specifics of interaction can certainly influence the user experience in VRMEs, we decided to investigate the effects of explicit versus implicit interaction modes on personal experience by means of body movements. For this purpose we deployed our XIM based Synthetic Oracle installation at the European Science Open Forum (ESOF'08), which took place on July 18–22, 2008 in Barcelona.

During the exhibition period, we collected tracking data and subjective data from their experience in the interactive room. All visitors were properly informed and agreed on the use of their data for research purposes. The experiment aimed at testing two main hypotheses.

Hypothesis 1. There should be a difference in subjective ratings between explicit and implicit interaction. Specifically, the explicit interaction should lead to higher levels of engagement and emotional experiences.

Hypothesis 2. There should be a correlation between the subjective ratings and the behavioral data representing users' movements in the space.

2 Methods

2.1 The Synthetic Oracle

The Synthetic Oracle consists of a 7.5 × 10 m long interactive field made of 3 m high luminescent pillars arranged to form a forest of 20 columns, a VR representation, and a music composition system that interacts with visitors at the audiovisual level. The Synthetic Oracle uses advanced machine perception, synthetic music composition, and neuromorphic control principles to transform questions of its visitors—posed through behavior—into answers expressed in a 3D sound and light composition. The Synthetic Oracle therefore generates responses to the actions of its visitors that are expressed in a language of sounds and lights.

The Synthetic Oracle installation is composed of a set of four overhead infrared cameras that are combined by a video merger hardware onto a single image. This image provides the input to a visual tracking system (AnTS) that locates the different visitors inside the mixed reality space boundaries (Mathews, Bermúdez i Badia, & Verschure, 2007). In parallel, the visitors are equipped with a Wii remote controller (hereafter referred to as RC) that provides direct input to the iqr neuronal simulator, a large-scale neural simulator that allows the user to define and run in real time neuronal models that can be interfaced to real world devices (Bernardet, Blanchard, & Verschure, 2002). Subsequently, iqr receives visitor position data from tracking and implements the main processing controller of the mixed reality space, that in turn controls a virtual reality rendering server (Torque, GarageGames, Inc., Oregon), the interactive music composition engine RoBoser (Wassermann, Eng, Verschure, & Manzolli, 2003), and a DMX controller that defines the color and luminance level of each of the luminous pillars of the installation (see Figure 1). The role and use of RoBoser in VMRE for enhancing the sensation of presence has already been addressed in previous studies (Le Groux, Manzolli, & Verschure, 2007). The light patterns in each of the pillars are created by 12 segments of light emitting diodes (LEDs).

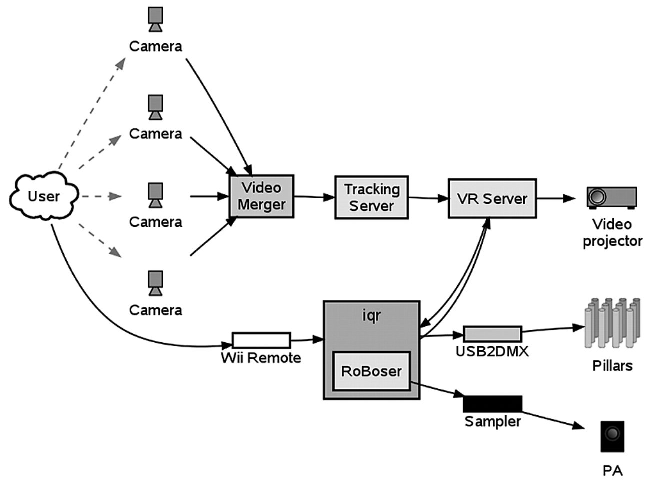

Figure 1. *Data flow diagram of the Synthetic Oracle installation. See text for further details.*

In one of the short sides of the installation, there is a screen (2.50 m × 2.50 m) where images from a virtual reality environment are projected (see Figure 2). The virtual environments used in the installation were extracted from the persistent virtual community (PVC). The PVC serves as a platform to conduct controlled multimodal experiments on presence, in particular social presence in mixed reality, and is being developed in the context of the PRESENCCIA project (http://www.presenccia.org; Slater et al., 2007).

Four different interactive scenarios were defined: fire, water, earth, and wind. The control loop of the installation used the user's position, velocity, and RC data as input. These data would influence the visual and music composition in different ways depending on the interaction scenario. For instance, in the water scenario, the speed of the visitor influenced the amount of rain in the VR world and music composition. The proximity to a pillar would turn its rain animation off, simulating an umbrella. Finally, the RC would affect both the sound and the VR world differently depending on the gestures. Different sets of interaction rules were explored for the four scenarios, allowing the visitor to interact in various ways with the different elements of the installation.

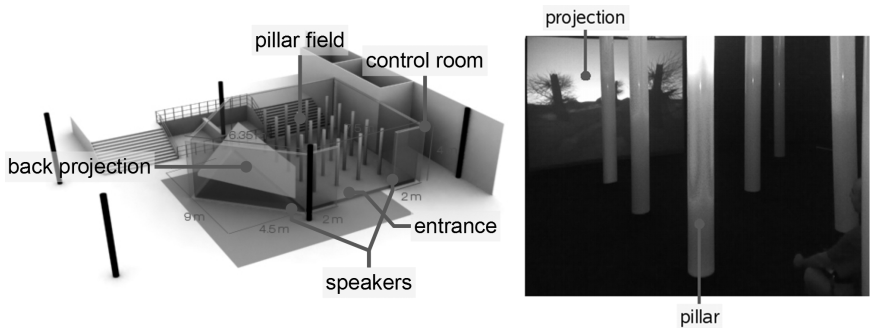

Figure 2. *The Synthetic Oracle installation. Left panel: construction plan. Right panel: fire—one of the four interactive scenarios of the installation.*

2.2 Experimental Procedure

Participants entered the room one at a time and were asked to explore the interactive space without any limitation of time. We placed the RC (a wireless three axis accelerometer capable of recording the acceleration of movements of the arm) on the dorsum of the right arm of each participant. The device we used was connected to iqr via Bluetooth. No information was collected about the handedness of the participants, and therefore no analysis could be performed to find possible effects of right versus left handed participants.

The participants experienced one of the following two interaction modes.

- **Implicit Interaction Mode (IIM group).** In this group, only the overhead tracking system data were used to interact with the mixed reality space. The RC was exclusively used to log the user's gestures, and could not influence the interactivity of the space.
- **Explicit Interaction Mode (EIM group).** In this second group, both the RC and the overhead tracking system were used to influence the interactivity of the space.

All visitors freely explored the space and experienced all the four different interactive scenarios. After the experience in the room, the visitors answered a questionnaire that was available in both English and Spanish versions.

2.3 Participants

Twenty-four subjects participated in the IIM part of the experiment (13 females, mean age 27, $SD = 16$) and 20 subjects participated in the EIM part (10 females, mean age 22, $SD = 10$).

2.4 Measures

2.4.1 Questionnaire Data. The subjective experience was evaluated using three types of questionnaires. First, we used a shortened form of the ITC-Sense Of Presence Inventory questionnaire (Lessiter et al., 2001). From this questionnaire we used 13 out of 44 statements on a five-point Likert scale (from 1—"strongly disagree" to 5—"strongly agree"). These correspond to the engagement factor and are averaged into a single value. Second, we used the nine-point valence and arousal pictorial scales of the self-assessment manikin (SAM; Lang, 1980). In previous research on cinema experience, it was found that ITC-SOPI engagement factor positively correlates to the SAM arousal scale (Väljamäe & Tajadura-Jiménez, 2007). Finally, we asked participants to respond to three aspects about the interaction.

1. "The space interacted with me" (Q1, ratings from 1 to 5);
2. "I actively explored the space" (Q2, ratings from 1 to 5);

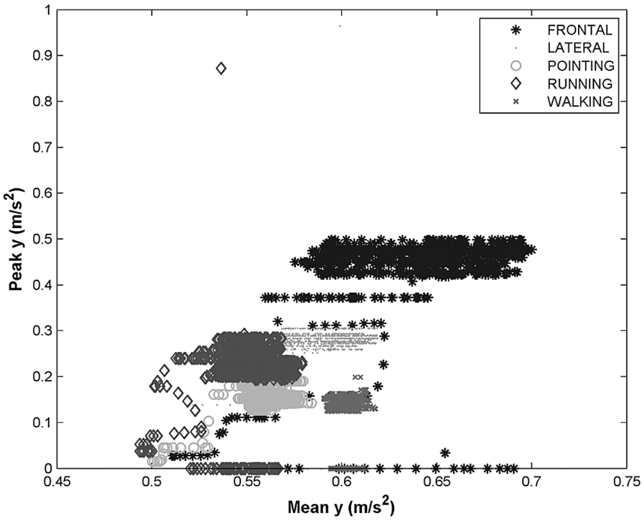

Figure 3. *RC data classification for gesture recognition. See text for further details.*

3. Participants were asked to mark the modality or modalities of the environment that they thought could be influenced by their behavior: (a) pillars, (b) sounds, or (c) projected virtual world (Q3).

2.4.2 Categorization of Arm Motion Tracking Data. The data from the RC provide information about the acceleration of the user's arm movements in *x, y, z* coordinates. The raw acceleration data were used to categorize the user behavior into five categories: WALK—walking movement pattern; RUN—running movement pattern; FRONT—frontal lifting of the arm; LAT—lateral lifting of the arm; and POINT—pointing behavior (lateral motion with the arm at around 90°). For this categorization, we designed a linear discriminant classifier trained with a data set of typical movements representing each of these five categories. The peak acceleration and mean acceleration measured with the RC are used for real-time gesture recognition. Figure 3 shows peak acceleration versus mean acceleration of the *y* axis of our training data set of gestures. These data are used to create a linear discriminant for the classification of the five categories of movements with the arm. The analysis revealed that the peak amplitudes and means of the accelerations on the *y* axis suffice to unambiguously classify all categories. In the particular case of the EIM group, the output of this classifier was also used to influence the state of the installation.

3 Results

The sample size is 24 for the IIM and 20 for the EIM experimental conditions. Corrupted tracking data from three participants from the first experimental group (IIM) were removed.

3.1 Questionnaire Data

The data from the ITC-SOPI, the SAM questionnaires, and two additional questions (Q1 and Q2) were tested using a between-groups *t*-test to find differences in the mean responses of the studied groups. The engagement ratings did not differ significantly between the IIM group ($M = 3.3$, $SD = 0.65$) and the EIM group ($M = 3.5$, $SD = 0.51$). Regarding the SAM ratings for the IIM, arousal ($M = 5.8$, $SD = 1.3$) and valence ($M = 6.3$, $SD = 1.6$) did not differ significantly with the arousal ($M = 5.6$, $SD = 2.1$) and valence ($M = 6.8$, $SD = 1.4$) ratings of the EIM group. None of the ratings was significantly correlated with the age of the participants.

We further examined the correlations between the engagement factor of ITC-SOPI and the SAM ratings. For the IIM group, only the valence ratings were positively correlated with the engagement ($r = 0.47$, $p <$ .05). Interestingly, arousal ratings were almost uncorrelated with engagement ($r = -0.04$, $p = .84$). On the contrary, the EIM group showed the reversed pattern—a small positive correlation between valence and engagement ratings ($r = 0.3$, $p = .2$) and a stronger correlation for the arousal ratings ($r = 0.4$, $p = .074$).

With respect to the questions about interaction, Q1 showed the trend that the EIM group participants were more convinced ($M = 3.3$, $SD = 1$) than the IIM group ($M = 3.3$, $SD = 1$) that the room was interacting with them ($t(42) = -1.5$, $p = .14$). Q2 confirmed that participants from the IIM group ($M = 3.5$, $SD = 0.93$) explored the room more actively than did the EIM

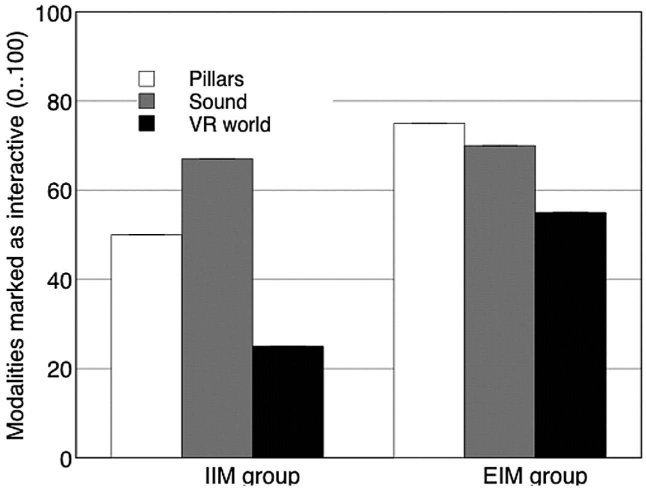

Figure 4. *Perceived interactivity of the different modalities of the Synthetic Oracle installation. See text for further details.*

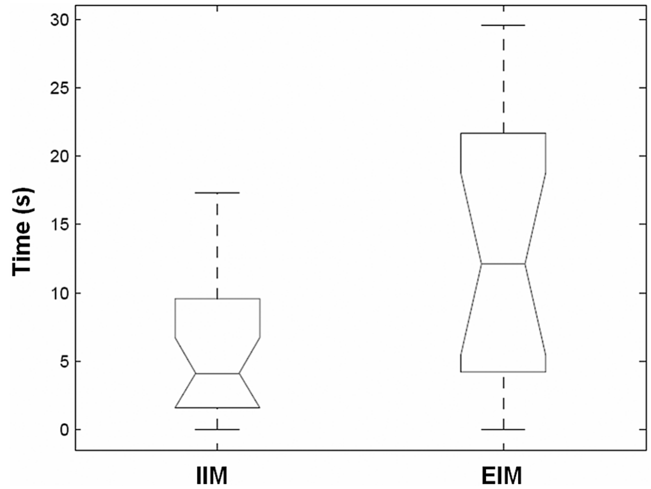

Figure 5. *Mean total pointing time for the IIM and EIM. See text for further details.*

group ($M = 4.4$, $SD = 0.67$), ($t(42) = -3.58$, $p < .001$). In addition, Q1 was negatively correlated with the age of the participants (Pearson's $r = -0.4$, $p < .01$).

The last question about interaction (Q3) assessed the perceived interactivity of different modalities of the room, that is, its pillars, sound system, and VR world. Figure 4 shows the percentage of the modalities that visitors perceived as being interactive, where 100% refers to all participants in the group. A Pearson chi-square analysis showed an increase of the perceived interactivity of the VR world $\chi^2(1, N = 44) = 4.14$, $p < .04$, and pillars $\chi^2(1, N = 44) = 2.88$, $p < .09$ for the EIM group participants. No such trend was found for the sonification of the space $\chi^2(1, N = 44) = 0.06$, $p = .81$.

3.2 Tracking Data

The raw acceleration data from both groups showed that the IIM group moved more ($M = 0.48$, $SD = 0.02$) than the EIM group ($M = 0.46$, $SD = 0.02$) in the x coordinate ($t(39) = 3.05$, $p < .005$) and z coordinates ($M = 0.47$ vs. 0.46), ($t(39) = 1.93$, $p = .06$). The comparison of the motion categories showed that the EIM group had significantly more pointing behavior (POINT index) ($M = 5.5$, $SD = 4.18$) than participants in the IIM group ($M = 13.8$, $SD = 9.2$), ($t(39) = -3.12$, $p < .001$) (see Figure 5). No other behavior category showed a significant difference between the groups.

3.3 Correlations Between Subjective Experience and Behavioral Data

The correlation analysis between the questionnaire data and users' behavior revealed several significant interactions and differences between the two interaction modes. First, the arousal ratings were positively correlated with the WALK index for the IIM group ($r = 0.7$, $p < .05$) and with the POINT index for the EIM group ($r = 0.46$, $p = .058$). Second, the ratings given by participants from the IIM group for Q1 "space interacted with me" were negatively correlated with the FRONT ($r = -0.44$, $p < .05$) and WALK activity indexes ($r = -0.64$, $p < .05$). On the contrary, for the participants of EIM who actively interacted with the space, the FRONT index was positively correlated with the Q1 ratings ($r = 0.47$, $p < .05$). Finally, Q2 "I actively explored space" ratings were positively correlated with the WALK index for the IIM group ($r = 0.8$, $p < .005$) and negatively correlated with the LAT index for the EIM group ($r = -0.84$, $p < .005$).

4 Discussion and Conclusions

In this study we used a public multimodal mixed reality installation called Synthetic Oracle to study the effects of implicit and explicit interaction on visitors' subjective experiences. We have addressed issues related to the plausibility of users' behavior and actions in VMREs. No assumption is made about body movements as a direct indication of presence. On the contrary, we assessed how different interaction types (i.e., implicit vs. explicit) affect the personal experience, the perception of the interaction, and the behavior of the visitors. In this sense, we believe that a bottom-up approach to the understanding of interaction types will allow us to design better mixed reality environments that can exploit the advantages of the appropriate interaction modes.

A wireless three axis accelerometer was used to log user arm movements and to further classify them in real time. Implicit interaction was defined as an interaction with the space by means of the visitor's position and speed, whereas explicit interaction was defined as an interaction by means of arm gestures. Both interaction modes were linked to the control of the Synthetic Oracle components. In order to study in isolation the effect of implicit versus explicit interaction, the Synthetic Oracle experience was chosen purposely to be of an abstract nature. This was done to preempt biases in the participant's way of interacting and behaving in the installation due to preconceptions of similar experiences.

To address the first hypothesis—there should be a difference in subjective ratings between explicit and implicit interaction—the data collected with the shortened ITC-SOPI, SAM, and three additional questions related to the Synthetic Oracle experience were analyzed. The interaction mode did not significantly affect the engagement and the emotional ratings. There could be several reasons for this. Firstly, sample size and homogeneity of participants might be one of the reasons. Indeed, this idea is supported by the strong negative correlation between age of the participants and their perception of the room as an interactive space. Secondly, the abstract nature of the experience and the novelty of the installation and its three interactive modalities could make it difficult to distinguish the effect between interaction modes. Finally, it might also be that generic media questionnaires such as the ITC-SOPI might fail to pick up the specifics of mixed reality interactive systems and that dedicated VMRE related questionnaires need to be developed.

Although no significant differences were found between groups in the emotional ratings, we have observed that arousal levels correlated significantly with different behaviors. In the case of the IIM group, arousal correlated with walking time, whereas it contested with pointing time for the EIM group. This suggests that the behavior of the IIM group was more exploratory (e.g., walking) than that of the EIM group (e.g., pointing). Therefore, these findings support the idea that the experience induced in the participants depends on their behavior, and that in turn, the behavior depends on the type of interaction with the VMRE or vice versa. Additionally, the interaction mode significantly modulated the perception of the various interactive modalities of the installation: in the IIM, sound tended to be the main modality visitors believed to be interactive, while the EIM drew their attention to the visual stimuli—pillars and, especially, to the virtual environment. From these results, it can be hypothesized that the user interaction mode (i.e., knowledge about the interactivity of the system) modulates both the behavior of the user and the perception of the surrounding environment. The behavioral data collected during the experiments were used in combination with the questionnaires to address the second hypothesis—there should be a correlation between the experience ratings and the behavioral data representing users' movements in the space. From the analysis of the arm movement data, the two types of interaction, that is, the implicit and explicit modes, could be clearly classified. For instance, subjects in the IIM group moved significantly more than in the EIM mode. However, movement in participants of the EIM group was more directed toward specific behaviors (e.g., pointing). For instance, while a passive observer can find the installation beautiful and nice (more close to the valence scale), the active observer will also find it exciting (arousal scale). The real-time behavioral data gathered with the RC informs us about the level of arousal, and it could also be reliably used to categorize users into groups with different interaction strategies. Nonetheless, we have to point out that results obtained with the different interfaces over short durations of time have to be taken with precaution since its effects may vary over longer time periods (Christoffersen, Hunter, & Vicente, 1996).

Therefore, in future installations, we can use these findings to select the most appropriate interaction mode to facilitate personal experiences and behavior. In this respect, VMRE with more heterogeneous and not only positive content can lead to a better understanding of such effects. For example, in a recent installation, Shower (Ponomarev & Mescheryakov, 2007), media artists used video sequences of negative and positive valence to modulate user experience referring to the metaphor of cold and hot showers.

The presented study contributes to our knowledge about the design of interactive and mixed reality spaces, and how to use different interaction modes to induce or bias behavior and experiences. However, it stresses again the limitation of using subjective post hoc measures of experience such as ITC-SOPI or SAM. Moreover, there is little known about the effect of pose and interface on perception, and further research has to be carried out in this sense. Ideally, future studies will include the continuous measurement of user engagement (both subjective and physiological, e.g., wearable electrodermal activity recording devices) with the surrounding environment. These data would allow us to precisely correlate particular interaction events to the behavioral data from motion tracking, and therefore detect behaviors of highly arousing experiences during the interaction with the installation.

Acknowledgments

The authors would like to thank M. Inderbitzin, S. Le Groux, S. Wierenga, Z. Mathews, E. Marcos, N. Valkanova, and A. Luvizotto for their help in the development of the Synthetic Oracle installation. This research is supported by the EU project PRESENCCIA (IST-2006-27731) and Fundació La Marató de TV3 (071932).

References

Benford, S., Greenhalgh, C., Reynard, G., Brown, C., & Koleva, B. (1998). Understanding and constructing shared spaces with mixed-reality boundaries. *ACM Transactions on Computer-Human Interaction (TOCHI), 5*(3), 185–223.

Bernardet, U., Bermúdez i Badia, S., & Verschure, P. (2007). *The eXperience induction machine and its role in the research on presence*. Paper presented at the 10th Annual International Workshop on Presence, Barcelona, Spain.

Bernardet, U., Blanchard, M., & Verschure, P. (2002). IQR: A distributed system for real-time real-world neuronal simulation. *Neurocomputing, 44,* 1043–1048.

Bernardet, U., Inderbitzin, M., Wierenga, S., Väljamäre, A., Mura, A., & Verschure, P. F. M. J. (2008). *Validating presence by relying on recollection: Human experience and performance in the mixed reality system XIM.* Paper presented at the 11th Annual International Workshop on Presence, Padova, Italy.

Camurri, A., Mazzarino, B., Ricchetti, M., Timmers, R., & Volpe, G. (2004). Multimodal analysis of expressive gesture in music and dance performances. *Lecture Notes in Computer Science,* 20–39.

Camurri, A., Volpe, G., De Poli, G., & Leman, M. (2005). Communicating expressiveness and affect in multimodal interactive systems. *IEEE Multimedia, 12*(1), 43–53.

Christoffersen, K., Hunter, C., & Vicente, K. (1996). A longitudinal study of the effects of ecological interface design on skill acquisition. *Human Factors, 38*(3), 523–541.

Eng, K., Mintz, M., Delbruck, T., Douglas, R., Whatley, A., Manzolli, J., et al. (2006). An investigation of collective human behavior in large-scale mixed reality spaces. *Presence: Teleoperators and Virtual Environments, 15*(4), 403–418.

Inderbitzin, M., Wierenga, S., Valjamae, A., Bernardet, U., & Verschure, P. F. M. J. (2008). *Social cooperation and competition in the mixed reality space eXperience induction machine*. Paper presented at the 11th Annual International Workshop on Presence, Padova, Italy.

Lang, P. (1980). Behavioral treatment and bio-behavioral assessment: Computer applications. In J. B. Sidowski, J. H. Johnson, & T. A. Williams (Eds.), *Technology in mental health care delivery systems* (pp. 119–137). Norwood, NJ: Ablex.

Le Groux, S., Manzolli, J., & Verschure, P. (2007). *Interactive sonification of the spatial behavior of human and synthetic characters in a mixed-reality environment.* Paper presented at the 10th Annual International Workshop on Presence, Barcelona, Spain.

Leeb, R., Keinrath, C., Friedman, D., Guger, C., Scherer, R., Neuper, C., et al. (2006). Walking by thinking: The brainwaves are crucial, not the muscles! *Presence: Teleoperators and Virtual Environments, 15*(5), 500–514.

Lessiter, J., Freeman, J., Keogh, E., and Davidoff, J. (2001). A cross-media presence questionnaire: The ITC-Sense Of Presence Inventory. *Presence: Teleoperators and Virtual Environments, 10,* 282–297.

Maes, P., Darrell, T., Blumberg, B., & Pentland, A. (1997). The ALIVE system: Wireless, full-body interaction with autonomous agents. *ACM Multimedia Systems, 5*(2), 105–112.

Mathews, Z., Bermúdez i Badia, S., & Verschure, P. (2007). *A novel brain-based approach for multi-modal multi-target tracking in a mixed reality space*. Paper presented at the INTUITION: International Conference and Workshop on Virtual Reality, Athens.

Modler, P., Myatt, T., & Saup, M. (2003). *An experimental set of hand gestures for expressive control of musical parameters in real time*. Paper presented at the 2003 Conference on New Interfaces for Musical Expression, Montreal, Quebec, Canada.

Ponomarev, A., & Mescheryakov, A. (2007). Shower. Retrieved April 1, 2009, from http://www.mdf.ru/english/search/authors/ponomarev_alxndr/

Slater, M., Frisoli, A., Tecchia, F., Guger, C., Lotto, B., Steed, A., et al. (2007). Understanding and realizing presence in the Presenccia project. *IEEE Computer Graphics and Applications, 27*(4), 90–93.

Tang, A., Biocca, F., & Lim, L. (2004). *Comparing differences in presence during social interaction in augmented reality versus virtual reality environments: An exploratory study*. Paper presented at the 7th Annual International Workshop on Presence, Valencia, Spain.

Tollmar, K., Demirdjian, D., & Darrell, T. (2003). Gesture + play: Full-body interaction for virtual environments. *CHI Extended Abstracts,* 620–621.

Väljamäre, A., & Tajadura-Jiménez, A. (2007). Perceptual optimization of audio-visual media: Moved by sound. In J. D. Anderson & B. Fisher Anderson (Eds.), *Narration and spectatorship in moving images*. Angerton Gardens, UK: Cambridge Scholars Press.

Wassermann, K., Eng, K., Verschure, P., & Manzolli, J. (2003). Live soundscape composition based on synthetic emotions. *IEEE Multimedia, 10*(4), 82–90.