Comparing Differences in Presence during Social Interaction in Augmented Reality versus Virtual Reality Environments: An Exploratory Study

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Abstract

In augmented reality (AR) environments, users experience the physical environment and other users directly along with mediated virtual objects embedded in the environment. In immersive virtual reality (VR), users experience of a visual environment (and sometimes other senses) is completely mediated. The representation of user's body in virtual environments granted us a new research territory in dualistic interaction between the mind and body: how do the virtual body and user's mind interact one another, and eventually affect user's behaviors to the environment? An experiment was conducted to explore potential effect of users and interactant's body to sense of presence in VR and AR environments. Results from the study suggest that the absence of representations of the user's body in VR environment may lessen sense of spatial presence comparing with AR environment

Keywords: Augmented reality, Presence, Body and Mind, Spatial cognition.

1. Presence and the continuum between mediated and unmediated experience

Presence, the sense of being there in a space, may be a psychological state associated with both mediated and unmediated experience; it is defined by some as the perceptual illusion of non-mediation [1, 2]. The user fails to perceive or acknowledge the existence of a medium and responds as if the medium is not there.

Media differ as well in the degree to which they mediate experience; that is the degree to which direct sensory experience of the environment is replaced with stimuli and representations generated by the medium. In the continuum between direct, unmediated perception of the environment and completely mediated perception, augmented reality (AR) is closer to unmediated perception than virtual reality (VR). In most typical configurations, VR and AR systems use head-mounted displays (HMD) and motion trackers to display virtual objects, environments, or other user. The first person perspective and tight coupling of the human body to the computer interface generate a compelling sense of being in the mediated space and the consciousness of user's body in the computing environment [3].

Marsh and others have argued that the degree of presence of an experience is dependent on the transparency and continuity of the interface [4]. Transparency is the elimination of mediation [1]: the lack of consciousnesses of the medium itself. Continuity is lack of disruption during interaction. Disruption may occur when the user becomes overly aware of the medium and the physical interface. For example, the sense of presence in the narrative world presented by the television disappears when the observer becomes aware of the television set. Slater and his colleagues have refer to this as breaks-in-presence [5, 6].

In typical VR and AR interfaces, users interact with the medium in a three dimensional space instead of a two dimensional surface in typical interfaces and media. The elimination of the frame of the detached media, such as interface screen and paper, provides a higher transparency and continuity. The use of head motion and hands gesture to interact with the computer transforms the human body to the primordial communication interface to the environment [7]. VR and AR technologies show promise for the ultimate interface of high degree of presence.

1.1. Mediation and the experience of one's body, other bodies, and the environment.

The representation of user's body in the virtual environment granted us a new research territory in dualistic interaction between the mind and body: how do the virtual body and user's mind interact with one another and affect user's behaviors in the environment, and eventually the body schema of the user in reality? The sensory cues of direct perception and action within an environment help locate the body of the user [8]. The first person viewpoint of immersive VR and AR environments provide visual information about one's view and head movement in space, but the rest of the user's phenomenal body in immersive VR is usually largely absent or distorted. It is technically difficult to capture all the movement and features of the user and project it to the avatar in the VR environment in real time. Most VR systems also have a mismatch body parts position, physical scale, and motion scale between the phenomenal body in VR and the actual user's body. For example, a VR user interface that use hand manipulation of objects typically shows only a limited virtual representation

of user's disembodied hands, neglecting the rest of the body. Those VR interfaces that implement a full body avatar for the user usually use a crude and primitive human-like figure. It may not be in the right size, shape, color and gender [9, 10].

The fundamental difference between VR and AR environments is that AR user is able to perceive the real world as well as the user's body and the body of an interactant. Instead of replacing perception in the natural surroundings, AR systems augment the human visual channel with computer generated graphics. So instead of relying on proprioception memory, the user has real time visual perception of every body motion. It is observed that AR systems users are generally more confident in making body motion than VR systems users. The increased consciousness of the user's body in AR environments also facilitates a more natural body movement.

Presence is part the sense of the location of one's phenomenal body when coupled to a medium. Presence may be increased by not only the perception of the environment but by the experience of ones own moving body and other bodies in the environment. Slater found that adding a fully body avatar and providing even primitive arm movement for the full body avatar increased the sense of presence [11]. But this experiment looked only at the presence or absence of an avatar. It did not compare the direct experience of a fully natural body.

1.2. Research question: Does the presence of unmediated cues increased presence

AR environments allow us to explore the role of unmediated direct experience of the body and other cues increases presence. The authors are not aware of any previous study on the sense of presence using AR system. A study was conducted to explore the following research questions: Does the direct visual experience of the one's body and that of partner increase the sense of presence? Or to put it another way, does the absence of visual cues of ones body and that of other in a virtual environments decrease presence?

2. Methodology

A within-subjects experiment was conducted to explore any potential difference in sense of presence between VR and AR environments. There was one independent variable, the interaction environment, with two levels: (a) AR Environment, and (b) VR Environment. The intent of the experiment is to measure the extent to which users are able to experience being physically presence when communicating with a human in an AR environment or with a virtual agent in an AR environment.

2.1. Participants

16 participants from an undergraduate class at a university volunteered to participate in the study. None had previous experience in any VR/AR environment. 11 of the participants are male, and 5 are female.

2.2. Materials

2.2.1. Virtual Environments

The study was conducted using hardware and software that could create a virtual or an augmented reality environment. Stimulus materials were displayed in stereo using the Sony Glasstron LDI-100B. Subject's head motion was tracked using the Intersense IS-900 ultrasonic/inertia hybrid tracker. Stereo graphics were rendered in real time based on the data from the tracker. Presentation of stimulus materials was written using ImageTclAR [12].

For the AR environment (see Figure 1), subjects directly experienced a simply black room where a set of virtual cell phones was present on physical table. Across the table was a partner, a confederate of the experimenter, directly visible and also wearing a head-mounted display. In the VR version of this environment (See Figure 2) all aspects of the visual environment were virtual. An avatar of the partner was presented in a virtual black room with a matching virtual table. In both cases, the participants interacted with the same female confederate.

Figure 1. A photograph taken from the see-through HMD in the AR condition. The cellular phones on the table were virtual objects but the confederate and environment were directly visible and unmediated.

Figure 2. Stimulus material displayed to the participant in the VR environment. In this environment, user's body is not visible. The cellular phones, partner, and environment are all mediated and virtual. The virtual partner was a full body avatar puppeteered by the confederate.

2.2.2. Measures

Participants were administered the ITC-Sense of Presence Inventory (ITC-SOPI) to evaluate their levels of physical presence felt [13]. The ITC-SOPI is a validated 44-item self-report questionnaire that was used in this study to measure how physically located users feel within any mediated space, how the mediated environment compares to the real world, and how realistic the environment feels. The items generate four factors: (1) Spatial Presence – how physically present users feel in the virtual environment; (2) Engagement – how involved users would feel toward the content of the virtual environment; (3) Ecological Validity – the level of realism and naturalness of the environment; and (4) Negative Effects – any harmful physical effects, such as eye-strain or nausea, that users may experience by being within the environment.

2.3. Procedure

The experimental procedure consisted of an initial demographic questionnaire and two user study phases. After filling out the demographic questionnaire, participants were brought to a cylindrical room covered with black cloth, and were immersed into an AR and a VR environment in turn. The sequence of the environment presenting to each subject was randomized and counter-balanced.

In each of the environment, participants were asked to carry out a social discussion with a confederate about personal preference about two cellular phone models. A typical discussion includes comparison of colors, buttons, shape of the two cellular phone and other personal preferences. The set of cellular phones displayed in each environment is also randomized and counter-balanced. The participants were asked to fill out the ITC-SOPI questionnaire right after the discussion in each environment. Participants were told that the confederate is one of the subjects. All experimental sessions took less than 30 minutes.

3. Results and Analysis

Table 1 and figure 3 illustrate the four mean factor scores generated by the ITC-SOPI questionnaire. Resulted were further analyzed using repeated measures ANOVA.

The effect of spatial presence between the two treatment conditions is significant [*F(1, 16) = 5.33, p = 0.04*]. Users experienced greater spatial presence in the augmented reality condition.

On the other hand, comparing engagement, naturalness and negative effect factor scores between the two treatment conditions, no significant differences were found between the two conditions [*F(1, 16) = 0.34, p = 0.86; F(1, 16) = 0.55, p = 0.47 and F(1, 16) = 0.20, p = 0.66* respectively].

	AR		VR	
	Mean	STD	Mean	STD
Spatial Presence	2.79 / 5	0.78	2.60 / 5	0.81
Engagement	2.85 / 5	0.64	2.83 / 5	0.67
Naturalness	3.01 / 5	0.76	2.90 / 5	0.97
Negative Effect	2.03 / 5	0.64	1.96 / 5	0.80

Table 1. Dimensions of the ITC-SOPI score by treatment condition: AR and VR environment. Average factor scores and standard deviation in each condition.

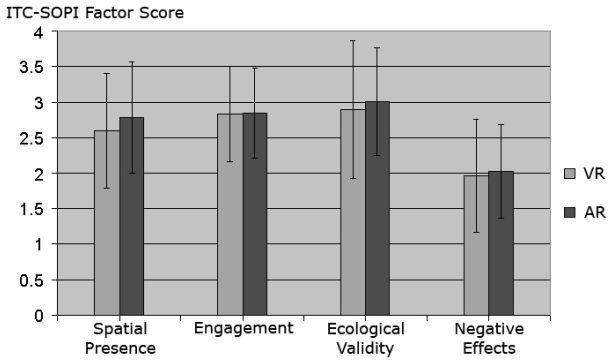

Figure 3. Dimensions of the presence by treatment condition: AR environment and VR environment.

4. Discussion

4.1. Difference in spatial presence between AR and VR

The simplest explanation for the difference in spatial presence between AR and VR is that the AR condition is largely unmediated. Therefore, there are more sensory cues as to ones' spatial location. But there may be more to this than the lesser level of sensory cues.

Human brain uses both sensory and motor information to construct an internal representation of the space we perceive. Research results from spatial cognition suggest that objects in the environment are represented in egocentric and allocentric references frames [14, 15]. Since all visual input is egocentric, all objects in the environment are originally egocentric before some of them are encoded and clustered into the allocentric reference frame.

We argue that a first person VR visual simulation without a user avatar interferes the behavior of the human brain's visuo-spatial perception system. This may weaken user's ability to perceive egocentric space accurately and negatively influence user's sense of spatial presence. By extension, we would predict that adding a realistic body for the user in the VR condition would make the level of presence more similar.

4.2. Lack of difference in Engagement and Naturalness

We were originally expected that the ecological validity/naturalness factor score of AR environment would be significantly higher than that of VR environment. Although the AR environment does score higher on both dimensions, the differences are not significance. This result

could prone to Type 1 errors. On the other hand, AR environments may present an ambiguous reference for self-report scales. Are users evaluating the whole environment including the unmediated one, or are they only evaluating the virtual components of the environment? Even some subjects skew towards a more limited interpretation then the difference between AR and VR scores would be diminished.

The ecological validity/naturalness factor score is calculated as the mean score of items B5, B11, B15, B20 and B27 in the ITC-SOPI questionnaire, as shown in the following:

(5) The displayed environment seemed natural.
(11) The content seemed believable to me.
(15) I felt that the displayed environment was part of the real world.
(20) The scenes depicted could really occur in the real world.
(27) I had a strong sense that the characters and objects were solid.

We believe the ecological validity/naturalness score in AR is not rated significantly higher than the VR condition because the computer generated graphics is juxtaposed with the real environment. By contrasting the computer generated graphics with the real environment, participants may find the environment less natural and less believable (in item B5 and B11). Also, optically overlaid computer graphics do not appear to be solid in the real environment, and item B27 is likely to be rated lower. This is especially true if the "reference" for their statements in this scale is the virtual objects. This suggests that some modification of the scale may be needed for AR environments.

6. Conclusions

An experiment was conducted to evaluate the difference of sense of presence generated by AR and VR environment using the ITC-SOPI inventory. There is some evidence for the proposition that users' perception of spatial presence is higher in AR environments than in VR environment. We speculate that the failure to find a difference between the AR and VR environments on the naturalness dimension may be caused by a possible ambiguity regarding what is being referenced (evaluated) in the scale items of the ITC SOPI measure of presence used in this experiment. Because the focal content of the interaction was the virtual cellular phones, the users may interpret that the questions to refer to the VR objects and not the whole environment. This would need to be confirmed by debriefing.

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