Does Brief Exposure to a Self-avatar Affect Common Human Behaviors in Immersive Virtual Environments?

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Abstract

A plausible assumption is that self-avatars increase the realism of immersive virtual environments (VEs), because self-avatars provide the user with a visual representation of his/her own body. Consequently having a self-avatar might lead to more realistic human behavior in VEs. To test this hypothesis we compared human behavior in VE with and without providing knowledge about a self-avatar with real human behavior in real-space. This comparison was made for three tasks: a locomotion task (moving through the content of the VE), an object interaction task (interacting with the content of the VE), and a social interaction task (interacting with other social entities within the VE). Surprisingly, we did not find effects of a self-avatar exposure on any of these tasks. However, participant's VE and real world behavior differed significantly. These results challenge the claim that knowledge about the self-avatar substantially influences natural human behavior in immersive VEs.

Categories and Subject Descriptors (according to ACM CCS): Computer Graphics [I.3.7]: Three-Dimensional Graphics and Realism-Virtual reality—H.5.1Information Systems: Multimedia Information Systems-Artificial, augmented, and virtual realities

1. Introduction

Over the last several years, immersive virtual environments (VEs) have become more seriously recognized in research areas of behavioral neuroscience and experimental psychology [LBB99, TW02]. This experimental paradigm is effective because it allows for testing human behavior under very natural conditions in which specific features can be varied systematically. The closer the VE-induced experience approximates a real life experience, the more likely the user will behave as if in the real world. Therefore, realism plays an essential role in these applications. One important element of a realistic VE might be the presence of a self-avatar [BB04] which represents the user's body within the immersive VE. Only a few studies have investigated this matter. Effects of self-avatars on human performance are reported on distance perception, and social interaction.

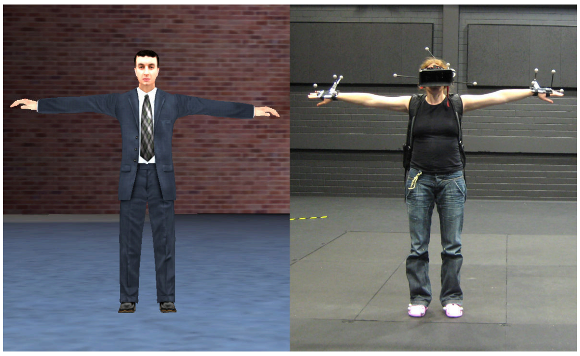

Figure 1: *The self-avatar (left) is used to represent the participant's body (right) within the VE. The body movements of the participant are directly linked to the movements of the self-avatar using inverse kinematics.*

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1.1. Effect of Self-Avatar on Distance Judgment

Distance compression refers to the well-known phenomenon that humans perceive egocentric distances in immersive VEs to be smaller than they are [LSFF92, PL97]. Interestingly, it has been reported that rendering parts of a user's body from a first person perspective in an HMD reduced distance compression [Dra95]. In line with this result, Mohler et al. [MBTCR08] showed that a five minute adaptation phase where participants were pre-exposed to a fully-articulated self-avatar improved egocentric distance judgments in immersive VEs to be near accurate. Note that distance compression in these studies was measured in the absence of visual information about the environment during the judgment task, e.g. participants had to walk blindly as close as possible to a predefined target location. However, these studies do not address the question whether a self-avatar also effects distance compression if visual feedback about the environment is available during the judgment phase.

1.2. Effect of Self-Avatar on Social Interaction

From a social interaction perspective avatars in VEs are considered highly important. One study [YB07] has found that changes in avatar representation are correlated with behavioral changes. Specifically, they showed that participant's assigned to more attractive avatars were more intimate with confederates in a self-disclosure and interpersonal distance task than participants assigned to less attractive avatars and participants assigned to taller avatars behaved more confidently than participants assigned to shorter avatars. Other researchers have also seen evidence for an effect of self avatar on social interaction and self-perception. In one experiment volunteers were asked to explore a VE as an avatar wearing a doctor's coat or one wearing the white robe and hood of the Ku Klux Klan. A personality test revealed that participants who wore the white robe and the hood of the Ku Klux Klan rated themselves as more aggressive than participants wearing a doctor's coat [Mil07]. Importantly, these studies were conducted in non-immersive VEs. It is not clear whether the presence of a self-avatar also affects human behavior in immersive VE.

Taken together the results of these studies suggest that the availability of self-avatars in VEs might render human performance in VEs to be more realistic. However, it is important to note that these findings cannot be fully generalized to self avatars in immersive VEs. First, it is unclear whether self-avatars have an effect on distance judgment if visual feedback about the environment is provided. That is, perceiving visual feedback while walking might allow the user to judge distances precisely regardless of the presence of a self-avatar. Secondly, Miller (2007) and Yee (2007) investigated the effect of self-avatar on social behavior by using self-avatars in non-immersive VEs (e.g. second life). Under these conditions the viewer sees the avatar from a third person perspective. In contrast self-avatars are seen from a first person perspective in immersive VE, which might affect social behavior differently. For example, the third person perspective shows more clearly the appearance of the self avatar and thereby one's social role, which might lead to different behavior. We therefore investigated the effect of a first-person perspective self-avatar on human behavior in an immersive VE in which the user constantly perceives visual feedback about this environment from an egocentric perspective.

2. Experiment

24 persons recruited from the local community in Tübingen (10 male, 14 female) participated in this experiment. All participants had normal or corrected-to-normal vision and received standard monetary compensation.

The system was set up in a large, fully tracked, free-walking space (12.8 by 11.7 meter). Participant's body movements were tracked through the monitoring of reflective markers using an optical tracking system (16 Vicon MX13 cameras). Each Vicon camera has a resolution of 1280x1024. Six sets of markers (rigid bodies) were attached to the participants' head, hands, feet and pelvis (see figure 1) in order to capture their positions and orientations in real time. The VE was rendered on a Dell Inspiron XPS Gen 2 laptop (with nVidia GForce2Go 6800 Ultra graphics card) which was mounted on a backpack worn by the experimenter (see figure 1). The nVisor SX HMD displayed a stereoscopic image of the virtual world with a resolution of 1280x1024 pixels, a frame rate of 60 Hz, and a FOV of 47 degrees horizontally and 38 degrees vertically.

2.1. Experimental Design

The experiment consisted of three behavioral tasks (walking, object interaction, social interaction) that were conducted by each of the 24 participants in real-space and in the immersive VE. 12 participants started with the three tasks in the VE and then conducted the same three tasks in real-space (VE-REAL group). The other 12 participants had the reversed testing order (REAL-VE group). Before each behavioral task, each participant conducted an adaptation task (in both virtual and real-space). Within each of REAL-VE and VE-REAL groups 6 out of the 12 participants did the adaptation task with a self-avatar and the other 6 participants saw no self-avatar. The task order was counterbalanced across each of the 6 participants of both the self-avatar and no self-avatar groups. Each participant completed each task four times. We therefore have a mixed ANOVA design with testing order (VE-REAL vs. REAL-VE) and self-avatar (present vs. absent) as a between-subject factor and task (walking, object interaction, social interaction) as a within-subject factor.

In the **Adaptation Task** participants looked down and then moved their left and right leg to the front (until their foot appeared in their view) in alternating fashion ten times. Following these ten leg movements, participants looked straight ahead and lifted their left and right arm in alternating fashion

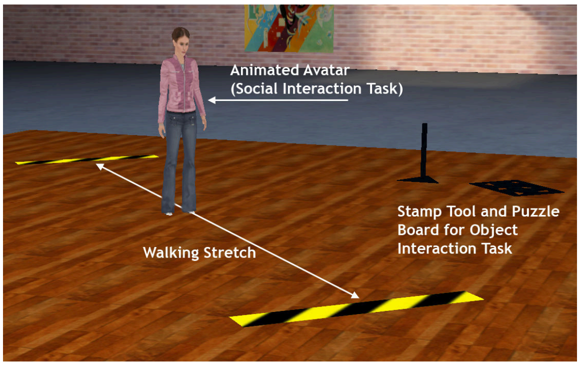

Figure 2: *Immersive VE programmed in Virtools: In this VE you can see all the items used for the three behavioural tasks. The lines on the floor indicated the points from which participants should begin and end walking for both the Walking and the Social Interaction Tasks. The tools for the object interaction task can be seen on the far right.*

from the side of their body to eye-height (until their hand appeared in their view) ten times. During all movements participants were instructed to count out loud to ten in synchrony with the completion of a left/right limb movement. The purpose of the adaptation task was to make participants aware of the presence or absence of a self-avatar.

In the **Walking Task**, subjects were instructed to walk naturally from one corner to the diagonal opposite corner of the room. The start and endpoint were marked by lines on the ground (7.5m). We measured participants' performance in this task using walking velocity and walking ratio.

The **Social Interaction Task** was identical to the Walking Task, except that a person (virtual or real) was placed in the centre of the room. Participants were instructed to walk the same stretch as in the Walking Task without bumping into the person placed in the centre. Social interaction performance was defined as the smallest distance between the person in the middle of the room and the participant (interpersonal distance).

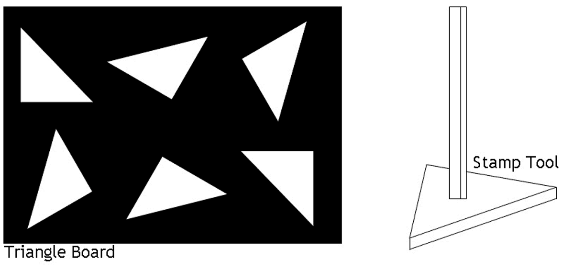

Figure 3: *Left is a schematic of the top view of the Triangle Board (100 x 70 x 20 mm) and right is a schematic of the stamp tool.*

In the **Object Interaction Task** participants had to insert a triangle that was fixed on top of a handlebar into 6 triangular openings cut into a wooden board (see figure 3) placed on the ground. Each opening had a different orientation. The time to complete all six insertions was measured (completion time). Participants repeated each task (walking, social interaction, and object interaction) four times in the virtual world and four times in the real world. The self avatar was only rendered in the adaptation task but not in the walking, social interaction, or object interaction task.

2.2. Results

All analysis was done on the difference scores between mean virtual performance and mean real-world performance. These difference scores were calculated for each dependent variable (distance, velocity, walking ratio, completion time), experimental condition (adaptation, testing order), and participants separately. We considered completion time differences between the virtual and the real-space condition longer than 50 secs as unreasonable because they are unlikely to reflect an avatar or testing order effect. We therefore deleted those scores from our analysis.

	Walking		Object	Social
Adaptation	Walking Ratio	Velocity (m/s)	Time (s)	Distance (m)
Self-Avatar	14.62 (6.59)	-0.13 (0.03)	12.40 (1.06)	0.12 (0.04)
No Self-Avatar	11.21 (4.11)	-0.15 (0.02)	13.56 (1.54)	0.13 (0.04)

Table 1: *Mean difference scores listed for each task, adaptation condition, and dependent measure separable. The number in brackets indicate one standard error.*

Object Interaction Task: We assessed the effect of adaptation and testing order on completion time in a two-way between subjects ANOVA with completion time as the dependent variable. The ANOVA revealed no significant main effect for adaptation ($F(1,18)=0.47$, $p=0.503$) but a significant main effect for testing order ($F(1,18)=5.11$, $p=0.036$). The interaction of adaptation condition and testing order was not significant ($F(1,18)=0.01$; $p=0.918$). A main effect of testing order was due to completion times being significantly shorter when participants were first tested in the real-space environment and then in the virtual environment than the other way around.

Social Interaction Task: A 2 way between subject ANOVA with adaptation condition and testing order as factors showed no significant main effect for testing order ($F(1,18)=0.00$; $p=0.956$) and adaptation condition ($F(1,18)=0.42$; $p=0.525$). The interaction of adaptation condition and testing order was significant ($F(1,18)=6.32$; $p=0.022$). We investigated this significant interaction with Bonferroni adjusted independent t-tests. We found testing order to be significantly different for participants in the no avatar condition (t(8)=2.79; p=0.024) but not in the avatar condition (t(6)=-1.08; p=0.323).

Walking Task: We assessed walking performance by means of walking velocity and walking ratio. We investigated the between-subject effects of testing order and adaptation task on walking velocity and walking ratio in two separate 2-way between subjects ANOVA. We did not find significant effects of testing order, adaptation task on walking velocity or walking ratio (p>0.10). Likewise there was no significant effect of the interaction of testing order and adaptation task on walking velocity or walking ratio (p>0.10).

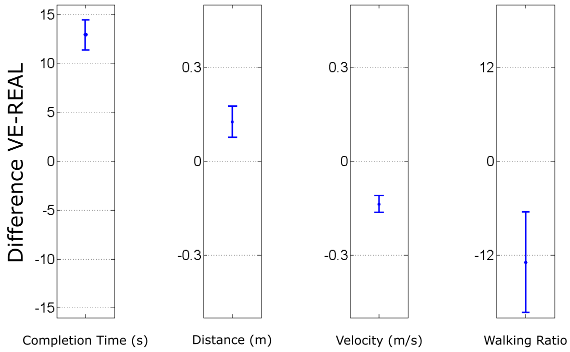

Figure 4: *Virtual minus real-space performance for all three tasks. Bars indicate the 95 percent confidence interval from the mean.*

VE vs. REAL: Finally we compared virtual vs. real-space behavior for all of our dependent measures. As can be seen in Figure 4 all performances differed significantly between virtual and real-space. These results are consistent with previous research, investigating the differences in gait parameters between virtual and real worlds while walking with eyes open and closed to previously seen targets [MCWB07].

3. Conclusions

Here we asked whether the presence of a self-avatar alters task performance in an immersive VE. We did not find an effect of self-avatar in any of the three tasks. Hence, the self-avatar has no effect on human behavior in immersive VEs using the viewing conditions described above.

One might argue that the reason of the absence of an effect of self-avatar on human behavior was due to the fact that the self-avatar was not visible during the actual task. However, the motivation for the absence of a self avatar during the task was given by technical constraints. That is the limited field of view of the HMD did not allow participants to see their own body during the walking task and the social interaction task even when the self avatar was switched on (see supplementary material). It is for exactly this reason that we had an adaptation phase in which participants were made aware of their self-avatar. Furthermore, note that even in real walking situations humans often do not see their own body during walking because their gaze is directed towards the goal. Therefore it seems that humans also rely on knowledge about their own body obtained previously to a task. We therefore think that our results of the walking and social interaction task illustrate that humans rather rely on knowledge about their physical body than on knowledge about their self-avatar in immersive VE.

Because a self-avatar would have been more visible during the object interaction task, its absence might have affected performance on this task more profoundly. We therefore think that the results from the object interaction task should be interpreted more carefully.

Overall, we conclude that the presence of a self-avatar in immersive VEs does not necessarily influence human behavior, especially when the field of view is limited. Future research will investigate whether these results also hold for tasks in which the self-avatar is visible during action performance and in which the field of view is increased.

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References

[BB04] Bailenson J. N., Blascovich J.: Avatars. In *Encyclopedia of Human-Computer Interaction*, Bainbridge W. S., (Ed.). Berkshire Publishing Group, 2004, pp. 64–68.

[Dra95] Draper M.: *Exploring the Influence of a Virtual Body on Spatial Awareness*. Master's thesis, Seattle, WA 98195, USA, 1995.

[LBB99] Loomis J. M., Blascovich J. J., Beall A. C.: Immersive virtual environment technology as a basic research tool in psychology. *Behavior Research Methods, Instruments, & Computers 31*, 4 (1999), 557–564.

[LSFF92] Loomis J. M., Silva J. A. D., Fujita N., Fukusima S. S.: Visual space perception and visually directed action. *Journal of Experimental Psychology: Human Perception and Performance 18*, 4 (1992), 906–921.

[MBTCR08] Mohler B. J., Bülthoff H. H., Thompson W. B., Creem-Regehr S. H.: A full-body avatar improves distance judgments in virtual environments. In *Proc. Symposium on Applied Perception in Graphics and Visualization* (Aug. 2008).

[MCWB07] Mohler B. J., Campos J., Weyel M., Bülthoff H. H.: Gait parameters while walking in a head-mounted display virtual environment and the real world. In *Proceedings of the 13th Eurographics Symposium on Virtual Environments* (2007), pp. 85–88.

[Mil07] Miller G.: The promise of parallel universes. *Science 317* (2007), 1341–1343.

[PL97] Philbeck J. W., Loomis J. M.: Comparison of two indicators of perceived egocentric distance under full-cue and reduced-cue conditions. *Journal of Experimental Psychology: Human Perception and Performance 23*, 1 (1997), 72–85.

[TW02] Tarr M. J., Warren W. H.: Virtual reality in behavioral neuroscience and beyond. *Nature Neuroscience 5* (2002), 1089–1092.

[YB07] Yee N., Bailenson J.: The Proteus effect: The effect of transformed self-representation on behavior. *Human Communication Research 33* (2007), 271–290.