Tomato Presence: Virtual Hand Ownership with a Disappearing Hand

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Abstract

Tomato presence is a term coined by Owlchemy Labs to refer to the observation that players of their game Job Simulator can experience 'hand presence' over an object that is not their hand. When playing the game, if a player grabs an object, their virtual hand disappears leaving the grabbed object. While players still observe a direct proprioceptive match between their hand movements and the object being manipulated, it seems that there should be a conflict with current theories of how users might react to visual/proprioceptive mismatch of their embodiment. We run a hand ownership experiment where we implement standard object grasp and the disappearing hand grasp. We show that on a body-ownership questionnaire there is evidence to support the notion that users still feel ownership over a virtual hand even though it is periodically disappearing. We also confirm that most users do not report that their hand disappeared.

Index Terms: Human-centered computing—Visualization—Visualization techniques—Treemaps; Human-centered computing—Visualization—Visualization design and evaluation methods

1 Introduction

Most applications for modern virtual reality (VR) systems contain a representation of the user within the virtual scene. While full body avatars are possible (e.g. [3]), the most common representation of the person is as dis-embodied hands or tools [6]. The rapid development of a consumer VR market has led to a lot of innovation in design and engineering of interactive experiences [9]. In this poster we focus on a particular technique from the game *Job Simulator* from Owlchemy Labs. In this game the user must perform a series of simple interactions that are modelled on everyday tasks. For example operating a computer, pouring coffee, cooking food, etc. Importantly, when an object is grasped, the hand disappears, but hand movements are directly mapped to the object [7]. In a talk about the development of Job Simulator it was claimed that the majority of players did not notice their hand disappearing [1] and that players maintained *hand presence*.

This seems to be at odds with work on body ownership in VR. Early papers demonstrated that if the user saw a virtual hand, and that visual representation matched their proprioception, the user felt an ownership over that virtual hand [8, 10]. This has now been explored extensively in the field, with many papers exploring how the visual representation of the hands and body affects the users attitudes (e.g. [5]) and strategies for interaction (e.g. [2]).

Previous work has usually assumed that the body is constantly visible. While the hand does disappear in the tomato presence interaction technique, there is a constant match between the user's proprioception and the visual motion. Thus, we can ask: if the body keeps disappearing, then does an ownership illusion take place? We describe an experiment investigating whether body ownership occurs in a situation where the hand disappears whenever an object is grasped. We find some support for the notion that the disappearing hand leads to an ownership illusion. We can confirm that our participants did not appear to notice that the hand was disappearing.

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Figure 1: Screen captures from the experiment. Top Left: First game where participants must point a remote control at flashing boxes on a monitor. Top Right: checkout counter. Note the sign to the left of the product scanner. Middle Left and MIddle Right: demonstrating the tomato presence technique: when the object is grasped the hand disappears. Bottom Left: showing the robot hand and the success response from the scanner. Bottom Right: the sign falls onto the hand.

2 Experiment Design

We ran a between-participants experiment with three conditions: each participant either had a virtual hand, a disappearing hand, or a robot hand at the location where their hand was tracked (see Figure 1, Middle Row and Bottom Left). The hypothesis was that the robot hand would not elicit the ownership illusion because of its non-realistic appearance. Participants performed two tasks in a virtual supermarket. First they played a Simon-like game, where they had to use a remote control to point at icons of objects flashing on a screen, see Figure 1, Top Left. This game was modelled on a similar game in [10]. The game allows the participant to exercise their visuo-proprioceptive match on a simple task. It also serves to generate a baseline for biosignals, see below. Next, participants had to "test" a new supermarket checkout scanner that would recognise fruit as it was scanned (Figure 1, Top Right). Fruit-shaped objects would travel down a conveyor belt towards the user who would have to pick them up, swipe them over a scanner and place them on their left. Successful scans were signalled by a beep and a flashed "Y" symbol (Figure 1, Bottom Left). Occasionally the scanner would not work, and the fruit would need to be scanned a second time. The fruit

appeared at a regular period and the 9^{th} would fail to scan. As the participant re-scanned this object, a sign would fall over and appear to collide with the user's hand (Figure 1, Bottom Right). Participants were seated throughout. They did not have a torso and arms. They would see a virtual seat if they looked down.

The scene was implemented in Unity 2018.4.6f1. The scene was shown on a HTC Vive system. Participants would only use one controller in their right hand. We used a MindMedia NeXus-4 device to record galvanic skin response (GSR). Participants would wear the sensors of this device on their left hand.

Our main measure was a body-ownership questionnaire. We used a version of the Gonzalez-Franco & Peck body ownership questionnaire [4] customised as suggested in the paper for experiments with only hands and no mirror. The questionnaire can be found in supplemental material. We are interested in the main effect of condition on overall body ownership, as well as the contributing factors. Our second measure is a question about anomalies in the environment. It asked: "During the experiment which of the following? Tick between zero and six of the following.". Four of the answers were distractor questions, that is they referred to events that did not happen (e.g. "The signs above the counter all changed"), one referred to an obvious event "A sign fell over onto my hand", and one referred to the disappearing hand "The virtual hand disappeared". We expect all participants to notice the sign falling, but we do not expect any participant to notice the hand disappearing, even if they are using the disappearing hand technique. Our final measure was the change in GSR response around the time of the apparent threat to the hand.

The study was approved by University College London's Research Ethics Committee. Participants were compensated £5. The study would take about 20 minutes.

3 Results

Thirty-one participants took part in the experiment. Four data sets were excluded because of technical problems. Thus there were 8, 10 and 9 participants respectively in conditions 1 (normal hand), 2 (disappearing hand) and 3 (robot hand). GSR responses appeared to be very individually variable and no significant effects were found.

A body ownership response was calculated based on the formula in [4]. As per that paper there are considered to be five contributing factors: Ownership, Agency, Location, Appearance and Response. Each factor is a sum of two or more Likert scale responses, some negated. The overall response (TotalEmbody) is then a weighted sum of the five factors. The five factors and TotalEmbody scores were analysed by one-way ANOVAs. Inspection of boxplots identified no outliers. The data were normally distributed (Shapiro-Wilk's test $p > .05$) and there was homogeneity of variances as assessed by Levene's test. There was no significant effect on Ownership $F(2,24) = .968, p = .394$. There was a significant between-groups effect on Agency $F(2,24) = 3.627, p = 0.042$. There was no significant effect on Location $F(2,24) = 1.51, p = .242$. There was a significant between-groups effect on Appearance $F(2,24) = 3.803, p = 0.037$. There was no significant effect on Response $F(2,24) = 1.662, p = .211$. There was a significant effect on TotalEmbody $F(2,24) = 4.419, p = .023$.

Tukey-Kramer post-hoc tests were performed to establish between-group effects. For Agency, condition 3 ($mean = 2.55, stddev = 5.59$) was significantly lower than 1 ($mean = 7.13, stddev = 2.1$). Condition 2 ($mean = 5.7, stddev = 1.88$) was not found to be significantly different from either 1 or 3 . For Appearance, condition 3 ($mean = -3.56, stddev = 4.67$) was significantly lower than 2 ($mean = 1.4, stddev = 3.03$). Condition 1 ($mean = .5, stddev = 4.04$) was not found to be significantly different from either 2 or 3 . For TotalEmbody, condition 3 ($mean = -.13, stddev = 1.13$) was significantly lower than 2 ($mean = 1.05, stddev = .69$). Condition 1 ($mean = 0.7, stddev = .74$) was not found to be significantly different from either 2 or 3.

For the question about anomalies in the environment 26 out of 27 participants noted the fall of the lamp (1 in condition 2 did not note this event). In condition 2 (disappearing hand condition), 2 of 10 participants noted that the hand disappeared. However, 2 of 9 participants in condition 3 (robot hand) also noted that the hand disappeared when it did not purposefully disappear. None in condition 1 noted the hand disappearing.

4 Discussion & Conclusion

The results show some support for the notion that the disappearing hand condition (condition 2) supports some form of the hand ownership illusion. However the significant results were mixed with the robot hand being significantly lower on mean response scores than either normal hand or disappearing hand depending on condition. While the disappearing hand was significantly different than the robot hand on a total embodiment score, it is a little surprising that the normal hand was not. One radical post-hoc hypothesis is that the normal hand supports less ownership because of its unnatural grasp shape, its behaviour, or its occlusion of the object (the fruit) that is the target of the interaction. This motivates further work on maintenance of correct grasp behaviour.

We can also confirm the claim from Owlchemy that most people do not notice the hand disappearing. While two participants did notice the hand disappearing in the disappearing hand condition, two other participants claimed it disappeared when it was not supposed to. We note that due to the tracking systems of the HTC Vive, it is possible for the hand to freeze out of view because of a tracking failure. So perhaps these participants were noticing the hand disappearing only because there was no visual feedback.

Overall the results suggest that the disappearing hand technique is a highly usable technique in VR environment. We did not find that it led to a decrease in embodiment.

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