The Effect of Realism on the Virtual Hand Illusion

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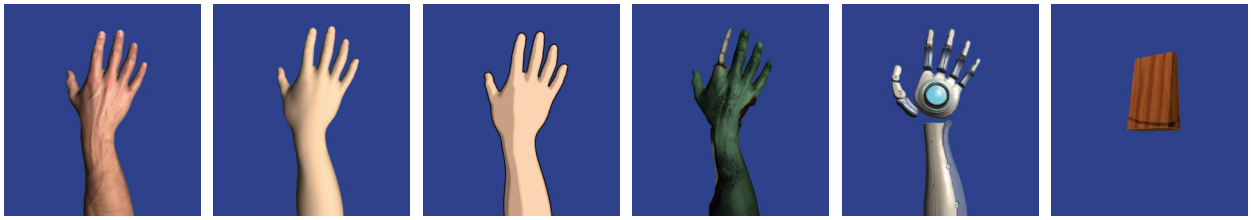

Figure 1: The six geometric models with different levels of realism used in this study. From left to right: realistic hand, toony hand, very toony hand, zombie hand, robot hand, wooden block

Abstract

The virtual hand illusion is a body ownership illusion that occurs in a virtual environment. Previous studies reached different conclusions on the effect of realism of the controllable virtual hand model on the intensity of the perceived illusion. In our experiments, we compare participants' responses to virtual impacts and threats when using hand models with different levels of realism.

Our findings indicate that an illusion can be created for any model but that the effect is perceived weakest for a non-anthropomorphic block model and strongest for a realistic human hand model in direct comparison. We furthermore find that the reactions to our experiments highly vary between participants.

1 Introduction

The rubber hand illusion, first shown by Botvinick and Cohen [1], is an illusion where participants report that a rubber hand feels like it is part of their body. It has been replicated in several studies in real and virtual settings. The virtual arm or hand ownership illusion [4] is a similar body ownership illusion that can occur in a virtual environment. Previous studies reached different conclusions on the effect of the realism of the used virtual hand on the intensity of the perceived illusion. Previous studies also at the most only compared two models at a time [2, 3, 4, 5]. As virtual reality applications become more and more common, the question of what level of realism is required to achieve a specific effect becomes increasingly important. In our experiments, we compare participants' responses to virtual impacts and threats when using hand models with different levels of realism (see Figure 1). Our hypothesis is that the virtual hand ownership illusion will be weakest with the non-anthropomorphic hand model and strongest with the most realistic human hand model.

2 Our Approach

We conducted an online survey and two studies (because the first study appeared inconclusive.) The survey was administered to verify that all of the models had distinct perceived levels of realism and sensitivity to pain, ranking from highest to lowest in the order of realistic hand, toony hand, very toony hand, zombie hand, robot hand, and wooden block. 137 participants, 82 male, 55 female, between eighteen and sixty years of age were recruited from social networking sites to volunteer for the online survey. A one-way ANOVA followed by Tukey's Q test showed the results were mostly as expected, with significant differences between each of the hand models for perceived realism and perceived sensitivity to pain with all $p<0.001$ with one exception, the comparison between the very toony hand and zombie hand in terms of realism.

2.1 Study 1

In the first study, we investigated the influence of the realism of a controllable virtual hand model on human reaction in immersive virtual reality. 60 participants, 32 male, 28 female, mostly consisting of college students volunteered. The study had a between-groups design, with each participant only seeing and controlling one model. Participants viewed a simple immersive virtual environment through an Oculus Rift head-mounted display. Hand tracking information was provided through a Leap motion controller mounted on the Oculus Rift. Skin conductance responses were collected through an Empatica E4 wristband fitted to the participants' left arm for explorative purposes. The motions of participants' right hands were tracked and represented with one of the six hand models. After blocking spheres for three minutes in a virtual environment, a knife as a virtual threat hit their virtual hand.

We expected participants' perceived illusion to rank from highest to lowest for the six models in the order of realistic hand, toony hand, very toony hand, zombie hand, robot hand, and wooden block. We collected participants' responses with an after-experiment questionnaire modified from previous hand ownership illusion studies; participants chose a rating on the seven-point Likert scale ranging from 1 for "strongly disagree"' to 7 for "strongly agree" on statements that observed the actual illusion, a feeling of ownership of the hand, investment in immersion and presence, or were fillers in previous literature. Surprisingly, of the fourteen statements on the questionnaire only two yielded significant differences amongst the different models, and these pertained to the appearance of the hand model rather than the strength of the illusion:

Q-A6: "The virtual hand/block on the screen began to resemble my own hand, in terms of shape, skin tone, freckles, or some other usual feature,"

Q-A13: "I thought the virtual hand/block on the screen looked re-

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alistic,"

For Q-A6, participants' disagreement with the block beginning to resemble their own hand was significantly stronger than for the realistic hand, toony hand, very toony hand, and zombie hand; and for question Q-A13, the realistic hand and zombie hand were perceived to be significantly more realistic than the toony hand, very toony hand, and wooden block.

Participants in one or multiple conditions agreed with three statements regarding the illusion occurring at a significant level:
Q-A4: "The movements of the virtual hand/block on the screen were caused by myself,"
Q-A5: "It sometimes seemed my own hand was located on the screen,"
Q-A6: "The virtual hand/block on the screen began to resemble my own hand, in terms of shape, skin tone, freckles, or some other usual feature,"
Q-A7: "Sometimes it seemed as if what I was feeling was caused by the knife that I was seeing on the screen,"
Q-A8: "Sometimes I felt as if the virtual hand/block on the screen was my own hand,"

This suggests that the hand ownership illusion indeed occurred at some level for all models regardless of appearance. Many of the responses show large ranges and variances, often including the full range or nearly the full range of possible answers from strongly agree to strongly disagree in each condition. One interpretation of these results is that the illusion is strong for some participants but does not work at all for others. Another possible confounding factor is that ten participants commented about the hand model disappearing at some point or the fingers moving unrealistically. Based on these results, we could not support our hypothesis that the virtual hand illusion was the weakest for the wooden block. The data retrieved from skin conductance responses was also too varied to lead to clear conclusions between participants.

2.2 Study 2

The second study was conducted to address the concerns of the first study, especially the large variance between participants. 15 participants, 14 male, 1 female, mostly consisting of college students volunteered. The study had a within-groups design. It first consisted of a pre-test to see if participants could experience the physical rubber hand illusion. Afterwards, it used the same equipment and setup as the first study. The order of the six hand models was randomly generated for participants before they entered the immersive virtual environment. Once participants were comfortable with the equipment, they were asked to play two-minute game sessions, each with a different hand model. A questionnaire modified from our first study was read to participants after each session. The knife came down at the hand one minute and thirty seconds into the last session; participants were asked further questions about the threat after the last session as well. Three participants did not experience the physical dummy hand illusion; their data was omitted from the final analysis, but it is interesting to note that of these three participants, two said they were able to experience the virtual hand illusion. The questionnaire for the second study was shortened to nine questions for time:
Q-B1. I had the sensation that I felt the ball touch my hand in the same location where the virtual hand on the screen was in contact with it.
Q-B2. The movements of the virtual hand on the screen were caused by myself.
Q-B3. It sometimes seemed my own hand was located on the screen.
Q-B4. The virtual hand on the screen began to resemble my own hand in terms of shape, skin tone, freckles, or some other usual feature.
Q-B5. Sometimes I felt as if the virtual hand on the screen was my own hand.
Q-B6. Sometimes it seemed as if what I was feeling was caused by the ball that I was seeing on the screen.
Q-B7. During the experiment there were moments in which it seemed that my own hand was catching the ball.
Q-B8. I thought the virtual hand on the screen looked realistic.
Q-B9. I was so immersed in the virtual reality, it seemed real.

Our preliminary results using the Friedman test showed significant results for all statements except Q-B2. The answers for Q-B6 failed to reach significancy with $p<0.1$. Amongst other differences, participants' ratings were lowest when using the block model in seven out of the nine questions. We can therefore confirm our hypothesis that participants felt that the virtual hand illusion was the weakest for the wooden block model. Furthermore, participants' ratings were highest for five of the questions when the realistic human model was used compared to some of the other models. We conclude out of this result that participants did have a preference for the high realism of that model. The other models can be ranked in between with some differences, such as the zombie model rated less than other models in three questions. However, those differences do not seem as strong and would need further investigation.

3 Discussion of Results

Our findings suggest that there are large differences between participants, but in direct comparison, anthropomorphic models lead to a stronger illusion and a realistic human model leads to the strongest effects. The illusion can happen for all models; even a wooden block led to comments that showed an effect of illusion for some participants. Another explanation for effects in the second experiment could be that participants gauge danger in virtual surroundings by context; one participant said he was not scared of the knife because he was controlling a zombie hand and he thought the knife was part of a Halloween theme, and another said he may have felt more surprise from the knife if he was not controlling the robot model. One participant said he criticized the human hand the most because it did not have a suspension of disbelief like the other models; however, the human hand still rated the highest across participants in general for the virtual arm illusion, suggesting that such an aesthetic is not detrimental to immersion. Finally, it is possible that people will have a high suspension of disbelief for any model as long as there is not a more realistic model or environment to compare it to in the virtual world, such as in the first study. Further research would be needed to confirm this because participants in the second study could have rescaled answers as they went along, and there was lower variance in the second study since it was within-groups.

In conclusion, our findings indicate that an illusion can be created for any model but that the effect is perceived weakest for a non-anthropomorphic block model and strongest for a realistic human hand model in direct comparison. We furthermore find that the reactions to our experiments highly vary between participants.

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