Body-Ownership Illusion by Gazing at a Blurred Fake Hand Image

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Abstract. Feeling body ownership over a fake body image in video games or virtual environments may enhance the immersion and feeling of presence in them. In these situation, the sharpness of the image may influence the induction of the body-ownership illusion. In this study, we investigated the effect of blurring the image on the rubber hand illusion experience under seven levels of blur intensity. The results showed that blurring the image within the limits of hand recognizability may induce stronger body ownership of the fake hand but may not influence agency. This indicates that body ownership of a body image can be controlled by the sharpness of the presented image.

Keywords: Body ownership · Agency · Rubber hand illusion · Blurred image

1 Introduction

The induction of feeling as if a body image on a computer screen is part of one's own body is expected to provide greater immersion and presence in the virtual environments or video games. The feeling of a part of one's body (body ownership) and the sense of authorship of body motion (body agency) [1,2] have been investigated in the rubber hand illusion (RHI) paradigm [3]. The RHI is an illusory experience one feels body ownership over a fake hand while gazing at it being exposed to spatially and temporally congruent visuohaptic stimuli.

Many studies have attempted to induce the RHI through a computer screen [4–7]. For instance, one study found that, when screen projection of the camera image of the hand was delayed by more than 300 ms, the RHI becomes weaker [4]. However, the conditions for inducing a body-ownership illusion has not been investigated thoroughly. In this study, we focused on the sharpness of the body image captured by a camera and projected on a computer screen, which

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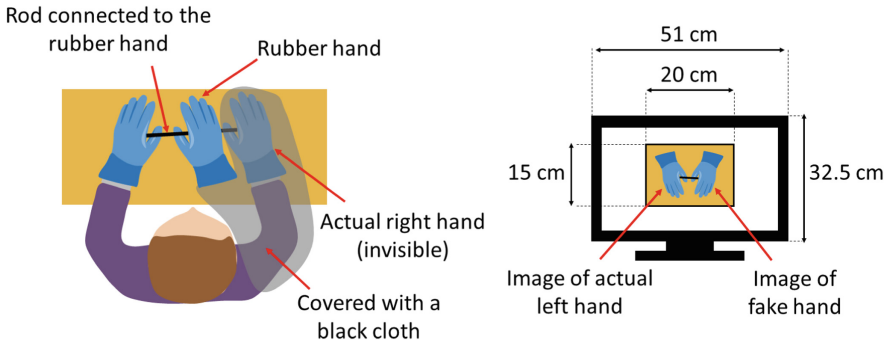

Fig. 1. Left: top view of the apparatus for inducing an active RHI. The right hand is covered with a black cloth. The movements of the actual and fake hands are synchronized by the rod. Right: specification of the screen and image used in the experiment.

is often restricted by the specification or performance of the camera, monitor, computer, and communication environment used. Determining the influence of image sharpness on the RHI contributes to the development of video games and virtual reality environments that employ the body-ownership illusion.

The influence of image sharpness on the RHI has not previously been investigated. Therefore, we investigated it in an RHI experiment where participants gaze at a fake hand image. Participants moved their own hand and the fake hand synchronously while gazing at seven images (each with a different level of blur) in a random order. Then, they answered to a questionnaire related to body ownership and agency. The results of this study are beneficial for controlling the body ownership of a fake body image on a computer screen.

2 Materials and Methods

2.1 Participants

Five university students (all right handed males aged between 21 and 23) who had no experience of the RHI participated in the experiment with informed consent. This experiment was approved by the ethical committee of the School of Engineering, Nagoya University (#17–12).

2.2 Experimental Setup for Inducing the RHI Through a Screen

Rubber gloves, an acrylic rod for synchronizing the hand motion, and a black cloth for covering the actual right hand and arm were used for inducing the RHI (Fig. 1 (left)). This apparatus was also used in [8]. Participants wore the rubber gloves and moved their hands synchronously with the fake hand by softly grasping the acrylic rod fixed to the fake hand.

The motion of the actual and fake hands was captured by a camera (HD WEBCAM C270, Logicool), and the camera image (15 cm × 20 cm, 408 × 544 pixel) was

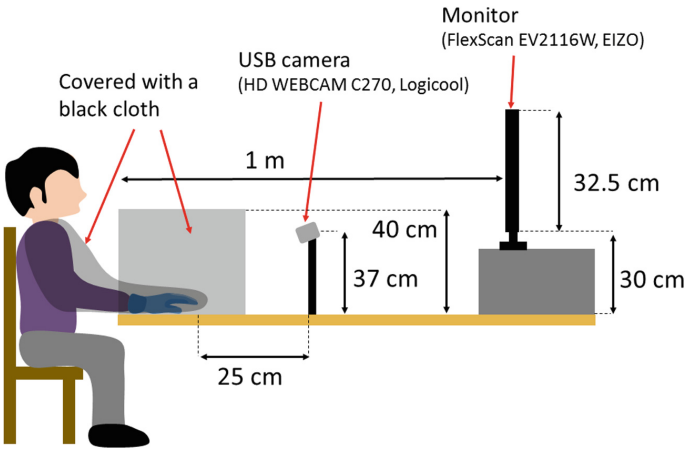

Fig. 2. Side view of the experimental setup for inducing RHI through a screen.

projected on a monitor (FlexScan EV2116W, EIZO) with a refresh rate of 59–61 Hz (Fig. 1 (right)). The captured image was flipped horizontally to give a mirror image [2]. The camera and monitor were located in front of the participant as shown in Fig. 2, and the captured image of their hands was shown on the monitor. The monitor height was same as the participant's eye level. The fake and actual hands were hidden by a frame covered with black cloth in order to prevent a direct view.

2.3 Methods

The camera images were blurred by an average filter. The blur levels were changed by the filter size, which had seven levels that range from not blurred (filter size: 0) to blurred beyond hand recognition (filter size: 75×75 pixel) in a geometrical series. The seven levels of blurred image are shown in Fig. 3.

2.4 Task

Before the experiment, participants tapped or rubbed the table with them on and experienced the RHI by gazing at the fake hand as shown in Fig. 1 (left), such that they could familiarize themselves with the rubber gloves. Then, participants experienced the RHI at seven levels of blurred image projected in a random order. The first four trials were used for practice. Then, 14 trials were conducted (each of the seven levels of blur was shown twice). Participants experienced the stimulus for one minute in each trail.

The magnitudes of body ownership and agency over the fake hand are rated by the questionnaire [1–3]. The questionnaire shown in Table 1 was a modified version of the one used by Botvinick and Cohen [3]. Q1 and Q2 are related to body ownership and agency, respectively, and the others are control items.

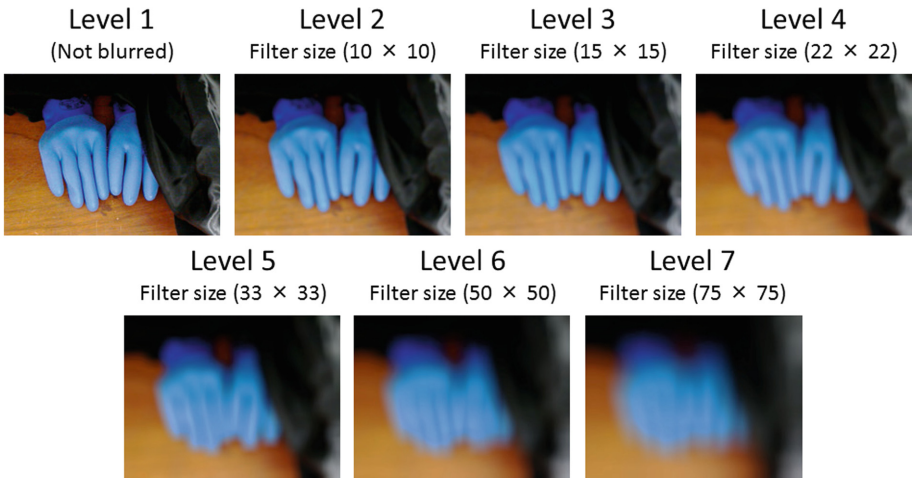

Fig. 3. Seven levels of blurred image used in the experiment. For the image of level 1, no filtering effect was applied. For levels 2–7, average filters of different sizes were applied.

Table 1. Questionnaire for evaluation of the RHI intensity

Q1	I felt as if the rubber hand was my own hand
Q2	It seemed like I was directly moving the rubber hand
Q3	It seemed as if I might have more than one right hand or arm
Q4	It felt as if my (real) hand was turning "rubbery"
Q5	It appeared (visually) as if the rubber hand was drifting towards the right (towards my real hand)
Q6	The rubber hand began to resemble my own (real) hand in terms of shape, size, or some other visual feature
Q7	I felt as if my (real) hand was drifting towards the left (towards the rubber hand)

Participants gave each question a score on a seven-level scale for each trial (−3 for strongly disagree up to +3 for strongly agree). A positive answer score indicates that the participant agreed with the question.

3 Results

The answer scores from each participant were averaged in each stimulus condition. Figure 4 shows the means and standard errors of the answer scores for each question and each blur level. The answer scores against Q3–Q7 (control items) were equally negative under all conditions, which denied the suggestibility of the setting. We applied a one-way ANOVA to the answer scores against Q1 and Q2, which are related to the RHI, by considering the blur levels as the factor to investigate the effect of blur process.

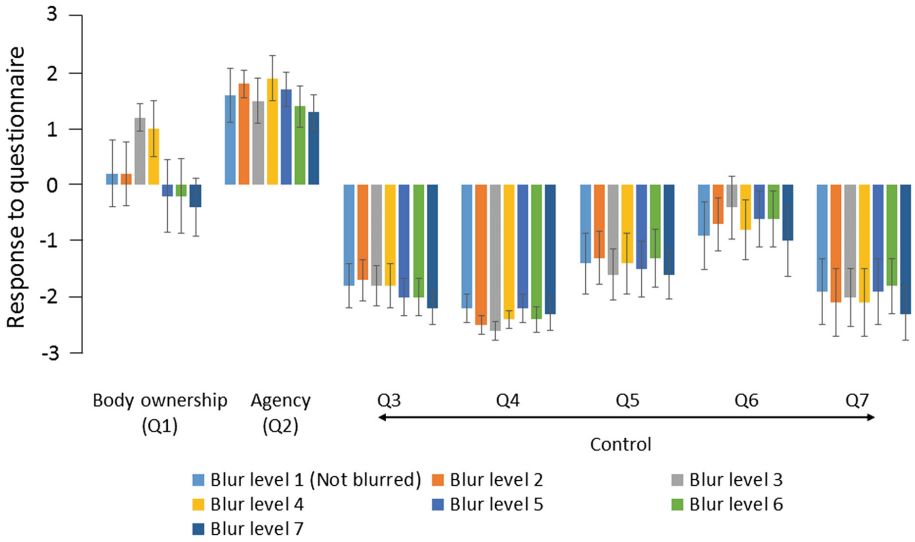

Fig. 4. The means and standard errors of the RHI questionnaire scores for each blur level.

The answer scores against Q1 (body ownership) were positive values for blur levels 1–4 and were negative values under stronger blurring conditions. Furthermore, they peak between blur levels 3 and 4. However, these were not significant results ($F(6, 63) = 1.27$, $p = 0.29$). The answer scores against Q2 (agency) were positive values under all blurring conditions and there was no significant difference among any conditions ($F(6, 63) = 0.35$, $p = 0.91$).

4 Discussion

Body ownership was reported in slightly blurred conditions (blur levels 3 and 4), but not in intensive blurring conditions where the hands become unrecognizable. Moreover, the answer scores against body ownership under blurring conditions within the limits of hands being recognizable (i.e., blur levels 3 and 4) were higher than under the unblurred condition. This result can be explained by the inverse effect [9], where the illusion, which is a multisensory integration of visuohaptic cues, might have been strengthened by degradation in the reliability of visual cues. Also, slightly blurred conditions (blur levels 3 and 4) may masked the visual difference between the fake and actual hands, and might have resulted in intensive illusions. However, given the limited number of participants, we could not achieve significant results and further investigation is required.

Although agency was reported regardless of the blurring intensity, the types of it differed between blur levels. Under blur levels 3 and 4, body agency may be induced since body ownership was also reported. On the other hand, under

stronger blurring conditions (blur levels 5–7), external agency [1] may be induced in the same way as when you use a tool or manipulate an object.

In this way, using an unclear image within the limits of hand recognizability may be effective for inducing body ownership on the fake hand image while remaining agency.

5 Conclusion

In this study, we investigated the effect of blurring a fake hand image on the RHI experience. Camera images of participants' hands were blurred to seven different extents and projected on a monitor in front of them. Participants answered a questionnaire related to illusion after moving their actual and fake hands synchronously while gazing at the blurred image. The results showed that blurring the image within the limits of hand recognizability induced stronger body ownership than under unblurred conditions. However, agency was induced equally under all blurring conditions. We suggest that the blurring process within the limits of hand recognizability may be effective for inducing body-ownership illusion with a fake hand image on a screen.

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