International Conference on Artificial Reality and Telexistence
Eurographics Symposium on Virtual Environments (2022)
R. Kondo and T. Teo (Editors)

Poster

Sense of Ownership, Self-location, and Gaze Responses in Virtual Rubber Hand Illusion

T. Komori[1], H. Ishimoto[1], G. Ganesh[2], M. Sugimoto[3], M. Inami[4], and M. Kitazaki[1]

[1]Department of Computer Science and Engineering, Toyohashi University of Technology, Aichi, Japan
[2]CNRS-UM Laboratoire de Informatique, de Robotique et de Microélectronique de Montpellier (LIRMM), France
[3]Department of Information and Computer Science, Keio University, Yokohama, Kanagawa, Japan
[4]Research Center for Advanced Science and Technology, The University of Tokyo, Meguro-ku, Tokyo, Japan

Abstract

It is known that the illusion of body ownership, like as the rubber hand illusion, affects the proprioceptive sense of body position. In the present study, we investigated whether eye movements and pupil responses to the location where the sense of body ownership was induced were also affected. We presented a virtual left hand on a head mounted display and stroked both the virtual hand and the real left hand with a brush, while a light suddenly appeared on the virtual left hand or empty right space randomly. The participants were asked to move the eyes on the light. We found that the illusory ownership of the virtual hand occurred with proprioceptive self-location drift by the synchronous stroking, but the saccade eye movements and pupil sizes were not affected by the illusory body ownership, suggesting that the gaze responses may be independent from the self-body representation.

CCS Concepts

• ***Human-centered computing*** → ***Virtual reality;***

1. Introduction

We can have an illusory ownership towards virtual objects other than the own body parts. If a hand is obscured by a partition, a rubber hand is placed in front of the partition in the same direction as the real hand and simultaneously stroked with a brush, after looking at the rubber hand for a while, the rubber hand is felt as if it were one's own hand. This is called the rubber hand illusion [BC98] [TH05]. This illusion of body ownership also occurs for the hand or body of an avatar in a virtual environment [YS10] [IdKH06]. The subjective rating using a questionnaire is the most common measurement for virtual embodiment, and the proprioceptive self-localization and its drift are often used as a behavioral measurement method for the rubber hand illusion. In addition, the skin conductance responses to threat stimuli are used as a physiological measurement method [AR03]. Recently, it is shown that the virtual embodiment modifies attention allotment for the benefit of dual motor task performance [INIG22], and the illusory body ownership positively correlates with pupil diameter [FBH*22]. Thus, we focused on gaze responses including saccadic eye movements that relate to attention and pupil diameter changes. We aimed to test the effects of illusory body ownership on the saccadic eye movements to the embodied position and pupil responses as new candidates for measurements of body ownership.

2. Methods

Twenty-four healthy adults participated in the experiment. They provided written informed consent before the experiment. The methods of the experiment were approved by the Ethical Committee at Toyohashi University of Technology, and all methods were carried out in accordance with the relevant guidelines and regulations.

Visual stimuli were generated and controlled by a computer and presented on a head-mounted display (HMD, HTC Vive Pro EYE). A brush attached with a tracker (HTC Vive Tracker 3.0) was used to present tactile stimuli.

Participants sat on a chair and put the left hand on a desk. A virtual left hand was presented 20 cm rightward of the real hand location. An experimenter stroked the participant's left hand with the brush, and synchronously the virtual hand was stroked by a virtual brush (synchronous condition). In the asynchronous condition, the virtual brush delayed 2 s compared to the real stroking. During the brush stroking with observing the virtual hand, the participants were asked to a fixation point, then move the eyes to a light suddenly appearing at one of eight locations; four of them were at tips of the virtual hand's fingers while the others were symmetric positions to the fixation point at empty space (Figure 1). After 40 trials for each condition (20 on the virtual hands and 20 on the empty space), the participants indicated the position of left middle

DOI: 10.2312/egve.20221301

finger and answered an embodiment questionnaire. Two conditions (sync./async.) were repeated twice in a counter balanced order

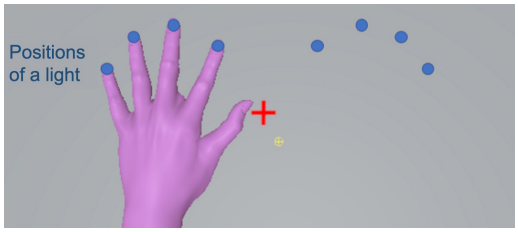

Figure 1: *Schematic image of participants' sight on the HMD. Blue dots were positions of a light for the saccade. The light suddenly appeared at one of these locations randomly..*

3. Results

Questionnaire results showed that the illusory body ownership occurred when the brush stroking was synchronous compared to the asynchronous stroking (t(23)=5.560, p<.001, d=1.135; Figure 2 Left). The proprioceptive self-location of the left hand drifted towards the virtual hand in the synchronous condition (t(23)=1.815, p=.041, d=0.370; Figure 2 Right). Thus, the illusory body ownership was induced by the synchronous brushing. The saccadic eye movement time was not different between the synchronous and asynchronous conditions (F(1,19)=0.073, p=.790, ηp2=0.004) or the virtual hand and the empty locations (F(1,19)=0.263, p=.614, ηp2=0.014; Figure 3). The pupil diameter change (difference between the stroking period and the pre-stroking period) was not different between the synchronous and asynchronous conditions (t(23)=0.184, p=.856, d=0.038; Figure 4). .

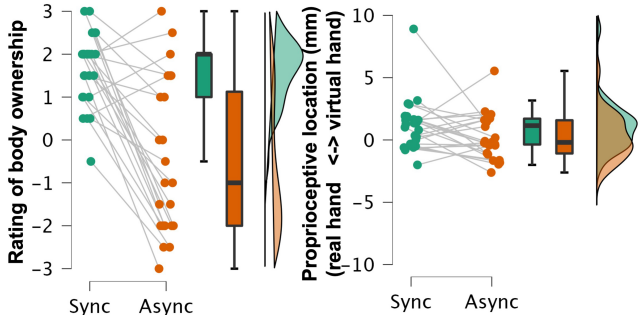

Figure 2: *Results of subjective ownership (Left) and proprioceptive drift (Right).*

4. Discussion

We found that the illusory body ownership towards a virtual hand by visual-tactile integration in the subjective rating and the proprioceptive self-location drifts. However, the illusory ownership did not affect the saccadic eye movements or the pupil responses. These results suggest that gaze responses may be independent from the virtual embodiment or self-body representation. However, our results were inconsistent with the previous study [FBH*22]. We should further study this discrepancy and need to look for other behavioral measurement for the virtual embodiment.

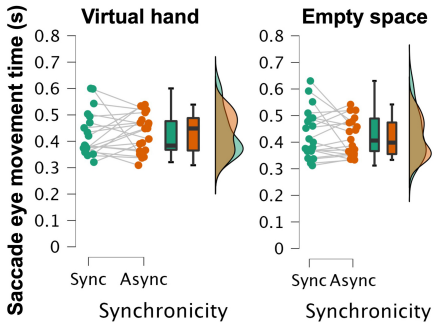

Figure 3: *Results of saccadic eye movement time.*

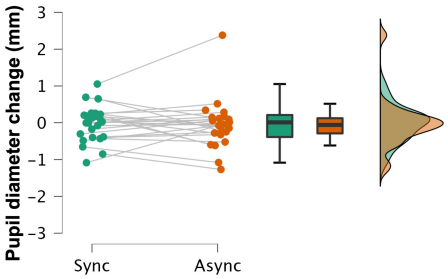

Figure 4: *Results of pupil diameter change.*

Acknowledgements

This research was supported by JST ERATO Grant Number JPMJER1701, and JSPS KAKENHI JP20H04489.

References

[AR03] ARMEL K. C., RAMACHANDRAN V. S.: Projecting sensations to external objects: evidence from skin conductance response. *Proc. Royal Soc. B 270* (2003), 1499–1506. 1

[BC98] BOTVINICK M., COHEN J.: Rubber hands 'feel' touch that eyes see. *Nature 391* (1998), 756. 1

[FBH*22] FALCONE S., BROUWER A. M., HEYLEN D., VAN ERP J., ZHANG L., PRADHAN S. S., ENGLEBIENNE G.: Pupil diameter as implicit measure to estimate sense of embodiment. In *Proceedings of the 44th Annual Meeting of the Cognitive Science Society* (Nov. 2022), pp. 2446–2453. 1, 2

[IdKH06] IJSSELSTEIJN W. A., DE KORT Y. A. W., HAANS A.: Is this my hand i see before me? the rubber hand illusion in reality, virtual reality, and mixed reality. *Presence: Teleoper. Virt. Environ. 15* (2006), 455–464. 1

[INIG22] IWASAKI Y., NAVARRO B., IWATA H., GANESH G.: Embodiment modifies attention allotment for the benefit of dual task performance. *Communications biology 5* (2022), 701. 1

[TH05] TSAKIRIS M., HAGGARD P.: The rubber hand illusion revisited: visuotactile integration and self-attribution. *J. Experiment. Psychol.:Human Percept. Perform. 31* (2005), 80–91. 1

[YS10] YUAN Y., STEED A.: Is the rubber hand illusion induced by immersive virtual reality? In *2010 IEEE Virtual Reality Conference (VR)* (Mar. 2010), IEEE, pp. 95–102. 1