

Abstract

Every day, we use our legs to walk, our arms and hands to manipulate objects, and our bodies to communicate with others. Healthy individuals without physical or mental problems unconsciously perform these movements. To move the body voluntarily, we need a sense of ownership of our bodies and a sense of control over the body motions and body parts without excess or deficiency. The former is called sense of body ownership, and the latter is called sense of agency.

In addition to the body parts, it has been confirmed that an illusion can make an external object feel like it belongs to the body. The generation of such illusion and suitable objects eliciting it are being currently explored. Research on the phenomenon and mechanism by which one's own body can feel like the body of another individual can clarify the mechanisms underlying human body perception. Moreover, this illusion may be applied to develop solutions to replace bodily functions or extend the body capabilities.

Prior research has examined the types of objects that create the illusion of the sense of body ownership, primarily focusing on human or human-like objects. When the sense of body ownership is elicited using such objects, the impressions of the objects change, suggesting that the sense of body ownership may also affect human psychology (e.g., empathy and likeability). Accordingly, the following research questions can be formulated:

- 1) Is it possible to elicit the sense of body ownership toward houseplants used as nonanthropomorphic figures?
- 2) Can passive and active methods be implemented to elicit the sense as stated in question 1?
- 3) Which method addressed in question 2 is the most effective?

This study was aimed to determine whether the sense of body ownership can be elicited by houseplants, which do not resemble the human body. This objective involved addressing the abovementioned research questions and may contribute to solving existing problems for eliciting the sense of body ownership.

Chapter 2 presents the mechanisms by which the sense of body ownership and agency can be elicited, experiments conducted to trigger these sensations, and conditions for creating the illusion of sense of body ownership in the context of previous studies. The spatiotemporal congruence of presented stimuli can elicit the sense of body ownership for a wide variety of objects. Therefore, the method implemented in this study delivers consistent spatiotemporal stimuli. However, the sense of body

ownership has been confirmed only for objects similar to body parts. Therefore, it remains necessary to examine whether the illusion of body ownership can be elicited by nonanthropomorphic objects, such as the houseplants considered in this study.

In Chapter 3, we formulate the research questions for this study and examine whether they can be addressed using houseplants. In addition, this chapter summarizes the results and discussions of the previous studies listed in Chapter 2. Regarding question 1, research on avatars used in virtual reality suggests that the illusion of sense of body ownership can originate from avatars that imitate animals. Therefore, we hypothesized that houseplants, which have not been considered in previous studies, can produce the illusion of sense of body ownership. Regarding question 2, it has been reported that plant behaviors and functions can be represented as human behaviors. Therefore, we considered that the sense of body ownership can be elicited by making the subject aware that houseplant behaviors are spatiotemporally consistent with delivered stimuli. Regarding question 3, passive and active methods for eliciting the sense of body ownership and their effectiveness evaluations have been scarcely studied, and no conclusive evidence of the most effective method is available. Therefore, we aimed to determine the most effective method for eliciting the sense of body ownership.

In Chapter 4, we define the experimental conditions under which visual, auditory, and tactile stimuli were superimposed to test the method for eliciting a sense of passive body ownership. In addition, two hypotheses were tested: 1) more stimuli presented to human participants increase the sense of body ownership and 2) more intense stimulus feedback to humans increase empathy. Experimental results confirmed that hypothesis 1 was valid for some participants. Although no significant differences were observed among the experimental conditions for each empathy item (multidimensional empathy scale) used to evaluate the effectiveness of this method, the corresponding values tended to be higher when visual, auditory, and tactile stimuli were superimposed. Furthermore, participants provided comments including “I experienced the perspective of the plant” and “I wanted to take care of the plant.” Such comments validated hypothesis 2.

In Chapter 5, to test the method of eliciting a sense of active body ownership, three conditions were established: 1) houseplants move in synchrony with human body movements, 2) houseplants move randomly regardless of human body movements, 3) houseplants do not move at all even if human body movements occur. We also examined the generation of a sense of bodily possession. In addition, two hypotheses were tested: 1) a sense of body ownership toward houseplants appears when the plants move in synchrony with human body movements, and 2) when a sense of body ownership is elicited, houseplants are more likeable to the participants. Experimental results confirmed that when the houseplants moved in synchrony with human body movements, the sense of body ownership and

inclusion of others in the self-scale for houseplants were the highest. In addition, the sense of body ownership for houseplants was perceived as illusory. These results validated hypothesis 1. In addition, the liking for houseplants, which was confirmed to evaluate the method effectiveness, increased when the movements of the body were synchronized with those of the houseplants. Furthermore, the likeability of houseplants, which was also confirmed by evaluating the method effectiveness, increased when the movements of the body were synchronized with those of the houseplants. Thus, hypothesis 2 was also validated.

In Chapter 6, we compare and verify the methods used to elicit the illusion of passive (Chapter 4) and active (Chapter 5) senses of body ownership. Each experiment was validated using the conditions that provided the best illusion of sense of body ownership. Specifically, these conditions were the feedback including visual, auditory, and tactile stimuli for eliciting the passive sense of body ownership and the houseplants moving in synchrony with human body movements for eliciting the active sense of body ownership. The results confirmed no significant differences between the two conditions, being consistent with a previous study that found no difference in the perception of the sense of body ownership when using a passive or active method. Therefore, the explored passive and active methods for eliciting a sense of body ownership provided the same level of body ownership illusion toward houseplants with nonanthropomorphic shapes.

Finally, Chapter 7 presents the conclusions of this study. The experimental results confirmed that both the passive and active methods examined in this study are effective for eliciting the sense of body ownership toward houseplants. In addition, a comparison of the two methods confirmed no significant difference in eliciting the sense of body ownership. Based on the findings, we answer the research questions and outline limitations and prospects of this study.