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Abstract (Doctor)

Title of Thesis	Investigating a minimal condition to induce illusory body ownership using virtual reality
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Approx. 800 words

Humans have a desire to have an ideal body. It seems that we want to change our self-image or self-consciousness by changing their own body. However, it has not been understood how to change the self-image. I assumed that the self-image could be updated by accumulating a temporary change of bodily self-consciousness. To investigate this issue, it is firstly required to investigate how to change bodily self-consciousness. Several studies have shown that we can change our body through illusory body ownership induced by visual-tactile and visual-motor synchronizations. A recent invisible body study has shown that stroking an empty space with a brush and stroking the subject's body at the same time produce body ownership in an empty space. This finding suggests a minimal condition for body ownership in visual-tactile synchronization. However, a minimal condition in the visual-motor synchronization is still unclear. It is one of the most fundamental issues to identify minimal conditions for the body ownership because we can change our bodily self-consciousness based on those minimal conditions. Therefore, the aim of this thesis was to investigate a minimal condition to induce illusory body ownership by visual-motor synchronization.

Study I aimed to test whether the illusory ownership of an invisible body could be induced by the method of visual-motor synchronicity and if the illusory invisible body could be experienced in front of the observer similar to the full-body ownership illusion. Participants observed left and right white gloves and socks in front of them, at a distance of 2 m, in a virtual room through a head-mounted display. The white gloves and socks were synchronized with the observers' actions. In the experiments, we tested the effect of synchronization, and compared this to a whole-body avatar, as measuring self-localization drift. We observed that visual hands and feet were sufficient to induce illusory body ownership, and this effect was as strong as using a whole-body avatar. The illusory ownership was also supported by a shift of proprioceptive self-localization.

Study II aimed to develop a method to separate the body ownership of full-body from that of body parts. Scrambled stimuli that disrupt the spatial relationship by randomizing the positions of body parts from the original/normal body part layout stimulus was developed to induce only body part ownership. We found that participants felt as if the space between the gloves and socks was their bodies only in the normal layout condition. They felt as if the gloves or socks were part of their bodies in both normal and scrambled conditions, but the feeling was stronger in the normal layout condition than in the scrambled body condition.

Study III aimed to investigate whether we can have illusory ownership of the invisible body with an elongated arm by presenting only hands and feet with modifying the position of the hands. As a result, the illusory body ownership to the body with a long arm was induced to an invisible body by synchronizing only gloves and socks with participants' movement. Learning of the invisible long arm gradually changed the reaching behavior to use the long arm more frequently than the normal arm. Thus, the body scheme could be changed by changing the position of the hand by maintaining the spatial relationship of body parts and visual-motor synchronicity in the same directions between the virtual body and the actual body.

Study IV aimed to see whether a re-association of the different body parts is induced by visual-motor synchrony in healthy adults. We focused on the re-association of the real right thumb with a virtual left arm because although the right thumb and the left arm are different in size and laterality, the directions of their movements are similar. We found that participants felt as if their right thumb had become the left arm and illusory body ownership of the virtual left arm was induced more in the visual-motor synchronous condition than in the asynchronous one.

To summarize minimal conditions to induce body ownership by the visual-motor method, the full-body illusion needs a spatial relationship and the synchronous movement of the hands and feet, while the body part ownership needs the synchronous movement of the body parts in motion directions and angles. The size, symmetry, or laterality does not have to be identical between the actual body and the virtual body. It has been proved that the body scheme can be changed by maintaining the minimal condition by modifying other parameters. The final goal is to update the self-image by accumulating temporary changes in bodily self-consciousness, and our findings should contribute to developing a method to change our bodily self-consciousness.