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## SHORT AND SWEET The Rubber Hand Illusion in a patient with hand disownership

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**Abstract.** A 78-year-old patient with a right hemispheric sensorimotor ischemic stroke suffered from problems in ownership of her left arm (somatoparaphrenia). After recovering from motor weakness, however, body ownership problems remained present. To assess whether disturbed feelings of ownership coincided with an enhanced or diminished susceptibility for gaining ownership over a foreign hand, we applied the 'Rubber Hand Illusion' (RHI) to the ipsi- and contralesional hand. The RHI was significantly stronger for the contralesional left arm than for the right arm. In addition, solely visual exposure to the left rubber hand was sufficient to elicit strong feelings of ownership over the rubber hand. These findings suggest that disturbances in the feeling of body ownership allow a foreign hand to be incorporated more easily.

Keywords: somatoparaphrenia, body representation, anosognosia, ownership

Body ownership has been defined as the feeling that one's body belongs to oneself. Disruptions in this sense can result in an unawareness of one side of the body, occasionally in co-occurrence with a delusional belief that the affected limb belongs to someone else (somatoparaphrenia) (Vallar and Ronchi 2009). This impairment has been reported in patients with acquired brain lesions, typically a large right hemispheric lesion. These types of lesion usually cause significant additional neuropsychological impairments and therefore limit experimental investigations. Therefore, evidence remains inconclusive whether patients with somatoparaphrenia suffer from a general diminished sense of ownership, or that the demarcation between what belongs to their own body and someone else's body has been faded. In other words, is a sense of ownership per se impaired, or is a patient more susceptible to gain ownership over a foreign hand?

A 78-year-old woman was admitted to the hospital with a clinical diagnosis of ischemic stroke in the right hemisphere. Initially, she had left-sided sensorimotor deficits and had a delusional belief that her left arm was her father's arm. Within two weeks, she recovered from almost all sensorimotor and cognitive impairments, as examined during a neuropsychological investigation. While the delusional belief largely receded, the patient remained confused about the ownership over her left hand. At this point we conducted the Rubber Hand Illusion (RHI) (Botvinick and Cohen 1998) to quantify the experience of ownership over a foreign hand. In this illusion the patient is asked to place her forearms in a framework with a movable board that occludes one of her arms, while a rubber hand placed closer to the body midline is visible (setup adopted from Kammers et al 2009) (see figure 1a). On each trial the rubber arm and the invisible real arm are stroked for 90 s, either synchronously or asynchronously. When in synchrony, multisensory integration causes an experience that the touch applied to the rubber hand is felt to the own hand, suggesting a sense of ownership over the rubber hand.

The asynchronous stimulation served as a control condition. A 2 × 2 design was used—that is, 2 stroking conditions (synchronous or asynchronous), and 2 hand sides (left or right), and each trial was measured for 4 times, 16 in total. After each trial the illusion was quantified by means of three outcome measures. First, the deviation between the felt location and the actual location of the own (stimulated) hand was calculated, known as the proprioceptive drift. This perceived drift towards the rubber hand is a well-established objective measure of the RHI. A two-factor (synchronicity and side of stimulation) ANOVA revealed a significant main effect for hand side ( $F_{1,12} = 39.72$ , p < 0.01), with a larger proprioceptive drift towards the rubber hand when the left hand was stimulated as opposed to the right hand (mean difference 8.5 cm) (see figure 1b). For the left but not for the right hand, the proprioceptive displacement was also present during asynchronous stroking. The interaction between synchronicity and side of stimulation reached significance ( $F_{1,12} = 6.76$ , p < 0.05), which was largely attributed to the proprioceptive drift of the left hand in the asynchronous condition. This suggests that the asynchronous condition did not serve as a control condition but rather reinforced the illusion, possibly due to the patient's perception of additional tactile stimuli in this condition.<sup>(1)</sup>

Second, the temperature of the skin of both hands before and after each stimulation trial was measured [Raytek handheld Autopro (ST25) laser thermometer], and the difference between those measurements was calculated. A temperature drop is considered as an objective measure of disownership of the own hand (Moseley et al 2008). A two-factor (synchronicity and measurement–stimulation congruency) ANOVA revealed a significant main effect of the side where the RHI was conducted ( $F_{1,24} = 5.94$ , p < 0.05) (see figure 1c). Specifically, stroking on the left hand resulted in a larger temperature drop for the left hand compared with stroking of the right hand (mean difference 0.85 °C, SE = 0.26). Also, during left hand stimulation no drop in temperature of the right hand was found, suggesting that the temperature drop was specific for the left hand rather than a physical response in general.

Third, a subjective illusion was quantified by means of a questionnaire that consists of both statements related to the illusion and statements that are considered as control items. Results show that the patient rated higher scores on the illusion-related statements for the left (affected) hand compared to the right hand, as measured with a paired sample *t*-test ( $t_7 = 2.52$ , p < 0.05) (see figure 1d). In addition, the patient reported a strong illusion during asynchronous stroking for the left hand, but not for the right hand. The patient reported maximum scores on the illusion- related questions but not on the questions that serve as a control, suggesting a genuine response to the illusion rather than task compliance or a general susceptibility.

In sum, for all three measures a stronger illusion for the contralesional hand compared with the normal right hand was observed. In addition, body ownership deficits were so profound that, when compared with synchronous stroking, asynchronous stroking of the left arm induced a RHI of similar (subjective experience) or even of larger (proprioceptive drift) magnitude. This suggests that the visual capture of the left rubber hand was sufficient to induce the RHI.

With this study we were able to objectify subjective reports of body ownership problems. The results show that deficits in body ownership result in an increased experience of ownership over a foreign hand. This suggests that a weakened sense of body ownership allows room to

<sup>&</sup>lt;sup>(1)</sup>The patient also reported a vivid illusion for the left hand (and not for the right) during asynchronous stimulation. In both stroking conditions she reported as if the rubber arm and her own arm felt "identical and as if they were one". For the asynchronous condition the patient reported that the asynchrony between the visual and tactile stimulation resulted in the experience that the tactile stimulation "felt as an echo". That is, the patient 'felt' the visual stroking on the rubber hand, which is also known as vision–touch synaesthesia (Aimola Davies and White 2013). In addition, the tactile stimulation on her real hand was experienced as if it was coming from the rubber hand. Thus she experienced twice as many tactile stimuli. On a speculative account, the perception of these additional stimuli (visual as well as tactile) may have contributed to the high scores on the proprioceptive drift as well as the subjective illusion.



**Figure 1.** [In colour online, see http://dx.doi.org/10.1068/p7583] (a) Experimental set-up of the Rubber Hand Illusion (RHI). (b) The proprioceptive drift: scores represent the deviation between the actual hand position and the estimated hand position. (c) The hand temperature: scores represent the difference between the temperature before and after RHI induction. (d) The subjective illusion: the illusion-related statements (averaged rating of statements 1–3) and the control statements (averaged rating of statements 4–10) for the synchronous and asynchronous conditions.

gain ownership over a foreign hand more easily. On a speculative account, body ownership deficits require a patient to rely more on sensory input to determine what belongs to the bodily self and is therefore more susceptible for illusion. These exciting findings warrant replication in a large sample of patients with ownership deficits.

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