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The Rubber Hand Illusion: Two's a company, but three's a crowd

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ABSTRACT

On the one hand, it is often assumed that the Rubber Hand Illusion (RHI) is constrained by a structural body model so that one cannot implement supernumerary limbs. On the other hand, several recent studies reported illusory duplication of the right hand in subjects exposed to two adjacent rubber hands. The present study tested whether spatial constraints may affect the possibility of inducing the sense of ownership to two rubber hands located side by side to the left of the subject's hand. We found that only the closest rubber hand appeared both objectively (proprioceptive drift) and subjectively (ownership rating) embodied. Crucially, synchronous touch of a second, but farther, rubber hand disrupted the objective measure of the RHI, but not the subjective one. We concluded that, in order to elicit a genuine RHI for multiple rubber hands, the two rubber hands must be at the same distance from the subject's hand/body.

1. Introduction

Since its (re)discovery by Botvinick and Cohen (1998), the Rubber Hand Illusion (RHI) has become the experimental tool for investigating the sense of body ownership. But why do we feel ownership towards the rubber hand in the RHI? Our only access to the rubber hand is visual. We do not even see the rubber hand in contiguity with our body. It could be anybody's hand. The only difference between anybody's hand and this specific rubber hand is the spatio-temporal correlation between the observed stroking of the rubber hand and the felt stroking of our biological hand. It has been argued that it is precisely multisensory correlation that is at the source of the sense of body ownership (Botvinick & Cohen, 1998; Ehrsson, Holmes, & Passingham, 2005; Makin, Holmes, & Ehrsson, 2008; Morgan & Rochat, 1997; Rochat, 1998).

However, as it stands, the hypothesis of intermodal matching leaves many questions unanswered. In particular, the sense of body ownership cannot derive from any kind of intermodal correlation. Imagine that you see and hear two hands clapping. Despite visuo-auditory correlation, you do not feel these hands as your own. You also need visuo-auditory information to correlate with proprioceptive and tactile information indicating that you, and nobody else, are clapping your hands. In other words, there must be information that is self-specific (e.g. somatosensory information) for intermodal correlation to play a role for ownership. Yet, even the involvement of self-specific information does not always suffice, as shown by a series of recent RHI studies (see Table 1).

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Table 1
Constraints that lay upon intermodal matching in the RHI.

Factors	That prevent the RHI	That do not prevent the RHI
Temporal	Asynchronous stimulation Cf. Botvinick and Cohen (1998)	
Spatial	Mismatch in direction of strokes (in hand-centered frame) Cf. Costantini and Haggard (2007) Mismatch in posture (orientation) Cf. Pavani, Spence, and Driver (2000), Tsakiris and Haggard (2005), Guterstam et al. (2011) Mismatch in location (distance from the torso) Cf. Armel and Ramachandran (2003), Lloyd (2007)	
Anatomical	Mismatch in anatomical shape (hand-shaped) Cf. Tsakiris et al. (2010)	Mismatch in visual appearance (monstrous arms, skin tone, etc.) Cf. Austen, Soto-Faraco, Enns, and Kingstone (2004); Longo, Cardozo, and Haggard (2008)
	Mismatch in hand laterality with mismatch in hand location (e.g., left RH on the left with right biological hand) Cf. Tsakiris and Haggard (2005)	Mismatch in hand laterality with no mismatch in hand location (e.g., left RH on the right with right biological hand) Cf. Petkova and Ehrsson (2009)
	Mismatch in size if rubber hand is smaller Cf. Pavani and Zampini (2007)	Mismatch in size if rubber hand is bigger Cf. Pavani and Zampini (2007)

Another counterexample is mirror reflection. When you look at your reflection in the mirror while combing your hair, you have self-specific somatosensory information that matches visual information. Yet, one may doubt that you really feel ownership towards the hand in the mirror in the same way that you feel ownership towards the rubber hand in the RHI. You know this is the reflection of your own hand, but the phenomenology does not seem to include a kind of primitive immediate feeling of mineness. What is then the difference between the RHI and mirror recognition? There is one striking difference between the rubber hand and your body reflection in the mirror: you feel tactile sensations on the rubber hand; you do not feel tactile sensations on the head that you see in the mirror when you comb your hair. One may then suggest that the ownership feeling of the rubber hand is grounded in the spatial content of tactile sensation. On this view, it is because touch is experienced as being located on the rubber hand that the rubber hand is experienced as your own. On the other hand, if the body in the mirror is not experienced as your own, it is because no sensation is experienced as being located there. This interpretation of the RHI is in line with a dominant theoretical approach to body ownership, also known as the spatial account of ownership (de Vignemont, 2007), which highlights the importance of the spatiality of bodily sensations.

There are several versions of the spatial account. Martin (1995) reduces the sense of ownership to the awareness of the boundaries of one's own body. He argues that the spatial structure of bodily experiences is such that sensations are necessarily experienced within the boundaries of one's own body. Indeed, in bodily sensations, there is nothing that does not fall within the limits of the bodily space. By contrast, the boundaries of the object that I see are not co-extensive with the visual field. Consequently, the body that I see does not bear the "indelible stamp of ownership" (Brewer, 1995). Martin's spatial account is exclusively at the phenomenological level. Alternatively, one may defend a representationalist view of body ownership, which aims at singling out the specific type of representation of the bodily space that grounds the sense of ownership (e.g., Carruthers, 2008; de Vignemont, 2007; Tsakiris, 2010).

For example, Tsakiris (2010) defends the view that ownership is constrained by what he calls a body model, defined as a "reference description of the visual, anatomical and structural properties of the body". However, a number of questions about the body model remain open. Does it represent the human body in general or more specifically, the subject's individual bodily parameters? Is there only a single model of the body as a whole or several models of parts of the body? How fine-grained is it? The answers to these questions are of importance. The body model is indeed supposed to determine what can or cannot be experienced as one's own. In other words, only objects that meet the description "given" in the body model can be processed as if they were parts of one's body. If the body model depicts anatomical properties and if it plays a role in the RHI, and thus in the sense of body ownership, then one can make the following predictions: (i) one can experience as one's own only objects that look like body parts (i.e. body part constraint); (ii) one can experience as one's own only bodily shape objects of identical laterality (i.e. laterality constraint); (iii) one can experience ownership only for two hands, and not more (i.e. two-hand constraint). The first prediction received so far some support. It was found that one could not induce the RHI with objects that do not present the visual appearance of a body part (Haans, Ijsselsteijn, & de Kort, 2008; Tsakiris, Carpenter, James, & Fotopoulou, 2010; Tsakiris & Haggard, 2005). The laterality constraint, however, is more controversial. On the one hand, Tsakiris and Haggard (2005) found no RHI when a right rubber hand was visually presented close to the stroked left biological hand. However, Petkova and Ehrsson (2009) were recently able to induce the RHI with a difference in hand laterality by introducing spatial separation between the stroked biological hand and the rubber hand. A right rubber hand was placed on the table, while the right biological hand was hidden behind a screen. The left biological hand was placed in full view, but participants were instructed to look at the rubber hand. Both the left biological hand and the right rubber hand were stroked. Despite the incongruence between the hands laterality, participants reported feeling touch on the rubber hand and displayed a proprioceptive drift. The only difference with the normal RHI was that it was more difficult to elicit (i.e. longer stimulation time and illusion on fewer participants). It therefore seems that the RHI can violate the hand laterality constraint posited by the body model.

The last prediction is that there can be only two hands experienced as one's own, a left hand and a right hand, and no more. The recently documented "supernumerary hand illusion" (SHI) constitutes a rather obvious violation of the two-hand constraint (Guterstam, Petkova, & Ehrsson, 2011). In this new illusion, participants saw both their own hand and a rubber hand being stroked (unlike the classic RHI in which only the rubber hand is in full view). They reported feelings of touch on both the rubber hand and the biological hand. Furthermore, they reported ownership for the rubber hand without inducing either subjective response or objective response (skin conductance) indicating disownership of the biological hand. As there is no way the rubber hand can replace the biological hand, the solution the brain finds is to appropriate both hands.

This is, however, a clearly different situation of intermodal correlation than in the classic RHI. Arguably, the plasticity of body representation may follow different principles depending on the perceptual context. Here we will exclusively focus on the two-hand constraint in the context of the classic RHI. There are then two ways to assess its validity. First, one can investigate the fate of the biological hand to determine whether the rubber hand replaces the biological hand, thus keeping the number of hands at two (Folegatti, de Vignemont, Pavani, Rossetti, & Farnè, 2009; Moseley et al., 2008). Second, one can test the possibility to simultaneously embody multiple rubber hands (Ehrsson, 2009; Newport, Pearce, & Preston, 2010). The difficulty is that results in both cases remain inconclusive. There is no evidence yet that the ownership of the rubber hand is accompanied by the disownership of the biological hand. At the physiological and behavioral level, it was found a decrease in skin temperature of the biological hand following the RHI, as well as a slowing down of tactile processes on the biological hand (Folegatti et al., 2009; Hohwy & Paton, 2010; Moseley et al., 2008). These results have been interpreted by Moseley and colleagues as evidence that the biological hand was replaced by its artificial counterpart. However, a similar slowing down of tactile processes was found following prismatic displacement (Folegatti et al., 2009). What the two experimental situations have in common is the visuo-proprioceptive conflict: participants see their hand in a different location than where they feel it. On the basis of these findings, we suggested that it is the visuo-proprioceptive conflict per se that modifies tactile perception, rather than disownership. Thus, it is not clear whether the biological hand is disowned or not, and thus whether one can experience more than two hands as one's own in the RHI.

A more definite answer can be found in studies using multiple rubber hands. Ehrsson (2009) reported illusory duplication of the right limb in subjects exposed to two adjacent rubber hands placed side by side above their biological hand, which was hidden below the table. When the two rubber hands were synchronously stroked with the biological hand, participants reported feeling touch on the two rubber hands and sometimes feeling as if the two rubber hands were their own. When any of the two rubber hands was stabbed by a needle, Ehrsson found a significant increase of the skin conductance response (SCR). He concluded that one could embody more than two hands. Newport et al. (2010) introduced a novel multiple hand illusion by using an active version of the RHI (i.e. active stroking of the paintbrush) in which videos of the subjects' own left hand were taken online to double the visual feedback of the subjects' biological left hand (unseen). Each hand was displayed slightly shifted (either leftward or rightwards compared to the biological hand) while the biological hand performed active movements to stroke the bristles of a toothbrush. When compared to a baseline condition where subjects only saw one hand displayed, the results indicated that participants reported feeling as if the two 'rubber' hands were their own. Overall these findings go in line with the pathological syndrome of supernumerary limbs. Some patients indeed experience the presence of one or two phantom hands or legs, in addition of their own biological hands and legs (Vallar & Ronchi, 2009). It may thus seem that we can be quite generous with our sense of ownership. We would not be limited to own two hands, but we could stretch our body limits and include three or even four supplementary hands (i.e. two rubber hands and two biological hands).

It may, however, be too early to draw such conclusion, especially on the basis of the described results. On the one hand, Ehrsson did not ask participants to rate their ownership illusion in a questionnaire. Furthermore, the set-up of his experiment prevented him to use the classic objective measure of the RHI, namely, the proprioceptive drift. The only measure he exploited was the SCR. But he never threatened both rubber hands at the same time. Hence, one cannot rule out the possibility that participants were 'insensitive' to the unthreatened rubber hand (or the subjects' biological hand, see Guterstam et al., 2011) when their autonomous system reacted to threat. On the other hand, the study by Newport and colleagues did use a questionnaire, but it is difficult to judge to what extent the results can be attributed to pure ownership because of the concomitant presence of an active movement (i.e. active stroking). Action might bring a new variable in the equation, namely, the sense of agency. Interestingly, they found that participants did not embody both displayed hands simultaneously in a subsequent motor task (i.e., to reach a target). Furthermore, one might wonder to what extent such an apparatus, displaying the exact visual appearance and movement of the subjects' biological hand, does not result into a mixture of the classic RHI and the SHI.

The aim of our paper was to determine the spatial constraints that lay upon the RHI by re-evaluating the possibility of multiple RHI. In particular, we kept the set-up of the experiment as close as possible as the classic RHI set-up. We then analysed in detail the interaction between the two rubber hands in light of their respective spatial location. To this end, we tested four different groups of healthy subjects in four separate experiments. In all experiments, two right rubber hands were presented in a position compatible with the subject's biological right arm, one rubber hand being farther than the other from the biological hand (hereafter, fRH for the farthest rubber hand and cRH for the closest rubber hand). We manipulated the number of hands that were stimulated, and the synchronicity between the rubber hands and the biological hand, as well as between the two rubber hands, and assessed both subjective (questionnaire) and objective (proprioceptive drift) aspects of RHI. For both measures, we predicted equal or additive illusory effects when two, instead of only one RH were stroked synchronously with the participants' biological hand.

In their original paper, Botvinick and Cohen (1998) noted: "While the Rubber Hand Illusion does not tell us precisely what ingredient might make only certain forms of intermodal correlation relevant to the self, it does show that intermodal matching can be sufficient for self-attribution". In this paper, we propose that the 'ingredient' in intermodal correlation that constitutes the mark of body ownership in the RHI can be found in the representations of the body boundaries. More particularly, we distinguish between two types of such representations, what we call the prototypical body (what is perceived as our own body with maximal degree of certainty) and the borderline body (what is perceived as potentially our body).

2. Methods

2.1. Participants

Forty-three subjects participated to the study. Nine healthy naïve participants (5 females, mean age 27.6 years; all right-handed) took part in our first experiment. A different group of 12 (7 females, mean age 23.8 years) participated in the second experiment. A group of 10 (5 females, mean age 25.6 years) was tested in experiment three and another group of 12 healthy participants (7 females, mean age 26.3 years) took part in experiment 4. All gave their informed consent to participate in the study that was conducted according to the Declaration of Helsinki and approved by the INSERM ethics committee.

2.2. Experimental design

Participants sat at a table with a one-way/two way mirror as surface. Their right hand was hidden from view under an obscured part of the glass. In full view they could see two rubber hands representing realistic reproductions of two right hands with forearm one placed rightward and the other leftward with respect to the participant's body midline. The former was thus closer to the biological hand (cRH) while the latter was farther (fRH). Lights were switched on and off under the mirror to make the rubber hands visible or to hide them. The distance between the participant's hand and the closest rubber hand was 15 cm, identical to the distance between the two rubber hands (all measures taken with respect to the stimulated middle finger). The rubber hands were slightly oriented anti-clockwise, to maximize posture plausibility with respect to the participant's right elbow. See Fig. 1.

Prior to multisensory stimulation, the participant was required to judge the position of her middle finger on a ruler, repeated six times. Then she was instructed to fixate a point located halfway between the two rubber hands during 2 min of visuo-tactile stimulation. Immediately after the visuo-tactile stimulation, the judgment of the finger position on the ruler was repeated and a questionnaire was administered to provide a subjective measure of the features and the vividness of the illusion.

This setup was designed to include four experimental manipulations.

In experiment 1 the participant's hand was brushed synchronously or asynchronously with the cRH (the closest rubber hand). The fRH (the farthest rubber hand) laid unstimulated (see Fig. 1A).

In experiment 2, the participant's hand was brushed synchronously or asynchronously with the fRH while the cRH laid unstimulated.

In experiment 3, the fRH was touched both in synchrony and asynchrony with cRH, which itself was synchronously or asynchronously touched with the biological hand. As a result, we had three conditions: (1) both rubber hands synchronous

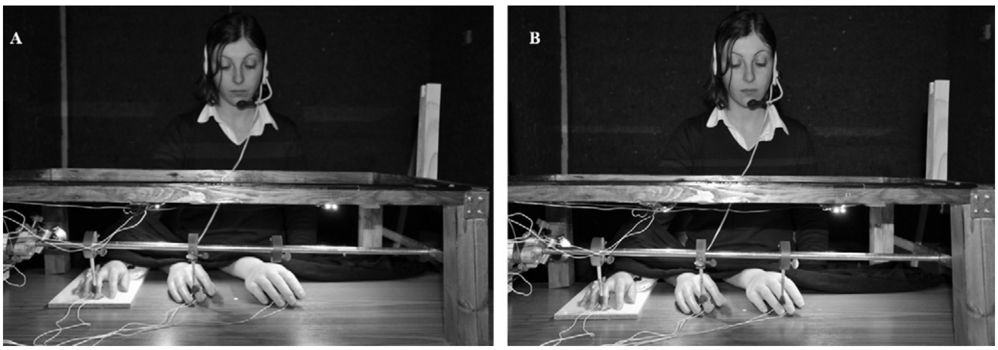

Fig. 1. Set-up in experiment 1 (panel A) and 2–3 (panel B). The pictures represent an actor who consented to be photographed for illustrative graphical purposes.

with the biological hand, (2) both rubber hands asynchronous with the biological hand, (3) fRH synchronous with the biological hand and cRH asynchronous with the biological hand.

In experiment 4, the cRH was synchronously touched with the biological one, giving raise to three conditions: (1) both rubber hands synchronous with the biological hand, (2) both rubber hands asynchronous with the biological hand, (3) cRH synchronous with the biological hand and fRH asynchronous with the biological hand (see Fig. 1B).

2.3. Proprioceptive judgment

Participants were required to estimate the position of their hidden right middle-finger by means of a ruler reflected on the mirror and appearing to be at the same depth as the hands (see Tsakiris & Haggard, 2005 for this method). They were instructed to report the number on the ruler corresponding to the position of their finger by mentally projecting a parasagittal line from the finger to the ruler. During proprioceptive judgments the lights under the mirror were switched off to make the rubber hand invisible while only the ruler was visible. Participants were required to repeat the judgment six times, with the ruler always presented with a random offset in order to avoid response strategies. The mismatch between the true position of the finger and the number indicated by the participant was calculated and resulted in a positive number if the displacement was towards the rubber hand and a negative number if it was away from it. This procedure allowed measuring the drift of the perceived position of the participant's own hand towards the rubber hand, a well established measure of the RHI (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005). When the cRH alone was touched, we expected to observe a drift comparable to that found in previous studies using the classical RHI setup, or alternatively a smaller drift if the presence of a second unstimulated fRH represented an obstacle for the induction of the RHI. When the fRH alone was touched, we expected to observe a smaller drift with respect to the previous condition due to the larger distance of this RH from the biological hand, as distance is known to decrease the strength of the RHI (Lloyd, 2007). When both rubber hands were touched in synchrony with the biological hand, we had two predictions: if both rubber hands can be embodied at the same time we should find an additive effect of the two rubber hands on the drift (so a larger drift), or at least the same drift as in experiments 1 and 2 if one of the rubber hands dominates on the other. If the two rubber hands cannot be embodied at the same time then we should expect to find no drift.

2.4. Visuo-tactile stimulation

After the judgment, the ruler was removed and the lights under the mirror were turned onto make the rubber hand(s) appear. A 2-min stimulation with identical paintbrushes followed. The real hand was stimulated with the rubber hands by means of two stepper motors through touches delivered along the dorsum of the middle-finger.

Experiments 1 and 2 consisted of two blocks characterized by different visuo-tactile conditions while experiments 3 and 4 consisted of 3 blocks with 3 different visuo-tactile conditions each, as described above. A resting period of 5 min was observed between blocks and their order was counterbalanced between participants.

The proprioceptive judgment was repeated after each 2 s-epoch of visuo-tactile stimulation.

2.5. Questionnaire

At the end of each block participants were required to complete a questionnaire, rating their agreement with eight statements describing the RHI experience (questions were slightly different for experiment 3 and 4, due to the differences in the setup, although they were all comparable between experiments, except for question 4, see Appendix). Participants were asked to judge their level of agreement with each statement by drawing a mark on a 14 cm long continuous line in which the left extreme indicated complete disagreement and the right extreme indicated complete agreement. For the questionnaire, we had similar predictions as for the proprioceptive drift. A level of agreement comparable to the classical RHI, or smaller, when the cRH alone was touched in synchrony with the biological hand, as compared to asynchronously. A smaller agreement when the fRH alone was touched alone. When both rubber hands were touched in synchrony with the biological hand we expected an additive effect and then a stronger agreement when compared to experiment 1 and 2 if both rubber hands can be embodied at the same time, or at least the same level of agreement as in experiment 1 and 2 if one of the rubber hands dominates on the other. Finally, we expected little or no agreement if the two rubber hands cannot be embodied at the same time.

The full questionnaire is reported in Appendix.

3. Results and discussion

3.1. Experiment 1

We performed an ANOVA on the mean error of the proprioceptive judgment (the displacement of the subjective from the objective location of the finger position, measured in cm). For this analysis we considered the variables synchrony (synchronous/asynchronous) and session (pre/post visuo-tactile stimulation). The variable session was significant [$F(1,8) = 11.69$,

$p = .009$], showing that following both kinds of visuo-tactile stimulation the subjective finger location was displaced leftwards, that is toward the rubber hands (3.13, SD = 2.96 vs. 6.36, SD = 5.05 in the synchronous condition and 3.54, SD = 3.32 vs. 4.57, SD = 4.25 in the asynchronous condition; $p < .01$ for all comparisons). As illustrated in Fig. 2, the significant interaction synchrony × session [$F(1,8) = 9.01$, $p = .02$] was due to the fact that the proprioceptive drift was larger following synchronous than asynchronous stimulation ($p = .008$).

Thus, the net proprioceptive drift attributable to the RHI amounts to 1.79 cm, which is comparable with that observed in previously published works on the RHI (e.g. Tsakiris & Haggard, 2005), and in particular with our previous study (Folegatti et al., 2009, Experiment 1: 1.2 cm of net proprioceptive drift) in which the same apparatus was used, but no second rubber hand was displayed.

In order to have a subjective measure of the illusion of ownership of the rubber hand we also performed an analysis of the mean values of agreement to the questionnaire with an ANOVA considering the variables synchrony of the stimulation (synchronous/asynchronous) and the variable question (question 1–8). The results are illustrated in Fig. 3. Both variables considered were significant: synchrony [$F(1,8) = 7.63$, $p = .02$] and question [$F(7,56) = 15$, $p = .0001$], as well as their interaction [$F(7,56) = 6.65$, $p = .0001$]. Participants expressed stronger agreement with the proposed questions after synchronous (4.5 cm, SD = 3.40) than asynchronous stimulation (2.0 cm, SD = 1.22). More in details, they strongly agreed with questions 1, 4 and 7 after synchronous visuo-tactile stimulation, but significantly less after asynchronous stimulation ($p < .001$ for all comparisons), while agreement to questions 2, 3, 5, 6 and 8 did not differ after the two kinds of stimulation. Question 1 is related to the localization of touch (touch is perceived as caused by the paintbrush touching the rubber hand), and questions 4 and 7 are related to the feeling of ownership for the touched rubber hand (the touched rubber hand belongs to the participant and is more her own as compared to the untouched rubber hand). Questions 2 and 3 relate to a different location of touch (touch is perceived as coming from a point between the participant's own hand and the closer rubber hand or from a point between the two rubber hands), and questions 5, 6 and 8 relate to the feeling of ownership involving also the untouched rubber hand (participants feel like they have more than 2 hands; both rubber hands belong to them; both rubber hands begin to resemble to their own hands). As expected, we observed stronger agreement for statements which locate the origin of touch on the touched rubber hand and expressing a feeling of ownership for the touched (as compared to the untouched) rubber hand.

We thus conclude that it is possible to induce the classical Rubber Hand Illusion, as measured both through a subjective report (questionnaire) and an objective measure (proprioceptive drift), also when a second (unstimulated) rubber hand is present and placed in a plausible position with respect to the subject's body. The mere presence of an additional rubber hand has no notable effects on the appearance of the illusion of ownership for the stimulated rubber hand or the localization of touch on it.

3.2. Experiment 2

As in Experiment 1, we performed a repeated measure ANOVA, with synchrony and session as independent variables (see previous experiment), on the proprioceptive drift (in cm). The variable session [$F(1,11) = 9.5$, $p < .01$] and the interaction synchrony × session [$F(1,11) = 5.16$, $p < .05$] were significant, showing a significant proprioceptive drift following synchronous stimulation (1.45, SD = 2.35 vs. 4.08, SD = 2.76, $p < .01$) while the drift following asynchronous stimulation was not significant (2.26, SD = 1.51 vs. 2.76, SD = 1.58) (see Fig. 4).

2The level of agreement with the items of the questionnaire was submitted to the ANOVA as in experiment 1, with synchrony and question as independent variables. Both variables and their interaction were significant: synchrony [$F(1,11) = 5.30$, $p < .05$]; question [$F(7,77) = 10.82$, $p < .0001$]; interaction synchrony × question [$F(7,77) = 2.74$, $p < .01$]. As in experiment 1, participants expressed stronger agreement for questions 1, 4 and 7 following synchronous than asynchronous stimulation; (see Fig. 5: question 1: 8.4, DS = 5.07 vs. 3.5, DS = 3.86, $p < .01$; question 4: 7.39, DS = 4.76 vs. 3.15, DS = 3.20,

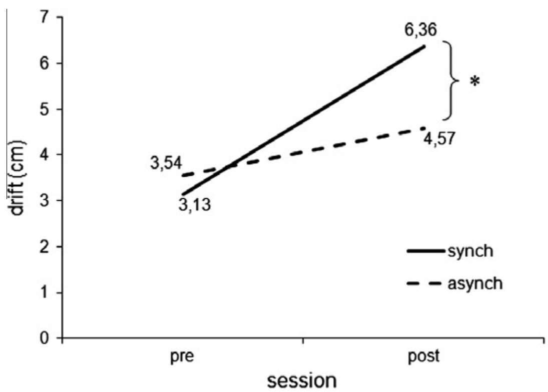

Fig. 2. Experiment 1, proprioceptive drift. Mean displacement (in cm) in the proprioceptive judgment task, as a function of session (pre–post) and synchrony (Synch–Asynch) of the visuo-tactile stimulation. Asterisk denotes statistically significant difference ($p < .05$).

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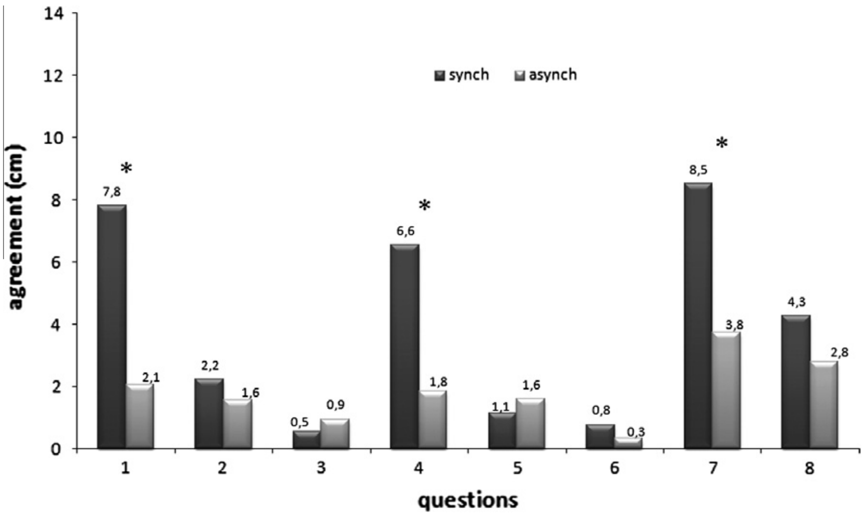

Fig. 3. Experiment 1, questionnaire. Mean level of agreement with the questionnaire statements (for specific questions, see Appendix). Asterisks denote statistically significant difference ($p < .05$).

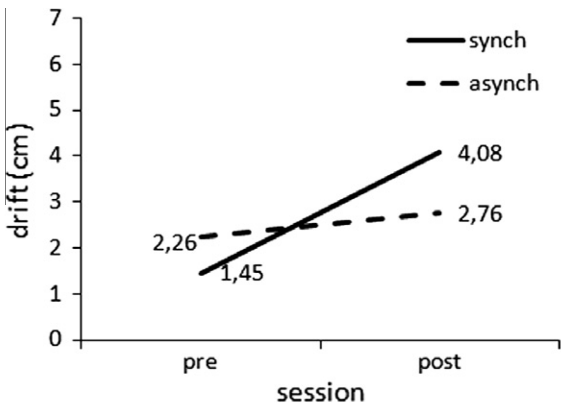

Fig. 4. Experiment 2, proprioceptive drift. Mean displacement (in cm) in the proprioceptive judgment task, as a function of session (pre–post) and synchrony (Synch–Asynch) of the visuo-tactile stimulation. Asterisk denotes statistically significant difference ($p < .05$).

$p < .02$; question 7: 11.5, DS = 3.53 vs. 6.34, DS = 5.58, $p < .001$). The level of agreement to the remaining questions did not differ.

The findings of experiment 2 thus show that, despite being relatively far from the subject's hand, at the limits of what Lloyd (2007) indicated as the space suitable to induce an effective RHI, it is possible to induce an illusion of ownership also for the fRH. In addition, this holds true despite the presence of a second, unstimulated rubber hand located in between the participant's and the farthest rubber hand. This conclusion is jointly supported by the measure of the proprioceptive drift and the questionnaire.

In line with Lloyd's observation, indicating an inverse relationship between the increasing of the distance between the RH and the real hand and the strength of the illusion, the amount of proprioceptive drift in the synchronous condition was numerically smaller in experiment 2 compared to experiment 1 (2.63 cm vs. 3.23 cm), although this difference did not reach statistical significance. In addition, in both experiments these amounts were significantly higher than the shifts observed in the asynchronous condition. Moreover, the results obtained from the questionnaire are fully comparable across experiments 1 and 2 (compare Figs. 3 and 5). Overall, these findings demonstrate a genuine and consistent RHI for both the close and far RH, when present simultaneously but stimulated singly, thus constituting the optimal condition for testing whether both rubber hands can be owned jointly, when co-stimulated (experiments 3 and 4 below).

3.3. Experiment 3

In an ANOVA on the proprioceptive judgment with synchrony [3 levels: both rubber hands synchronous (SS)/both asynchronous (AA)/fRH synchronous and cRH asynchronous (SA) with the biological hand] and session (pre/post visuo-tactile

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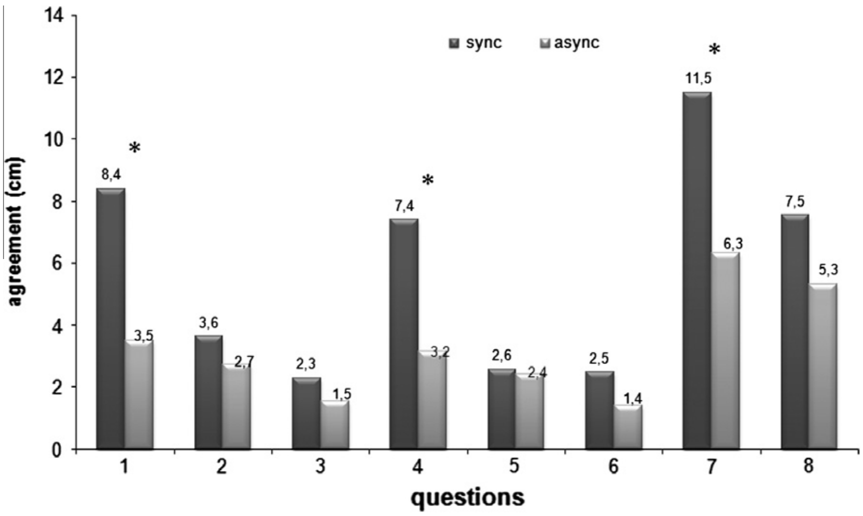

Fig. 5. Experiment 2, questionnaire. Mean level of agreement with the questionnaire statements (for specific questions, see Appendix). Asterisks denote statistically significant difference ($p < .05$).

stimulation) as within-subject variables, none of them resulted significant. Visual inspection of Fig. 6 makes clear that subjects slightly and non-significantly tended to judge their hand as being closer to the rubber hands following both synchronous (SS) and asynchronous (AA) stimulation of the two rubber hands. The amplitude of this non-significant drift (0.6 cm, SD = 1.94 in SS and 1.1 cm, SD = 2.13 in AA) was small and comparable to the drift typically induced by asynchronous visuo-tactile stimulation, as for example in Experiment 1 (1 cm). Noteworthy, the synchronous stimulation of fRH coupled with asynchronous stimulation of cRH (SA), did not produce any significant proprioceptive drift.

Interestingly, the questionnaire showed a differential effect of the kind of visuo-tactile stimulation on the illusion of ownership (see Fig. 7). The variable question [$F(7,63) = 6.88$, $p < .0001$], and the interaction between synchrony and question [$F(14,126) = 2.88$, $p < .001$] were significant. In particular, the stronger agreement concerned questions 1 (comparison SS–AA with Newmann–Keuls post hoc $p < .01$) and 2 (comparison SS–AA with Newmann–Keuls post hoc $p < .05$), relative to the localization of touch on the rubber hands, and question 7 (for both comparison SS–AA and SA–AA with Newmann–Keuls post hoc $p < .001$), which was relative to the feeling that one rubber hand was perceived as more owned by the subject than the other one. Systematically questioned on the latter point, all subjects reported feeling the cRH as being more part of their body than the fRH.

To sum up, when a second rubber hand is added further leftward to the classical RHI setup, and it is also stroked in synchrony with the subjects' biological right hand, the proprioceptive drift does not testify the presence of an illusion of ownership. Noteworthy, this conclusion holds true irrespective of whether the cRH is stroked asynchronously or synchronously with the fRH. However, the subjective measure of the feeling of ownership, as rated in the questionnaire, clearly indicated that participants felt the cRH as their own (more than fRH) both when the rubber hands were synchronously stroked and when they were asynchronously stroked (see Table 2). Thus, it could be suggested that the synchronous stimulation of fRH and cRH was insufficient to bring about ownership of the two rubber hands in terms of proprioceptive drift, but it

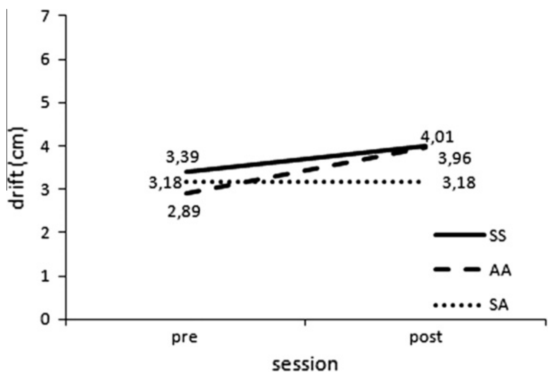

Fig. 6. Experiment 3, proprioceptive drift. Mean displacement (in cm) in the proprioceptive judgment task, as a function of session (pre–post) and synchrony (SS–AA–AS) of the visuo-tactile stimulation.

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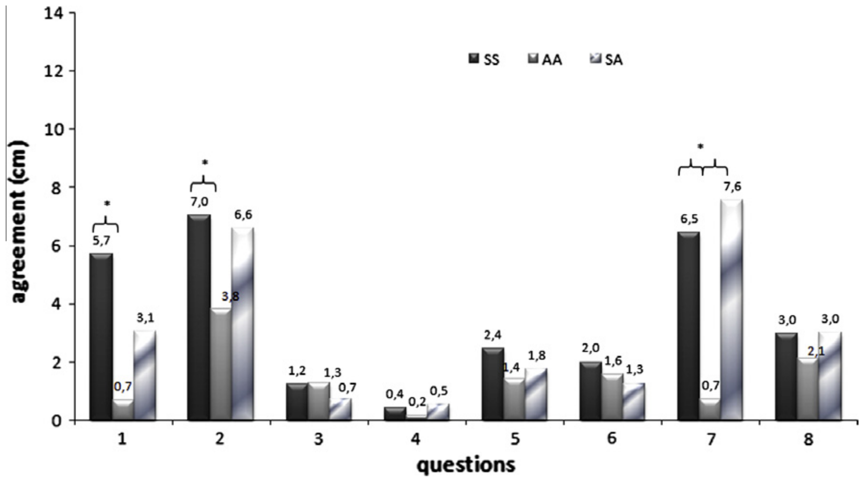

Fig. 7. Experiment 3, questionnaire. Mean level of agreement with the questionnaire statements (for specific questions, see Appendix A). Asterisks denote statistically significant differences ($p < .05$).

nevertheless resulted in a subjective feeling of ownership for the cRH. This underlines the notion that two different mechanisms can be responsible of the subjective illusion of ownership and its objective measurement via the proprioceptive drift (see Holmes & Spence, 2007; Rohde, Di Luca, & Ernst, 2011).

3.4. Experiment 4

In the fourth experiment, we evaluated the effect of the visuo-tactile stimulation [both rubber hands synchronous with the biological hand (SS)/both asynchronous (AA)/fRH asynchronous and cRH synchronous (AS)] on the proprioceptive judgment (pre/post visuo-tactile stimulation) by running the same ANOVA as in experiment 3. Fig. 8 illustrates that the proprioceptive drift differed significantly between pre and post stimulation (session [$F(1,11) = 5.98$, $p > .05$], interacting significantly with the kind of visuo-tactile stimulation (interaction synchrony × session [$F(2,22) = 3.84$, $p > .05$]. The post hoc analysis (Newmann–Keuls) showed that, as a consequence of the synchronous stimulation of the cRH with the biological hand, while the fRH was stroked asynchronously, the judgment of the subjects' finger position was significantly misplaced leftwards, that is to say toward the rubber hands, relatively to all the other conditions ($p < .005$ for all comparisons). Again, the net amount of proprioceptive drift (1.3 cm) was comparable to that obtained both in our previous work (Folegatti et al., 2009) using the same set-up (1.2 cm) and with that observed here in Experiment 1 (1.7 cm). In sharp contrast, and similar to experiment 3 here above (see Table 2), no significant proprioceptive displacement was observed either when both rubber hands were stroked asynchronously (AA) or even synchronously (SS) with the subjects' biological right hand ($p > .2$ in all comparisons).

Table 2
Results summary.

Experiment	Condition	Proprioceptive drift	Questionnaire items
1	cRH S	✓	✓
	cRH A	✓	✗
2	fRH S	✓	✓
	fRH A	✗	✗
3	c & f RH SS	✗	✓
	c & f RH AA	✗	✗
	fRH S & cRH A	✗	✓[a]
4	c & f RH SS	✗	✓
	c & f RH AA	✗	✗
	fRH A & cRH S	✓	✓[a]

The presence of the RHI is here reported as a function of experiment (1–4) and condition of visuo-tactile stimulation (S = synchronous; A = asynchronous with the participant's hand) according to whether significant (✓) or non-significant (✗) changes in position sense (proprioceptive drift) and sense of ownership (questionnaire items) were observed.

[a] In this condition, participants reported the cRH was more their own than the fRH.

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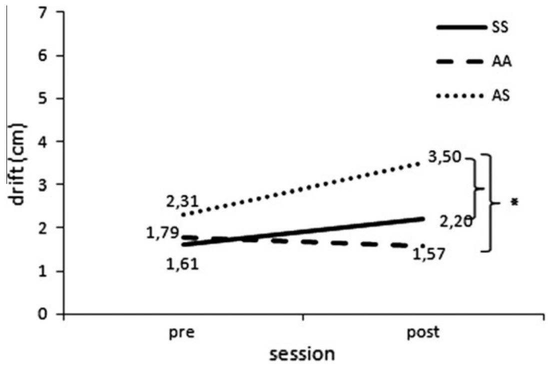

Fig. 8. Experiment 4, proprioceptive drift. Mean displacement (in cm) in the proprioceptive judgment task, as a function of session (pre–post) and synchrony (SS–AA–SA) of the visuo-tactile stimulation. Asterisk denotes statistically significant differences ($p < .05$).

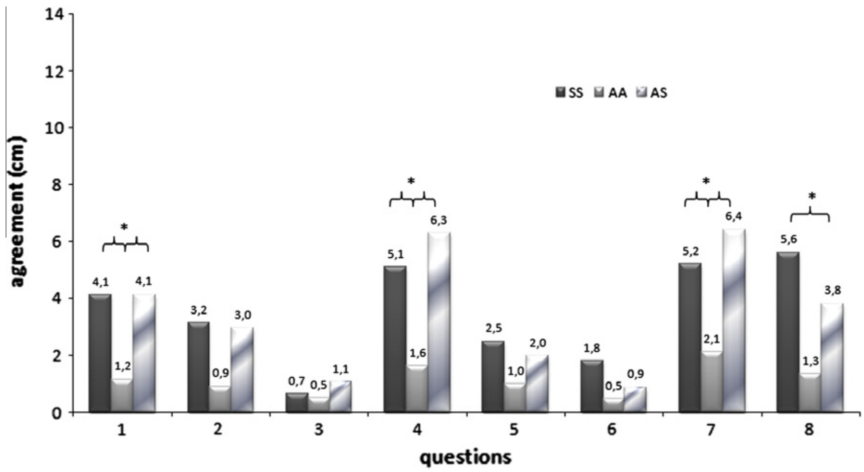

Fig. 9. Experiment 4, questionnaire. Mean level of agreement with the questionnaire statements (for specific questions, see Appendix A). Asterisks denote statistically significant differences ($p < .05$).

An ANOVA on the questionnaire with synchrony (SS/AA/AS) and questions (8 questions) as within-subject variables, showed a different level of agreement with the various questions [$F(7,77) = 6.71$, $p < .0001$] and following the different kinds of visuo-tactile stimulation [$F(2,22) = 8.64$, $p < .01$]. When both rubber hands were stimulated synchronously (mean 3.36 cm) with the biological hand or the closer one synchronously and the further one asynchronously (mean 3.25 cm), the agreement to the questionnaire was higher than when they were both stimulated asynchronously with the subjects' biological hand (mean 1.09 cm, $p < .005$ for both comparisons). Fig. 9 illustrates this difference, which was significant for questions 1, 4, 7 (comparisons SS–AA and AS–AA, $p < .05$ for all questions) and 8 (comparison SS–AS, $p < .001$). As in the previous experiment, the feeling of ownership was clearly attributed to the closest RH.

4. Discussion

Our study aimed at deepening our understanding of the critical constraints for multiple embodiment of rubber hands. In order to do so, we used a novel variation of the RHI, in which two right-handed rubber hands (cRH, which is close to the biological hand and fRH, which is farther on the left) were simultaneously visible while the subject's biological right hand was unseen. In our analysis of the results, we distinguished within the RHI the contribution of a subjective component, which was assessed by the questionnaire, and an objective component, which was measured by the proprioceptive drift. Our results can be summarized into three main conclusions: (1) the RHI, as eye-witnessed by both proprioceptive drift and questionnaire, is not affected by the mere visual presence of an additional (unstimulated) rubber hand, irrespective of the closeness of the latter with respect to the real hand; (2) but the RHI is affected by the simultaneous stimulation of an additional rubber hand, whether it is synchronous or asynchronous; (3) the interference due to the simultaneous stimulation of an additional rubber hand differs as a function of the measure considered (i.e., questionnaire or proprioceptive drift). After describing these results in details, we will discuss possible explanations and their implications.

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In Experiments 1 and 2, one rubber hand was stroked, while the second rubber hand was lying there unstimulated. We found an illusion of ownership of the stimulated rubber hand, as reflected at the subjective level by the questionnaire rating and at the objective level by the proprioceptive drift. So, the mere visual presentation of a second rubber hand in the experimental setup, even in a plausible position, did not prevent the emergence of a full RHI. This was true even if the rubber hand that was stimulated was the farthest (fRH), despite the fact that it was 30 cm apart from the biological hand and that the cRH was halfway in between the biological hand and the fRH.

However, when participants also saw the second rubber hand being touched, the scenario changed profoundly. In Experiments 3 and 4, when both rubber hands were touched in synchrony, we observed no subjective or objective indication of RHI for the fRH. As for the cRH, the results are more contrastive. On the one hand, the synchronous stimulation of both rubber hands made the proprioceptive drift disappear. On the other hand, participants reported feeling as if the cRH were their own hand, as indicated by the questionnaire. Unlike the objective measure of the RHI (proprioceptive drift), the subjective measure (questionnaire) was thus immune to the stimulation of the additional rubber hand. In this respect, whatever the combination of the synchronous touch with the biological hand, that is both rubber hands synchronous (SS, experiment 3 and 4), or the farthest synchronous and the closest asynchronous (SA, experiment 3) or vice versa (AS, experiment 4, see Table 2), a consistent feeling of ownership for the closest RH was uniformly observed. Consequently, the objective and the subjective measures of the illusion can be dissociated when using multiple rubber hands, thus strengthening our own previous findings (Folegatti et al., 2009; see also Holmes & Spence, 2007). A recent interesting study has further investigated this dissociation and called into question whether the proprioceptive drift alone can be considered as a counterpart of the RHI (Rohde et al., 2011). According to the authors, the proprioceptive drift relies exclusively on visuo-proprioceptive integration. This process normally takes place even by simply looking at an unstimulated rubber hand, but it can be inhibited by asynchronous stroking. Although of broad interest for our understanding of the RHI phenomenon, this dissociation does not fully account for our results. In particular, it does not explain why the double *synchronous* stimulation in experiment 3 and 4 does not induce any proprioceptive drift.

Two further conditions are of interest: condition SA in Experiment 3 and condition AS in Experiment 4. In condition SA, the fRH was stimulated in synchrony with the biological hand, unlike the cRH. In other words, only the stimulation of one rubber hand correlated with the stimulation of the biological hand. Yet, this failed to induce any proprioceptive drift, or clear feeling of ownership for the fRH. The condition AS was exactly the reverse. The cRH was stimulated in synchrony with the biological hand, unlike the fRH. This led to a proprioceptive drift comparable to that obtained for cRH when stroked alone (Experiment 1, see Table 2). As for the subjective RHI, both SA and AS induced to some extent some ownership feelings, primarily directed at the cRH in both cases.

To recap, we could induce a RHI for cRH and for fRH alone when two rubber hands were present, but only in some circumstances. We elicited a proprioceptive drift for the cRH in Experiment 1 (when only the cRH was stroked) and in Experiment 4 (when the fRH was stroked in asynchrony). On the other hand, when considered only on the basis of this objective measure, the RHI was apparently suppressed by the synchronous stimulation of the fRH in both Experiments 3 and 4. In addition, we elicited a proprioceptive drift for fRH in Experiment 2 (when only the fRH was stroked), but we failed to do so in Experiment 3, no matter whether the cRH was stroked in synchrony or asynchrony.

What is noticeable in our study is that the simultaneous stroking of the two rubber hands and the biological hand determined a change in the objective measure of the RHI, and this in two ways: (i) full suppression of the drift itself, when the second rubber hand was also touched in synchrony (SS condition in experiment 3 and 4), and (ii) weakening of the drift (AS condition, experiment 4). Indeed, the amount of proprioceptive drift, even when statistically significant, was weaker when both rubber hands were touched (AS: 1.2 cm) than when only one rubber hand (cRH S) was touched (3.2 cm; t-test for independent groups = 2.26; $p < .04$).

At odds with the objective indication of the RHI, the subjective measure, as derived from the questionnaire, did not seem as sensitive in distinguishing between different combinations of stroking of the rubber hands. Indeed, the subjective illusion of ownership was consistently present across the four experiments, with only small variations when comparing Experiments 3 and 4 with experiments 1 and 2, where only one RH was 'touched'. In both Experiments 3 and 4, subjects expressed a feeling of misplacement of the origin of touch, as if it originated from the cRH, and a strong feeling of ownership for the cRH. Even when there was no proprioceptive drift (experiment 3), some sense of ownership was observed in the questionnaire, although limited to the cRH. More interestingly, a comparable feeling was also reported for the two rubber hands when they were both synchronously stroked, but again the subjective illusion of ownership appeared to be mainly directed toward the cRH. Noteworthy, across the three experiments subjects never declared to feel ownership for both rubber hands (question 6), whatever the experiment and the conditions of stimulation. When asked towards which of the two rubber hands the feeling of ownership was stronger, they consistently attributed it to the cRH. Still, a weakening of the illusion of ownership is numerically evident also in the questionnaire scores, when comparing them to the scores of experiment 1 and 2: participants were more likely to refer touches to the rubber hand and to have a stronger feeling of ownership of one of the two rubber hands in experiment 1 and 2 relative to experiments 3 and 4, although this difference was not statistically significant.

In summary, our series of experiments made clear that, when considering the classic objective measure of the RHI, it is not possible to simultaneously embody two rubber hands, at least with our set-up. Instead, when considering the subjective experience of the illusion, a diminished, but significant sense of ownership can be obtained, but stronger for the cRH. So why in our experiments is it possible to induce only a mitigated RHI for two rubber hands? And why the stroking of a second

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rubber hand prevents the emergence of the proprioceptive drift also for the rubber hand that should induce it? We want first to rule out two possible explanations.

First, one may be tempted to explain our results by the location of the fRH. According to Lloyd's study (2007) the strength of the RHI decreases with the rubber hand being located at distances larger than 27.5 cm. In our study, the fRH is located 30 cm far from the subject's hand, therefore just beyond this limit. However, the stimulation of the fRH alone produced a significant proprioceptive drift and significant agreement with the ownership questionnaire. Although numerically smaller, the proprioceptive drift elicited by stroking the fRH alone was statistically comparable to the one observed after stroking of the CRH alone. In any case, if the influence of the fRH were still weaker, simply because it was located far from the subject's hand, then the condition SS should produce a normal proprioceptive drift at least for the cRH, but this was the case neither in Experiment 3 nor in Experiment 4. It is worth noting that the asynchronous stimulation of the fRH did not prevent the emergence of a genuine RHI for the cRH (experiment 4, AS condition), suggesting that an active process intervened in the SS condition to prevent the establishment of the RHI, even for the cRH.

Alternatively, one may offer an attentional explanation of these puzzling results: the RHI was prevented in the SS condition because there was something driving attention away from the cRH. However, the attentional drift should apply also to the AS condition of Experiment 4. There should be a disturbing effect of "attention moving" away from the cRH also when the latter was touched in synchrony with the subject's hand. Yet, this did not prevent the RHI to emerge in the AS condition. Conversely, synchronous stimulation of the fRH was not attracting enough attention to establish a RHI for that hand, even when the cRH was touched asynchronously with the subject's hand (experiment 3, SA condition). Therefore, attentional shifts can neither account for the whole pattern of results.

If our results cannot be explained by the location of the farthest rubber hand or by attentional effects, then how can one explain that we fail to replicate other studies that were able to induce RHI for multiple rubber hands (Ehrsson, 2009; Newport et al., 2010)? In Ehrsson's study, the measure of the proprioceptive drift was made impossible by the experimental design. There was no spatial separation between the two rubber hands, which were located side by side above the subject's unseen hand. The RHI was measured through subjective reports and SCR. Having repeatedly found a dissociation between the subjective feeling of ownership and the proprioceptive drift, one may argue that the SCR is possibly a better behavioral correlate of the RHI. However, this remains controversial (de Vignemont, 2011). Arguably, increased SCR is a consequence of the sense of ownership. However, it is a logical fallacy to claim that the antecedent in an indicative conditional is true because the consequent is true. In other words, the increase of SCR in the synchronous condition compared with the asynchronous condition cannot be taken as evidence of ownership. It could be if and only if SCR was an exclusive measure of ownership (a measure M of a process P is exclusive if M obtains if *and only if* there is P). However, SCR can hardly qualify as an exclusive measure of ownership since it is also affected by many factors, including empathy, attention, and so forth.

All in all, it is possible that the spatial proximity of the two rubber hands is the key differential element enabling double RHI in Ehrsson's study (see Körding et al., 2007). The side-by-side set-up might cast doubts on the simultaneous embodiment of the two rubber hands, indeed, one cannot fully exclude the possibility that the reaction to the threat did not arise for both rubber hands simultaneously.

Likewise, the experimental setup and procedures in Newport and colleagues' study are basically different from ours and from the typical RHI set-up in general. They induced a RHI for the subject's own hand reduplicated via a video system, and produced it through observation of an active movement of the hand(s) repeatedly stroking a toothbrush. Moreover, the illusion was quantified subjectively, with a questionnaire, and objectively, with a subsequent pointing task. Pointing errors provide an indirect measure of the misplacement of the perceived position of the hand itself (see also Holmes, Snijders, & Spence, 2006, for a similar approach without active induction of RHI). Interestingly, while a subjective feeling of ownership was reported through the questionnaire for the video images of both hands moving in synchrony, only the video image of one hand influenced the trajectory of the pointing movement. Owing to this dissociation, the authors concluded that the subjective feeling of ownership reflects the incorporation into the body image, which can concern more than one rubber hand at a time, whereas the pointing task requires an update of the body schema, which can concern only one limb at a time. However, we cannot use the dissociation between the body image and the body schema to explain the present results. In particular, our way of testing the proprioceptive drift is not appropriate (and was not meant to) tackle the body schema. It relies on perceptual estimation with no link to action.

To conclude, the success in establishing the subjective feeling of ownership for multiple rubber hands in other studies seems to underline the need for the two rubber hands (or the real hand and the rubber hand, see Guterstam et al., 2011) to be at the same distance from the subject's hand/body. This spatial condition, which was clearly violated in our experiments, might thus be crucial. Even by considering the fRHI as being possibly weaker in its proprioceptive component (numerically, though, but not statistically) when compared to the cRHI, the synchronous stroking of both rubber hands, had a clear suppressive impact on the possibility of inducing RHI proper (i.e., both objectively and subjectively) even for the cRH. Our study suggests that this suppressive mechanism could depend on the plausibility of information coming from different sensory modalities: if multisensory signals cannot be integrated in a plausible percept then the RH cannot be perceived as part of the subject's body. This can be true also when speaking of the subject's own hand, as recently proved by Newport and Gilpin (2011) who were able to induce a sensation of loss of ownership of the real limb through the disintegration of sensory signals. Such a kind of suppressive mechanism could be useful in maintaining a distinction between self and other bodies and its disruption could be responsible for neuropsychological deficits such as misoplegia or somatoparaphrenia.

Instead of the distinction between the body schema and the body image, our study highlights another distinction between three types of spatial representations: (i) the space of what belongs to our body, (ii) the space of what can belong to our body and (iii) the space of what can affect our body. This distinction cannot be reduced to the opposition between the personal space and the peripersonal space, frequently found in the literature (Brozzoli, Gentile, Petkova, & Ehrsson, 2011; Halligan & Marshall, 1991; Làdavas, di Pellegrino, Farnè, & Zeloni, 1998; Làdavas & Farnè, 2004). One difficulty with this classic dichotomy is that it is unclear how and where to draw the boundary between the personal space and the peripersonal space (Cardinali, Brozzoli, & Farnè, 2009). For example, it is sometimes unclear whether rubber hands are included within the personal space (Tsakiris, 2010), or within the peripersonal space (Makin et al., 2008). The same debate can be found about the embodiment of tools (Cardinali et al., 2009; Holmes & Spence, 2004; see also de Vignemont & Farnè, 2010 and de Vignemont, 2011 for discussion).

In contrast, our distinction leaves no ambiguity. It clearly takes apart what is part of the body, what can be part of the body and what is external to the body, but still relevant for it. Arguably, the brain computes the boundaries of the biological body, but taking into account some margin of spatial errors, thus creating a gray zone of possibilities of body ownership. The perceived boundaries of our body are thus relatively vague. We may compare it to the perception of colors. Some shades of color are clearly identified as yellow, others are clearly identified as green, but there are some in between for which the categorization oscillates between yellow and green. Furthermore, the context can influence the categorization of the borderline cases.

Likewise one may suggest that there is a prototypical body (what is perceived as our own body with maximal degree of certainty) and a borderline body (what is perceived as potentially our body). The borderline body corresponds to a spatial overestimation of the boundaries of our body, a gray zone that seems to go as far as 27.5 cm from the biological body (Lloyd, 2007). From an evolutionary perspective, it is indeed safer to overestimate the boundaries of one's body than to underestimate them. One may further suggest that the constraints that lay upon the gray zone differ from the constraints that lay upon the clearly identified space of our biological body. In particular, the two-hand constraint may not apply. This would explain why Ehrsson and Newport and colleagues succeeded in inducing multiple RHI. The space above and beyond the gray zone should not be considered as completely irrelevant for the body. On the contrary, it could influence the boundaries of the gray zone by giving perceptual and social context. We suggest that the influence of this contextual space occurs at the level of the decision criteria that are exploited by the brain in order to decide whether a limb belongs to one's body or not. For instance, one may easily conceive that the limits of the gray zone shrink when one is surrounded by many people. In the presence of other limbs, one has better use stricter decision criteria to avoid confusion. The suppression of the proprioceptive drift for the cRH in our experiments may reflect this general principle, which could be exploited by the brain in operational terms: the fRH could be close enough to subjectively think it could be part of my body, but too far to affect proprioceptively based decision such as moving or not. To conclude, our findings indicate that a further constraint for the cRH to be experienced as one's own hand is that no other hands are synchronously touched at a distance, even when such a distance is sufficient for the fRH (alone) to be experienced as one's own.

In conclusion, and despite the previous reported findings, it does not appear so obvious to induce a double ownership of two rubber hands when they are not located at the same distance from the biological hand. When sticking to a situation as close as possible to the classic RHI studies, like in our experiments, the presence of a stimulated second rubber hand actually seems to actively suppress the illusion and prevent its emergence. We suggest that, if the RHI is the result of the solution of a multisensory conflict, conflict there is only when it is plausible (one rubber hand, or two rubber hands located side by side). In an implausible situation, like with two (or more) right rubber hands located far apart, the conflict is solved in a more conservative way, by preventing embodiment also for the closest rubber hand. We offered here a new conceptual framework to interpret these complex results, revising the classic dichotomy between the personal space and the peripersonal space. Rather, we speculated that the perception of bodily boundaries should be construed in the same way as categorical perception, which allows for prototypical instances and borderline instances, the categorization of the latter being influenced by the context. Similarly, one should distinguish the prototypical body and the borderline body, the sense of ownership of the latter being influenced by the peripersonal space.

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Appendix A

Questionnaire experiment 1–2/experiments 3–4:

1. It seemed as if the touch I were feeling was caused by the paintbrush touching the rubber hand/s.
2. It seemed as if I were feeling the touch of the paintbrush somewhere between my own hand and the touched rubber hand/the rubber hand closer to it.
3. It seemed as if I were feeling the touch of the paintbrush somewhere between the two rubber hands.

4. It seemed as if the touched rubber hand was my hand/the touch I were feeling was caused by the paintbrush touching one of the rubber hands more than the other. (Which one?).
5. It seemed as if I might have more than two hands.
6. I felt as if the rubber hands were my hands.
7. I felt as if one of the rubber hands were more my hand than the other. (Which one?).
8. It seemed as if the rubber hands began to resemble to my own hand, in terms of dimension, shape, skin tone or some other visual feature.

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