Acta Psychologica 132 (2009) 166–172

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Self awareness and the body image

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ARTICLE INFO

Article history:
Received 14 July 2008
Received in revised form 3 February 2009
Accepted 5 February 2009
Available online 16 March 2009

PsycINFO classification:
2320
2380

Keywords:
Body image
Similarity
Embodiment
Rubber hand illusion

ABSTRACT

What mental representations give us the sense of our body as a unique object in the world? We investigated this issue in the context of the rubber hand illusion (RHI), an illusion of body image in which a prosthetic hand brushed synchronously, but not asynchronously, with one's own hand is perceived as actually being one's hand. We conducted a large-scale study of the RHI, and used psychometric analysis to reveal the structure of the subjective experience of embodiment [Longo et al. (2008). What is embodiment? A psychometric approach. *Cognition, 107*, 978–998]. Here, we use this dataset to investigate the relation between incorporation of a rubber hand into the body image and the perceived similarity between the participant's hand and the rubber hand. Objective similarity (as measured by skin luminance, hand shape, and third-person similarity ratings) did not appear to influence participants' experience of the RHI. Conversely, incorporation of the rubber hand into the body image did affect the similarity that participants perceived between their own hand and the rubber hand. Participants who had experienced the RHI perceived their hand and the rubber hand as significantly more similar than participants who had not experienced the illusion. That is, embodiment leads to perceived similarity, but perceived similarity does not lead to embodiment. Furthermore, similarity ratings following the illusion were selectively correlated with some components of embodiment, but not with others. These results suggest an important role of a mental body image in the perception of the relation between the self and others.

1. Introduction

Several recent theories have suggested that perception and cognition are fundamentally shaped by the body (e.g., Barsalou, 2008; Gallagher, 2005; Gallese & Lakoff, 2005; Proffitt, 2006). A wide range of cognitive processes either invoke, or are influenced by, representations of the body (for review, see Barsalou, 2008). For example, non-informative vision of the body increases the spatial acuity of touch (Kennett, Taylor-Clarke, & Haggard, 2001). However, it is less clear what sorts of body representation underlie such effects. Psychologists and philosophers have classically drawn a major division between two representations of the body: the *body image* and the *body schema* (e.g., Gallagher, 1986; Paillard, 2005). The body image represents the perceived form of our body, in terms of its size, shape, and distinctive characteristics. The body schema, in contrast, is predominantly somatosensory, and is concerned with tracking and updating the positions of body parts in space during movement. Except in unusual situations (e.g., Gallagher & Cole, 1995), both the body image and body schema are always present. This highlights a major problem in testing the role of embodiment in perception: the body, as James (1890) wrote, is "always there". This makes it difficult to perform experimental manipulations involving the body, since the crucial control condition – in which the participant does not have a body – is impossible to implement.

One approach to this problem involves using bodily illusions that incorporate an external object into the body. In the *rubber hand illusion* (RHI), for example, a prosthetic hand that is touched in perfect temporal synchrony with touches of the participant's unseen hand is perceived as actually being part of the participant's body (Botvinick & Cohen, 1998); identical, but temporally asynchronous, stimulation does not produce this sensation. Thus, the RHI allows manipulation of body representations, by comparing conditions in which the rubber hand and the participant's hand are touch in phase (synchronous stimulation) or out of phase (asynchronous stimulation). On the one hand, the RHI involves linking a visually appropriate object, the rubber hand, to the self, suggesting a body image component (Tsakiris & Haggard, 2005). On the other hand, a strong component of the illusion, and indeed one commonly used way of measuring it, is the change in *location* of the participant's hand towards the rubber hand (e.g., Holmes,

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doi:10.1016/j.actpsy.2009.02.003

Snijders, & Spence, 2006; Longo, Schüür, Kammers, Tsakiris, & Haggard, 2008b; Tsakiris & Haggard, 2005). Since spatial location is a key feature of the body schema, but not of the body image, this suggests an involvement of the body schema. The RHI offers the possibility to study the relation between these two components of bodily experience. Location biases are selectively related to certain aspects of the conscious experience of embodiment, but not to others (Longo et al., 2008b), suggesting that the body imagistic and body schematic components of the illusion, while related, are dissociable. In this study, we accordingly used the RHI to investigate the role of body image in the perception of similarity between oneself and others.

The idea that similar things share some level of identity is deeply seeded in the human psyche (Frazer, 1922). Botvinick and Cohen (1998) initially suggested that the similarity between the participant's hand and the rubber hand was important for the occurrence of the RHI. Armel and Ramachandran (2003), in contrast, found that the illusion could be elicited by brushing a table synchronously with the participant's hand. They argued that that the illusion resulted as a purely bottom-up result of visuotactile synchrony. Tsakiris and Haggard (2005), however, demonstrated that the disturbances of proprioceptive location occurred only when a congruent rubber hand was presented, and not when viewing either a block of wood, or a rubber hand with the opposite handedness from that stimulated. Similar results were found by Holmes et al. (2006). This suggests that the body image functions in a top-down manner as a filter, allowing only stimuli that are sufficiently similar to be incorporated, and inducing adaptations of the body schema as a result (cf. Tsakiris, Costantini, & Haggard, 2008).

However, none of these studies systematically manipulated the similarity between the rubber hand and the participant's own hand, or even attempted to quantify degree of similarity. Thus, the parameters of the filter remain unclear, that is, how severe the constraint of similarity must be for a physical object to become incorporated into the body image. This issue could be investigated in two quite different ways. One could attempt to elicit an RHI with a variety of objects, varying along a continuum for very similar to the participant's own hand, to very dissimilar. Here, we take a more naturalistic approach, relying on the natural morphological variation between people's hands, and investigate whether a specific rubber hand evokes a stronger RHI in participants whose hands happen to more closely resemble the rubber hand. For example, participants whose hands are more similar to the rubber hand (e.g., in complexion) might experience the RHI more strongly than participants whose hands are less similar to the rubber hand. Alternatively, the filtering effect of the body image may be categorical, allowing anything which has the general characteristics of a hand to be incorporated into the body image, without regard to within-category similarity. Evidence in favour of the latter proposal comes from a study by Holmes et al. (2006), who found that a white rubber hand evoked comparable RHIs in white and black participants. These results suggest that objective similarity may play little role in the formation of embodiment.

We conducted a large-sample, psychometric study of the RHI (Longo et al., 2008b), with the aim of dissociating the experience of embodiment evoked in the RHI into distinct components. Following blocks of synchronous and asynchronous brushing, we collected data on 27 questionnaire items assessing a wide range of experiences participants might have had. Principal components analysis (PCA) on these data revealed four components that emerged in both experimental conditions: *embodiment*,[1] reflecting feelings that the rubber hand belonged to the participant, the participant had control over the rubber hand, the rubber hand and real hand were in the same location, and the rubber hand had taken on features of the actual hand; *loss of own hand*, reflecting feelings of being unable to move one's hand, one's hand disappearing, and one's hand being out of one's control; *movement*, relating to perceived motion of one's own hand, and to movement of the rubber hand; and *affect*, relating to the experience of the block being interesting and enjoyable, and the touch of the paintbrush is being pleasant. An additional fifth component, *deafference*, appeared only in the asynchronous condition, which related to the sensation of pins-and-needles and numbness in one's hand, and the experience of the hand being less vivid than normal. Furthermore, a secondary PCA revealed that the *embodiment* component itself comprised three dissociable components: *ownership*, related to the feeling that the rubber hand was part of one's body, the feeling of looking directly at one's hand, and the rubber hand taking on the characteristics of one's own hand; *location*, related to the feeling that the rubber hand and one's own hand were in the same place, and also to sensations of causation between the seen and felt touches; and *agency*, related to the feelings of being able to move the rubber hand and control over it.

In the present study, we used this same data set to investigate the relation between the experience of embodiment and the perception of similarity that participants perceive between their own hand and the rubber hand. In addition to the subjective report data described previously, participants were asked to rate the similarity they perceived between their own hand and the rubber hand. Moreover, their hand was photographed so that an objective measure of similarity (skin luminance) and third-person similarity ratings could be obtained. These similarity data are analyzed and presented here for the first time, in order to investigate three main issues. First, we investigated whether objective morphological similarity affects the incorporation of a rubber hand into the body image. Second, we investigated the converse effect, whether the incorporation of the rubber hand into the body image has functional consequences for subsequent perception of similarity between one's own hand and the rubber hand. And third, we investigated the relation between these effects and specific components of the experience of embodiment that we identified in our previous psychometric study (Longo et al., 2008b).

2. Methods

2.1. Participants

The studies were approved by the local ethical committee. In study 1, 131 current and prospective students at University College London (75 females) participated in the RHI session and made first-person similarity ratings. The RHI measures from this dataset were reported previously (Longo et al., 2008b), but the similarity judgements are presented here for the first time. In study 2, 25 new University College London students (21 females) made first-person similarity ratings without having experienced the RHI. In study 3, a further group of four new participants (1 female), including one of the authors (MRL), made third-person similarity ratings of the rubber hand and each participant's hand for both the RHI and no-RHI groups. The third-person raters did not know about the performance of individual participants in the RHI study, nor about individual participants' first-person similarity ratings. That is, the third-person ratings were blind and independent.

2.2. Rubber hand illusion and first-person similarity ratings

Participants sat across from the experimenter, and placed their hand into a specially constructed box. Participants wore a cloth

[1] Italics are used to indicate components of the experience of the RHI extracted by Longo et al. (2008b).

smock which was attached to the front edge of the box, such that their arms were out of view throughout the experiment. There were two experimental conditions, presented in two successive blocks (order counterbalanced across participants). In the *synchronous* condition, the hands were stroked at the same time; in the *asynchronous* condition, they were stroked 180° out of phase. Each block began with the cover lowered and participants placed either the right ($N = 67$) or the left ($N = 64$) hand into a hole cut into the front of the box. Another hole was cut on top of the box, through which the participant could see the rubber hand; and most of the back of the box was removed, so that the experimenter was able to brush the hands. Each box was 36.5 cm wide, 19 cm high, and 29 cm deep. The inside of the box was lined with grey felt, and a small Velcro disk indicated where the tip of the participant's index finger should be placed. A black cover (59.5 cm by 29 cm) was connected to the box by two hinges. When the cover was open, the rubber hand could be seen by the participant, but the experimenter was hidden from view; when it was closed, the opposite was true. The cover was raised and a 60-s induction phase began, in which both the rubber hand and the participant's hand were brushed with two identical paintbrushes (Winsor & Newton, London). Brush strokes were made at ~1 Hz. The rubber hands were life sized prosthetic hands, one of a right hand, the other of a left hand.

After induction, participants removed their hand from the box and the questionnaire was given. Participants indicated their agreement or disagreement with 27 statements in each block, using a 7-item Likert scale. A response of +3 indicated that they "strongly agreed" with the statement, −3 indicated that they "strongly disagreed", and 0 indicated that they "neither agreed nor disagreed", though any intermediate value could be used. Before the questionnaire in the first block, the scale was explained to the participant. A sheet of paper showing the scale and the seven possible responses was placed on the box in front of the participant throughout the questionnaire. The first two items presented were always items (20 and 21) relating to the experience being interesting and enjoyable; the order of subsequent items was randomized separately for each participant in each condition.

PCA with orthogonal varimax rotation was used to investigate the structure underlying the experience of the RHI (for details, see Longo et al., 2008b). Separate PCAs were conducted for the synchronous and asynchronous conditions. As described in the introduction, four components were extracted in the synchronous condition: *embodiment of rubber hand*, *loss of own hand*, *movement*, and *affect*. The same four components were observed in the asynchronous condition, plus a fifth component, *deafference*. Detailed methods for the collection of the subjective reports and for extraction of components from the PCAs are described in our previous paper (Longo et al., 2008b).

Following the questionnaires, participants were asked to rate the similarity of the rubber hand and their own hand, using the same Likert scale used for the RHI questionnaire. Finally, a photograph of each participant's hand (resting dorsum-up on a sheet of white paper) was taken with a digital camera. One participant preferred not to have her hand photographed, and so was not included in the analyses involving photographs.

2.3. Third-person similarity ratings

The images of participants' hands were cropped so that the hands took up most of the frame. Raters were instructed to rate how similar each hand was to the corresponding rubber hand using the same −3 to +3 scale used for first-person ratings. No specific instructions were given regarding which aspects of hand appearance were relevant, except that ratings should be made on the similarity of the intrinsic characteristics of the hands, not on their posture or position. Images were presented to raters on a computer monitor, displayed by a MATLAB script (MathWorks, Natick, MA). On each trial, the image of the appropriate (i.e., right or left) rubber hand was first presented for 2000 ms, followed by a blank screen for 500 ms, and then the image of the to-be-judged hand was displayed until the rater responded. Responses were untimed, and made by pressing one of a set of keys on a keyboard labelled from −3 to +3. The order of images was randomized.

2.4. Skin complexion

Skin complexion was quantified by calculating the mean luminance of a large selection of the dorsum of the hand using ImageJ software (US National Institutes of Health, Bethesda, MD; Abramoff, Magelhaes, & Ram, 2004). In order to adjust for potential differences in luminance between testing sessions, the luminance of a large selection of the white sheet of paper was calculated as well, and the ratio of skin to paper luminance was used. These ratios were strongly correlated with uncorrected luminance measured from the hand alone, $r(129) = .803$, $p < .0001$, and so the Z-transformed ratios were used for subsequent analyses.

2.5. Shape index

To compute a measure of overall hand shape from photographs, we used a modified version of the *shape index* developed by Napier (1980). This index reflects the ratio of hand width to hand length. Napier computed maximum hand width on the palmar surface, and the distance between the wrist and the tip of the middle finger. Here, as these values had to be coded from photographs, we used the distance between the knuckles of the index and little fingers as our measure of hand width and length of the middle finger (from centre of fingertip to knuckle on the hand dorsum) as our measure of hand length. Following Napier, we computed the shape index as 100 times the ratio of width to length. This produces a shape index that is conceptually similar to Napier's, though the two indices are not directly comparable numerically. A smaller shape index indicates a more slender hand, and a larger value indicates a fatter hand. The mean shape index for participants in study 1 was 61.16 (SD = 4.86, range: 49.85–75.64), and in study 2 was 62.22 (SD = 3.86; range: 51.12–69.26). The shape index for the rubber hands was 69.23, near the extreme end in terms of fatness. Thus, larger shape indices indicate increasing objective similarity in shape to the rubber hand.

3. Results

3.1. Relations between measures of similarity

Interestingly, first- and third-person similarity ratings were uncorrelated across all participants, $r(154) = .045$, as well as for the subsets of participants who had experienced the RHI (study 1), $r(129) = .057$, and those who had not (study 2), $r(24) = -.047$. Fig. 1 shows scatterplots of the relations between first-person similarity, third-person similarity, and skin complexion for participants in study 1.

Multiple-linear regression was used to investigate the relation between hand complexion and shape and similarity ratings by including complexion and shape index scores as simultaneous regressors of judged similarity. While there was a significant (though modest) correlation between complexion and size index, $r(154) = .257$, $p < .005$, including both variables as regressors isolates the independent effect of each. For third-person similarity ratings in study 3, both complexion, $\beta = 5.132$, $t(152) = 9.42$, $p < .0001$, and size index, $\beta = .044$, $t(152) = 2.86$, $p < .005$, were significant independent predictors. The lighter a participant's skin and

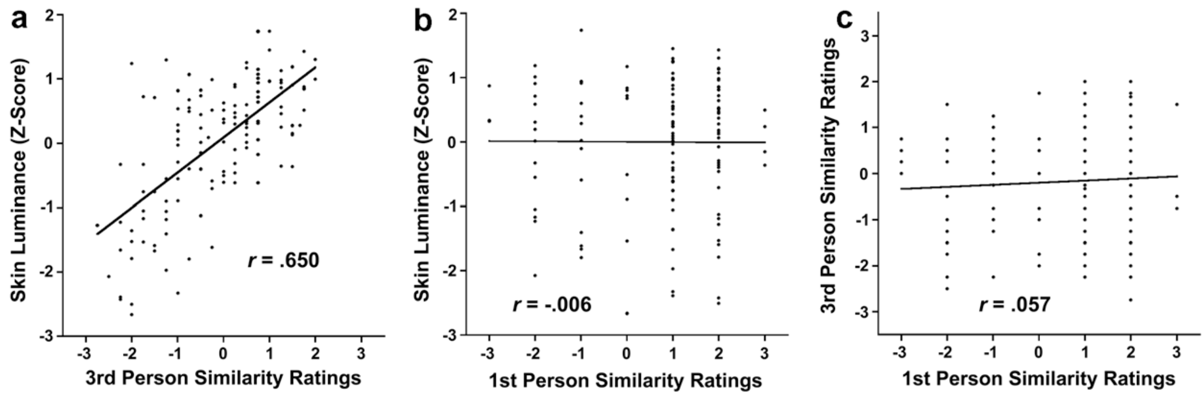

Fig. 1. Scatterplots showing relations between (a) third-person similarity ratings and skin luminance, (b) first-person similarity ratings and skin luminance, and (c) first- and third-person similarity ratings.

the fatter their hand, the more similar their hand was judged by other people to be similar to the (fat white) rubber hand. This demonstrates, unsurprisingly, that skin colour and hand shape are salient features of perceived similarity.

First-person similarity judgments of participants in study 1, who had experienced the RHI, were predicted neither by complexion, $\beta = -.052$, $t(127) = -.05$, nor by size index, $\beta = -.001$, $t(127) = -.05$. However, for participants who had not experienced the RHI (study 2), size index was a significant predictor of first-person similarity ratings, $\beta = .203$, $t(22) = 2.62$, $p < .02$, though complexion remained non-significant, $\beta = -5.41$, $t(22) = -1.53$, $p > .10$.

3.2. Effects of similarity on the experience of embodiment

To examine how similarity judged by a third person might relate to the participants' first-person experience of the RHI, we ran multiple-linear regressions on third-person similarity judgments and on skin complexion with RHI component scores (Longo et al., 2008b) as predictor variables. Separate regressions were conducted on overall effects across conditions (i.e., the average of component scores in the synchronous and asynchronous conditions), and on the specific effect of multisensory synchrony (i.e., the residuals remaining after regressing scores in the synchronous condition on those in the asynchronous condition). These residuals were used in favour of the difference between the conditions as they more effectively isolate the *variance* attributable to the synchronous condition. Nonetheless, there was a strong correlation between the two measures: $r = .913$, .850, .878, and .905, for the *embodiment*, *loss of own hand*, *movement*, and *affect* components, and $r = .814$, .864, and .870 for the *ownership*, *location*, and *agency* components.

Neither skin complexion (see Table 1), shape index (see Table 2), nor third-person similarity (see Table 3) were significant positive predictors of *embodiment*.[1] Complexion was, however, a significant positive predictor of *affect* across conditions, suggesting that similarity may influence the affective dimension of touch (cf. Essick, James, & McGlone, 1999). A similar trend was observed for the relation between third-person similarity judgments and the *affect* component. There were also two components in the primary PCA (*loss of own hand*, and *movement*) and one in the secondary PCA (*location*), which were *negatively* related to complexion and to third-person similarity across conditions. The *location* component, furthermore, was also negatively predicted by hand shape. It is not clear why such negative relations should occur. In the case of the *loss of own hand* component, a similar rubber hand may be *mistaken* for one's own hand, while a dissimilar rubber hand may *displace* one's own hand in the body image. One would experience the loss of one's own hand only in the latter situation. Nevertheless, these results clearly demonstrate that similarity between a participant's hand and the rubber hand is not a necessary condition for the incorporation of the rubber hand into the body image, consistent with the findings of Holmes et al. (2006).

Table 1
Relation between components of RHI and skin complexion (luminance).

Primary components	Synchronous + asynchronous			Residuals		
	β	t(125)	p	β	t(125)	p
Embodiment	−.011	−1.64	>.10	−.007	−.99	>.10
Loss of Own Hand	**−.016**	**−2.14**	**<.05**	−.013	−1.64	>.10
Movement	**−.017**	**−2.10**	**<.05**	−.013	−1.62	>.10
Affect	**.026**	**2.76**	**<.01**	.005	.43	>.10
Secondary Components	β	t(126)	p	β	t(126)	p
Ownership	.009	1.23	>.10	.002	.38	>.10
Location	**−.031**	**−4.64**	**<.0001**	**−.018**	**−2.68**	**<.01**
Agency	−.012	−1.63	>.10	−.004	−.73	>.10

Table 2
Relation between components of RHI and shape index of hand.

Primary components	Synchronous + asynchronous			Residuals		
	β	t(125)	p	β	t(125)	p
Embodiment	−.159	−.65	>.10	−.265	−1.00	>.10
Loss of own hand	−.153	−.55	>.10	−.155	−.57	>.10
Movement	−.001	−.00	>.10	.077	.28	>.10
Affect	.303	.85	>.10	−.616	−1.47	>.10
Secondary components	β	t(126)	p	β	t(126)	p
Ownership	.260	.94	>.10	−.115	−.51	>.10
Location	**−.524**	**−2.01**	**<.05**	−.057	−.24	>.10
Agency	−.170	−.58	>.10	−.140	−.64	>.10

Table 3
Relation between components of RHI and third-person similarity judgments.

Primary components	Synchronous + asynchronous			Residuals		
	β	t(125)	p	β	t(125)	p
Embodiment	−.011	−.19	>.10	−.044	−.68	>.10
Loss of own hand	**−.177**	**−2.75**	**<.01**	−.061	−.92	>.10
Movement	**−.160**	**−2.26**	**<.05**	−.028	−.42	>.10
Affect	.142	1.72	.08	.026	.25	>.10
Secondary components	β	t(126)	p	β	t(126)	p
Ownership	.057	.93	>.10	.014	.26	>.10
Location	**−.245**	**−4.19**	**<.0001**	−.071	−1.23	>.10
Agency	.057	.87	>.10	.008	.15	>.10

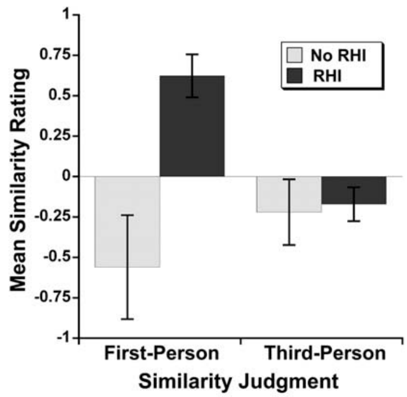

Fig. 2. Mean similarity judgments between participants' hands and the rubber hand as a function of whether they had experienced the rubber hand illusion, as judged by participants themselves (first-person), or by a separate sample of raters (third-person). Error bars reflect one SEM.

Table 4
Relation between components of RHI and first-person similarity judgments.

Primary components	Synchronous + asynchronous			Residuals		
	β	$t(126)$	p	β	$t(126)$	p
Embodiment	**.238**	**3.30**	**<.005**	.060	.73	>.10
Loss of own hand	**.173**	**2.13**	**<.05**	.115	1.36	>.10
Movement	.135	1.51	>.10	.082	.96	>.10
Affect	.187	1.81	.07	.022	.17	>.10
Secondary components	β	$t(127)$	p	β	$t(127)$	p
Ownership	**.215**	**2.71**	**<.01**	.090	1.28	>.10
Location	.081	1.07	>.10	.051	.70	>.10
Agency	**.192**	**2.27**	**<.05**	**.134**	**1.98**	**<.05**

We also investigated the relation between similarity and proprioceptive biases induced by the RHI. There were no significant relations between either complexion, shape index, or third-person similarity ratings and the average proprioceptive bias across conditions, $r(119) = .11, -.04, .07$, p's > .20, nor the difference in bias between conditions, $r(119) = .00, .01, .01$, p's > .20.

3.3. Effects of embodiment on the perception of similarity

Participants in study 2, who had not experienced the RHI, showed a trend to perceive their hand as dissimilar to the rubber hand, $t(24) = -1.74$, $p = .09$ (see Fig. 2). In contrast, participants in study 1 who had experienced the illusion reported significant positive similarity, $t(129) = 4.69$, $p < .0001$. A between-study comparison showed that first-person experience of the RHI leads to a strong increase in the perceived similarity between their hand and the rubber hand, $t(153) = 3.40$, $p < .001$. Interestingly, mean ratings of the third-person raters from study 3 did not differ significantly between these two groups, $t(153) = .22$ (see Fig. 2), suggesting that there were no intrinsic differences in the similarity of the two groups to the rubber hand. These results demonstrate that the first-person experience of embodiment significantly increased the perceived similarity participants felt between their own hand and the rubber hand.

Does this increased similarity reflect a change in their perception of their own hand, or of the rubber hand? A common finding among numerous studies of the RHI is that participants show more agreement with statements relating to the perception of the rubber hand becoming more like one's own hand, rather than the converse (e.g., Botvinick & Cohen, 1998; Longo et al., 2008b; Peled, Ritsner, Hirschmann, Geva, & Modai, 2000). This was true as well in the present data set. For example, the questionnaire item "it seemed like the rubber hand began to resemble my real hand" loaded on the *embodiment* component (Longo et al., 2008b) and participants showed significant agreement with it following synchronous stroking, mean Likert score: .53, $t(130) = 3.16$, $p < .005$, but not following asynchronous stroking, mean Likert score: $-.53$, $t(130) = -2.98$, $p < .005$. In contrast, the item "it seemed like my own hand became rubbery" did not load on any component at all (Longo et al., 2008b), and did not elicit agreement following synchronous stroking, mean Likert score: $-.50$, $t(130) = -2.90$, $p < .005$, or asynchronous stroking, mean Likert score: $-.847$, $t(130) = -5.27$, $p < .0001$. Thus, it seems likely that the increased similarity is related to changed perceptions of the rubber hand, rather than one's own hand. To examine this issue, we used multiple-linear regression to investigate the relation between participants' responses to these two questionnaire items and the similarity they perceived between their own hand and the rubber hand. Separate regressions were run on responses in the synchronous and asynchronous conditions. The item concerning the rubber hand beginning to resemble one's own hand was a significant predictor of perceived similarity both following synchronous, $\beta = .20$, $t(128) = 2.55$, $p < .02$, and asynchronous stroking, $\beta = .18$, $t(128) = 2.45$, $p < .02$. In contrast, the item relating to one's own hand becoming rubbery was not a significant predictor of perceived similarity in either condition, $\beta = .10, .05$, $t(128) = 1.37, .61$, p's > .20, respectively. This pattern confirms that the increase in similarity participants perceived reflects a change in their perception of the rubber hand, rather than their own hand.

The effects of each component of the RHI on perceived similarity were investigated with multiple-linear regression. As above, separate regressions were conducted on overall effects across conditions (synchronous + asynchronous), and on the specific effects of multisensory synchrony (residuals remaining after regressing synchronous scores on asynchronous scores). Results are shown in Table 4. The *embodiment* and *loss of own hand* components in the primary PCA, and *ownership* and *agency* in the secondary PCA, were significant predictors of perceived similarity across conditions. The specific effect of multisensory synchrony was a significant positive predictor of the sense of agency, but not of any other effects.

First-person similarity was not significantly correlated with proprioceptive biases, either across, $r(119) = .08$, $p > .20$, or between, $r(119) = -.12$, $p > .20$, conditions.

4. Discussion

Similarity does not appear to affect the rubber hand illusion; the rubber hand illusion, however, does affect perceived similarity. The experience of incorporating a rubber hand into the body image altered the perception of the relation between oneself and the rubber hand. Participants who had experienced the RHI reported significantly greater similarity between their own hand and the rubber hand than participants who had not experienced the RHI. This increase, furthermore, was related to specific aspects of the experience of the illusion, i.e., the feelings of ownership and agency over the rubber hand, and the feeling that one's own hand had disappeared (the *ownership*, *agency*, and *loss of own hand* components), but was unrelated to other aspects of the experience (i.e., the *movement*, *affect*, and *location* components). The influence of the RHI on perceived similarity was limited to the subjective experience of the illusion, and was not related to proprioceptive biases induced by the illusion. This suggests that similarity is related more to body imagistic than body schematic components of the RHI, by *what* the body is, not *where* the body is. Thus, not only do the present results show that the body image has functional effects on perception, they isolate this effect to specific components of body representation. Conversely, with the possible exception of affective experience, the pre-existing similarity between participants' hands and the rubber hand, as measured by skin luminance, shape indices, and third-person ratings, had no major influence on the RHI.

These results have important implications for our understanding of the body image. First, these results demonstrate that embodiment is not a fleeting experience, but has functional consequences for perception. Even after the initial experiences of multisensory stimulation and of embodiment of the rubber hand have gone, measurable effects remain on our representation of the relation between our body and the world. This provides a first clue about how current sensory experience may be continuously integrated to produce an enduring, diachronic body image and sense of self, and of our relation to others. Previous results suggested that a level of morphological similarity was necessary for embodiment to occur (e.g., Holmes et al., 2006; Tsakiris & Haggard, 2005). Our result now also shows that the relation is reciprocal; embodiment increases perceived similarity. This dovetails with a recent finding that shared multisensory experiences in the form of assimilating someone else's face alters self-face recognition (Tsakiris, 2008).

Most of these effects of the experience of embodiment on the perception of similarity were related to the overall amount of embodiment across synchronous and asynchronous stroking conditions, rather than specific to the synchronous condition. While it is tempting to consider the asynchronous stroking condition to be merely a no-illusion control condition, this result suggests, in contrast, that it produces a complex experience in its own right, with meaningful variation across participants. This fits with the finding from our initial study (Longo et al., 2008b) that structure (specifically the *deafference* component) appears only in the asynchronous condition. The sense of agency, however, was significantly related to perceived similarity both across conditions, but also when variance specific to the synchronous condition was investigated. This result shows both that there are qualitative, as well as quantitative, differences between the synchronous and asynchronous conditions (cf. Longo et al., 2008b), and further suggests important functional differences between the sense of agency and other components of embodiment, such as the experience of ownership (cf. Longo & Haggard, 2009; Tsakiris, Prabhu, & Haggard, 2006).

How might the experience of embodiment affect perceived similarity? Several studies have demonstrated that categorization and top-down effects of visual imagery modulate visual perception. In addition to the well-known categorical perception effects in colour perception (e.g., Kay & Kempton, 1984), studies have shown that categorizing an object leads to perceptual changes such that the object takes on properties characteristic of the category (Goldstone, 1995; Hansen, Olkkonen, Walter, & Gegenfurtner, 2006). Hansen et al. (2006), for example, found that the point at which participants judged a picture of a banana (which is prototypically yellow) to be achromatic was slightly blue (the opponent colour of a prototypical banana). An analogous effect could occur in the context of the RHI, such that the illusion of embodiment over the rubber hand could lead to genuine changes in the perception of the rubber hand, such that it would adopt features known to characterize the participant's own hand. We suggest that this may occur specifically for the perceived shape of the rubber hand, given that shape – but not colour – appeared to underlie first-person similarity judgments for participants who had not experienced the RHI. This interpretation can account for the finding that participants who had experienced the RHI did not appear to base their similarity judgments on the actual shape of the rubber hand, since these participants would have been *misperceiving* the actual shape.

In contrast to the effects of embodiment on similarity, similarity in terms of skin complexion, overall shape, or as rated by other participants was generally unrelated to the first-person experience of embodiment. That a rubber hand has the shape of a hand appears to be a necessary condition for eliciting the experience of embodiment (Holmes et al., 2006; Tsakiris & Haggard, 2005; Tsakiris et al., 2008). Given that it is shaped like a hand, however, it need not be at all similar in its specific characteristics to the participant's hand. This suggests that the body image filter applied is a person-independent, *generic body image*, representing hands generally, rather than a *self-specific body image*, representing my hand specifically (cf. Longo, Cardozo, & Haggard, 2008a). The representation of bodies generally may be crucial for the creation of the image of what my body, specifically, is like (cf. the 'looking glass self', Cooley, 1902). This is consistent with the proposal of Brugger et al. (2000) that experience of phantom limbs in congenital limb absence may result from the constant perception of others with intact limbs.

Our results, furthermore, shed light on the direction of change in embodiment. Interactions between the body and the external world can occur in two directions: outwards from the body to the world (*egofugal*), or inwards from the world to the body (*egopetal*). Previous studies of multisensory embodiment have focussed on the egofugal extension of the body into the outside world, as in studies of tool-use (e.g., Iriki, Tanaka, & Iwamura, 1996). While these positions are often difficult to distinguish experimentally, the present data suggest that the RHI may reflect an egopetal, rather than an egofugal, process. Specifically, participants' similarity ratings were correlated with the subjective experience that the rubber hand was becoming more like their own hand, but not with the converse. This finding is consistent with several pieces of evidence from our previous study (Longo et al., 2008b). First, following synchronous stroking, participants report the subjective experience that the rubber hand was becoming like their own hand, but not *vice versa*. Second, only the item reflecting perceived changes in the rubber hand loaded on a component (*ownership*) in our PCA, suggesting that the other item reflecting perceived changes in the participant's own hand was not an important aspect of any of the components of the experience of the illusion. Third, the *loss of own hand* component was significantly stronger following synchronous than asynchronous stroking, suggesting that the rubber hand had, at least in part, displaced the participant's own hand. Thus, the first-person experience of embodiment appears to lead to incorporation of external objects by assimilating them into a pre-existing body image, rather than by extending the self outwards to include the external object, as if it were a supernumerary limb (cf. McGonigle et al., 2002).

Lastly, these results have potential implications for the role of the body image in interpersonal relations. The lack of relation between first- and third-person similarity judgments is striking, as is the fact that first-person similarity judgments were completely independent of skin complexion. Furthermore, while participants in study 2 who had not experienced the RHI used hand shape as a cue to similarity, there was no evidence for this in participants in study 1 who had experienced the illusion. These findings suggest that the first-person experience of embodiment may alter our perception of the relation between our body and the external world.

Mitchell, Banaji, and Macrae (2005) had participants rate the similarity of their own face with photographs of a number of other faces. Their participants did not rate same-sex faces as any more similar to their own face than other-sex faces. That complexion was not used in our first-person similarity judgments, however, is more striking, given that other studies have found that sex and age did not affect third-person similarity judgments (e.g., Maloney & Dal Martello, 2006). Such effects have been interpreted as evidence that third-person similarity ratings are implicit proxies for perceived genetic relatedness, which is of course independent of sex and age. Complexion, however, *is* a cue to genetic relatedness, suggesting a qualitative difference between first- and third-person judgments. It is important to note, however, that interpreting such differences is not unproblematic, given that first-person judgments were only made of oneself, whereas third-person judgments were made of a large set of individuals. This raises the possibility of a range restriction problem for first-person judgments, which could have been less precise as a result. Mitigating this concern, however, is the fact that we find an apparent double-dissociation between first- and third-person similarity judgments, which would not be predicted if one measure was simply more precise. That is, first-person judgments systematically related to the experience of embodiment, but not skin complexion, while third-person judgments systematically related to skin complexion, but not the experience of embodiment.

Skin complexion is a purely superficial feature of the body. Our results suggest that people may rely on such superficial features when making third-person judgements, but are effectively blind to them when judging first-person experience. An interesting challenge for social psychology would involve investigating conditions that allow the surface-blindness of embodied first-person judgements to affect third-person judgements also. Our data suggest that superficial features such as skin complexion are relevant to third-person judgments, but not to judgements based on embodied experience. We therefore suggest that activities in which several individuals share embodied experience may enhance social cohesion. This point has long been recognized in anthropology (Mead, 1928). Individuals, even those who are physically dissimilar, might *feel* themselves to be quite similar if they have shared embodied multisensory experience linking their two bodies. For example, reciprocal action observation, joint action (e.g., Sebanz, Knoblich, & Prinz, 2003), and automatic imitation (e.g., Bertenthal, Longo, & Kosobud, 2006; Chartrand & Bargh, 1999) all provide correlated multisensory inputs across individuals that are broadly comparable with the inputs eliciting the RHI. Under such situations, the generic morphological body image, which all humans essentially share, essentially from birth (cf. Meltzoff & Moore, 1977), may emphasise the broad similarities between individuals' bodies, rather than superficial differences.

Acknowledgment

This research was supported by Biotechnology and Biological Sciences Research Council (BBSRC) grant BB/D009529/1 to Patrick Haggard.

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