


## Cognitive Psychology

# What Do Participants Expect to Experience in the Rubber Hand Illusion? A Conceptual Replication of Lush (2020)

Arran T. Reader<sup>1</sup> 

<sup>1</sup> Department of Psychology, Faculty of Natural Sciences, University of Stirling, Stirling, UK

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The sense of body ownership (the feeling that the body belongs to the self) is commonly believed to arise through multisensory integration. This is famously shown in the rubber hand illusion (RHI), where touches applied synchronously to a fake hand and to the participant's real hand (which is hidden from view) can induce a sensation of ownership over the fake one. Asynchronous touches weaken or abolish the illusion, and are typically used as a control condition. Subjective experience during the illusion is measured using a questionnaire, with some statements designed to capture illusory sensation and others designed as controls. However, recent work by Lush (2020, *Collabra: Psychology*) claimed that participants may have different expectations for questionnaire items in the synchronous condition compared to the asynchronous condition, and for the illusion-related items compared to the control items. This may mean that the classic RHI questionnaire is poorly controlled for demand characteristics. In the current work a conceptual replication of Lush (2020) was performed. Participants were presented with a video of the RHI procedure and reported the sensations they would expect to experience, both in free response and by rating questionnaire items. Participants had greater expectations for illusion statements in the synchronous condition compared to the asynchronous condition, and for illusion statements compared to control statements. However, free responses suggested that such expectations may be at least partially driven by exposure to the questionnaire items. Further work is necessary to understand whether similar expectations exist for the true RHI procedure, what might drive them, and whether they have an impact on reported RHI experience.

## Introduction

The sense of body ownership refers to the feeling that a given body is our own. This sensation is believed to stem primarily from multisensory integration, whereby different sources of sensory information (e.g., vision, touch, proprioception) are combined to generate the feeling that our body is something distinct from the surrounding environment and associated with the self (Ehrsson, 2020; Kilteni et al., 2015; Tsakiris, 2010). The rubber hand illusion (RHI) is one of the most commonly used paradigms to examine the sense of body ownership (Botvinick & Cohen, 1998), highlighting how it can be altered through the manipulation of multisensory stimulation.

In the classic RHI, touches applied to a fake hand in temporal and spatial synchrony with the real hand (hidden from view) can induce the feeling that the fake hand is part of one's body. Participants can also experience the sensation that the felt touches arise from the fake hand (referral of touch), as well as proprioceptive sensations arising

from the fake (Longo et al., 2008). Temporally asynchronous touches considerably weaken or abolish the illusion, and so are typically used as a control condition. Converging research from a wide range of behavioural, neuroimaging, clinical, and animal studies suggest that the RHI is a perceptual illusion, likely arising through the same top-down and bottom-up processes involved in multisensory integration which mediate the sense of ownership over the real body (e.g., Bekrater-Bodmann et al., 2012; Brozzoli et al., 2012; Chancel, Ehrsson, et al., 2021; Chancel & Ehrsson, 2020; Costantini et al., 2016; Costantini & Haggard, 2007; Crucianelli et al., 2019; Ehrsson et al., 2004, 2008, 2022; Fahy et al., 2018; Fang et al., 2019; Graziano, 2000; Guterstam et al., 2019; Kilteni & Ehrsson, 2017; Limanowski & Blankenburg, 2015; Lloyd, 2007; Petkova & Ehrsson, 2009; Preston, 2013; Pyasik et al., 2019, 2021; Samad et al., 2015; Shimada et al., 2009, 2014; Tidoni et al., 2014; Tsakiris et al., 2007, 2010; Tsakiris & Haggard, 2005; Ward et al., 2015; Zeller et al., 2011; Zopf et al., 2011, 2013, see Ehrsson, 2020 for review).

a Correspondence: [arran.reader@stir.ac.uk](mailto:arran.reader@stir.ac.uk)

There are three common approaches to measuring the magnitude of the RHI (in addition to, more recently, psychophysical forced-choice procedures, Chancel, Ehrsson, et al., 2021; Chancel, Hasenack, et al., 2021; Chancel & Ehrsson, 2020). Measures commonly referred to as ‘implicit’ aim to evaluate responses to the illusion by recording skin conductance (in response to a threat towards the fake hand) (e.g., Petkova & Ehrsson, 2009) or proprioceptive drift (to see if the perceived position of the real hand is shifted towards the fake one) (e.g., Abdulkarim et al., 2021; Abdulkarim & Ehrsson, 2016; Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005). These measures are usually used to complement questionnaires which assess subjective experience. In these questionnaires participants are asked to provide their level of agreement to statements regarding the feeling of ownership over the fake limb and referral of touch (Botvinick & Cohen, 1998; Longo et al., 2008).

Agreement to these statements in the synchronous condition tends to be positive, which is taken to indicate the presence of the illusion. As an experimental control, researchers may record participant agreement to such illusion statements in the asynchronous condition, where touches applied to the hands are temporally incongruent, and visual and tactile signals cannot be integrated. In this condition, even though the location and frequency of tactile stimulation of the real hand and visual stimulation of the fake hand is the same as in the synchronous condition, the temporal mismatch results in disagreement with illusion statements (Ehrsson, 2020). The asynchronous control condition may also be combined with other control conditions in a factorial design by, for example, introducing spatial incongruence in tactile stimulation, or by changing the position of the fake hand to introduce visuoproprioceptive as well as visuotactile mismatch (e.g., Ehrsson et al., 2004; Holle et al., 2011; Kalckert & Ehrsson, 2014; Preston, 2013). By combining such factorial designs with an implicit measure (such as proprioceptive drift) researchers aim to probe the prevalence of condition-specific effects on both subjective experience and low-level sensory processes related to bodily self-perception (in the case of proprioceptive drift, this would be the localisation of one’s own upper limb in space).

As a further control for the assessment of subjective experience, experimenters may also record agreement to ‘control’ questionnaire items that capture sensations one does not expect participants to experience (e.g., ‘It seemed as if I might have more than one right hand or arm’). The difference in responses to the illusion and control statements is usually proposed to capture unspecific effects and address the influence of demand characteristics on compliance (providing responses that the participant believes the experimenter is looking for) or suggestibility (e.g., confabulation or mental imagery). However, empirical evidence in favour of this approach is limited (Riemer et al., 2019) meaning it remains unclear how effectively control statements can prevent the impact of demand characteristics on experiment results.

Whilst the RHI is commonly performed in the aforementioned fashion to examine the sense of body ownership and related phenomena, several studies have critically examined the paradigm. For example, researchers have studied the phrasing used in RHI questionnaires (Tamè et al., 2018),

the relationship between different sensations elicited by the illusion (e.g., Kalckert et al., 2019; Reader et al., 2021), and the roles of individual differences and suggestibility in influencing participant responses (e.g., Germine et al., 2013; Lush et al., 2020; Marotta et al., 2016; Perepelkina et al., 2017; Romano et al., 2021; Tsakiris et al., 2011; Walsh et al., 2015). Notably, researchers studying suggestibility have proposed a potential limitation of the RHI: that demand characteristics are not well matched across control and experimental conditions, meaning that participants may have different levels of expectation for certain experiences.

Specifically, Lush (2020) examined the degree to which participants might expect to experience the phenomena described in the classic RHI questionnaire (Botvinick & Cohen, 1998) without actually taking part in the experiment. Participants were presented with verbal descriptions of the synchronous and asynchronous conditions, as well as videos displaying the induction procedure, and asked to report the degree to which they would expect to experience each of the questionnaire statements. Lush observed that participants had stronger expectations for referral of touch and feelings of ownership over the fake hand in the synchronous condition compared to the asynchronous condition. They also observed that expectations were greater for illusion statements than control statements in the synchronous condition.

If participants do have differing expectations across statement types or conditions, as proposed by Lush (2020), this may influence the interpretation of questionnaire results in RHI experiments: such expectations might play a role in driving participant responses in addition to (or instead of) multisensory perception. This could occur either through compliance or suggestibility (Lush et al., 2020). Whilst a reanalysis by Ehrsson et al. (2022) of suggestibility data (Lush et al., 2020) shows that suggestibility can predict responses to both experimental and control conditions in the RHI, the fact that expectations may be unmatched across conditions could still pose a problem for interpreting questionnaire responses. Indeed, it is known that not every participant reports experiencing the illusion (Reader et al., 2021). If participant expectations for the illusion are in keeping with responses that are taken to indicate the presence of the illusion, then compliant or suggestible participants could respond in a complementary fashion even if they do not develop an experience of the fake hand being their own through the putative multisensory integration mechanism of body ownership.

However, there are several methodological factors that might better explain the results reported by Lush (2020). Firstly, they recruited a limited sample of procedure-naïve participants. Whilst these participants did show a similar pattern of results, the strongest evidence comes from those who had already heard of the illusion. These participants might have stronger expectations about what they would experience during the illusion. Secondly, participants were informed that the purpose of the RHI is to “generate changes in experience”, which might have biased individuals who would have otherwise disagreed that they would experience certain phenomena. Thirdly, the synchronous and asynchronous conditions were named and clearly defined to participants. Participants in RHI experiments are

**Table 1. RHI questionnaire items**

Item	Statement
<b>S1</b>	<b>It seemed as if I were feeling the touch of the paintbrush in the location where I saw the rubber hand touched</b>
<b>S2</b>	<b>It seemed as though the touch I felt was caused by the paintbrush touching the rubber hand</b>
<b>S3</b>	<b>I felt as if the rubber hand were my hand</b>
S4	It felt as if my (real) hand were drifting towards the left (towards the rubber hand)
S5	It seemed as if I might have more than one right hand or arm
S6	It seemed as if the touch I was feeling came from somewhere between my own hand and the rubber hand
S7	It felt as if my (real) hand were turning 'rubbery'
S8	It appeared (visually) as if the rubber hand were drifting towards the right (towards my hand)
S9	The rubber hand began to resemble my own (real) hand, in terms of shape, skin tone, freckles or some other visual feature

Illusion statements are in bold.

not usually informed about the nature of the different conditions. Fourthly, both synchronous and asynchronous conditions were presented together in the same video, and participants were asked to provide their expected responses to both conditions in tandem, which could promote comparisons between the two conditions rather than considering each condition separately. Finally, experimental conditions and questionnaire statements were presented in a fixed order, with illusion-related items appearing first, which might also have biased participant responses.

Whilst the issue of naïve participant sample size was addressed in a recent replication (Lush et al., 2021), the experimenters still alerted participants to “changes in experience” and the names of the conditions, as well as presenting both conditions in the same video and presenting questionnaire items in a fixed order. To address these concerns, a conceptual replication of Lush (2020) was performed. Two hypotheses were tested: that participants have greater expectations for illusion statements in the synchronous condition compared to the asynchronous condition, and that participants have stronger expectations for the illusion statements than the control statements in the synchronous condition. Participants were also provided an opportunity to freely state what they might expect to experience in the RHI prior to exposure to the questionnaire statements. This was done to provide a more detailed examination of participant expectations based only on exposure to information about the RHI procedure, rather than potentially biased, reflective consideration following questionnaire exposure.

## Method

### Participants

160 participants were recruited from the University of Stirling as an opportunity sample for a student research project. All participants were studying psychology modules and participated in exchange for research tokens that contribute to module completion. 130 participants aged between 18 and 38 years fully completed the experiment (106 women, 21 men, 3 non-binary individuals, mean±SD age = 20.4±3.07 years), of which 58 were retained for analysis following exclusions (see below). The final sample included 51 women and 7 men, mean age = 20.8±3.21 years, range

= 18–38 years. Participants provided informed consent, and ethical approval for this experiment was granted by the University of Stirling Division of Psychology's delegated authority for the General University Ethics Panel (review reference: GUEP 2021 1701 1408).

### Materials and stimuli

Data were collected using Qualtrics web software (Qualtrics, Provo, UT). Experiment text and stimuli were adapted from Lush (2020) (<https://osf.io/9c8mq/>). A summary of the instructions given to participants is presented in the procedure below, and full details are provided as supplemental material.

Two videos were used to present participants with the synchronous and asynchronous conditions of the RHI, both from the experimenter's and participant's perspective. To generate these videos the video originally used by Lush (2020) was split into two. In each video subtitles state that “The participant is positioned so that they can see the fake hand but cannot see their own hand”, and “The fake and real hands are stroked with brushes. The participant can only see the brush stroking the fake hand.” However, in contrast to the video used by Lush (2020), the subtitles describing the synchronicity of the touches in the two conditions were cropped out. The synchronous video was 42 seconds in duration, whilst the asynchronous video was 45 seconds in duration. In the asynchronous condition the touch applied to the fake hand began approximately one second after the touch applied to the real hand. Video stimuli can be accessed at <https://doi.org/10.17605/OSF.IO/3T9QK>.

To assess participant expectations of illusion-related experience, an adaptation of the RHI questionnaire by Botvinick and Cohen (1998) (Table 1) was used, for which participants could provide a rating of how much they would expect to experience the control and illusion statements on a 7-point scale from -3 (“I am certain I won't feel any effect”) to +3 (“I am certain I will feel some effect”). A foil statement was added to ensure participants were not responding randomly (“If you are paying attention, please select '0'”).

## Procedure

Participants completed the experiment on their personal computers at a place and time of their choosing. After providing consent and demographic information, they then took part in two conditions examining their expectations about synchronous and asynchronous stroking of the real and fake hands during the RHI procedure. The order of presentation was counterbalanced across participants. Participants were first provided with the following passage (which unfortunately included the missing apostrophes):

*You will shortly be shown some videos of a procedure used in psychological experiments. In this procedure, a participant's own right hand is hidden from their view and a fake, rubber hand is placed in front of them. An experimenter then uses brushes to stroke the participants hidden real hand and the visible fake hand. The location of the brush strokes on the real and fake hands is matched, so that a downward brush stroke on the participants index finger will be accompanied by a downward brush stroke on the fake hand. Participants can therefore see a paintbrush brushing down the finger on a fake hand while they feel a paintbrush brushing down the finger on their real hand (which they cannot see). After you have watched each video you will be asked to answer a short questionnaire about the procedure described here and shown in the video.*

Participants were then presented with the video of the synchronous or asynchronous RHI procedure, and asked to watch the video in full. The time each participant spent on the webpage with the video was recorded to ensure engagement. After watching the video participants were presented with the following passage and space to freely respond:

*In the video, an experimenter performed brush strokes on the participant's right hand and a fake (rubber) hand in matching locations (the index fingers) on each hand. The participant could see the fake hand but could not see their real hand. If you were a participant undergoing the procedure shown in the video, what do you think you might experience as you felt the strokes on your real hand and observed the stroking of the rubber hand?*

The aim of this question was to allow participants to consider what they might experience without being guided by the questionnaire statements. Following participants' response to this question, they were then provided with the questionnaire and foil items. They were asked to report how much they would expect to experience each of the specific effects, responding on a 7-point scale from -3 to +3. Participants were informed that -3 indicated "I am certain I won't feel any effect", -2 indicated "I am fairly certain I won't feel any effect", -1 indicated "I think I won't feel any effect", 0 indicated "I have no idea either way", 1 indicated "I think I will feel some effect", 2 indicated "I am fairly certain I will feel some effect", and 3 indicated "I am certain I will feel some effect". The order in which the questionnaire items and foil were presented was randomised. After providing their responses to the questionnaire, participants were asked to report whether the touches applied to the real and fake hands were applied in time or out of time with each

other (or indicate if they did not know). This question was to ensure that participants were aware of the synchrony of the touches in each video (as they would be during synchronous and asynchronous conditions of the real RHI).

Participants then repeated the procedure for the second of the two conditions (synchronous if they first watched the asynchronous video, or vice versa). After repeating this procedure, they were asked whether there was anything they might expect to experience in both scenarios they were presented with (free response). The aim of this question was to see if there were any consistent responses that might guide the development of new control statements for the RHI. To ensure that only procedure-naïve participants were examined, they were also asked if they had heard of the procedure shown in the videos before or if they had previously participated in an experiment in which the procedure shown in the videos was used. Participants were then debriefed.

## Data analysis

To ensure that analysis included only participants who were correctly following task instructions, those who did not watch the entire video in either condition, or spent more than three times the video duration on the page ( $n = 24$ ), were excluded. Participants were also excluded if they failed the foil question in either condition ( $n = 2$ ), or failed to accurately state the synchronicity of the touches ( $n = 34$ ). Finally, participants were excluded if they had previously heard of the RHI or taken part in a similar experiment ( $n = 47$ ). Following these exclusions, data were analysed for 58 participants. Note that some participants met more than one of the exclusion criteria.

For each participant an 'Illusion' score was created for the synchronous conditions based on the mean of S1, S2, and S3. A 'Control' score was created based on the mean of the control statements (S4-S9). Two Wilcoxon signed-rank tests were used to examine whether participants had stronger expectations for the Illusion statements in the synchronous condition compared to the asynchronous condition, and whether expectations for Illusion statements were greater than expectations for the Control statements in the synchronous condition. The effect size was calculated as the rank-biserial correlation ( $r$ ). Data analysis was performed in JASP (JASP Team, 2020). Output files can be accessed at <https://doi.org/10.17605/OSF.IO/3T9QK>.

To assess whether participants had any expectation for referral of touch or a feeling of ownership over the fake hand before being exposed to the questionnaire items, participant responses were examined based on the first free response question they were exposed to (i.e., for the synchronous or asynchronous condition). Any statements clearly mentioning feeling the touches applied to the fake hand were considered as referral of touch. Statements suggesting a duplication of touch (i.e., experiencing two sets of touches, from both the real and the fake hands), were not considered referral of touch. Any statements mentioning experiencing the fake hand as one's own, that the real and fake hand are the same, or that the real hand was replaced, were considered to capture sense of body ownership. All supporting statements are provided in Table 2. The percent-



age of participants who expected to experience referral of touch or a feeling of ownership when their first condition was synchronous ( $n = 36$ ) or asynchronous ( $n = 22$ ) was calculated. A descriptive summary of the final free response was also performed, examining referral of touch, sense of ownership, and any consistent experience participants reported that they would expect in both conditions.

## Results

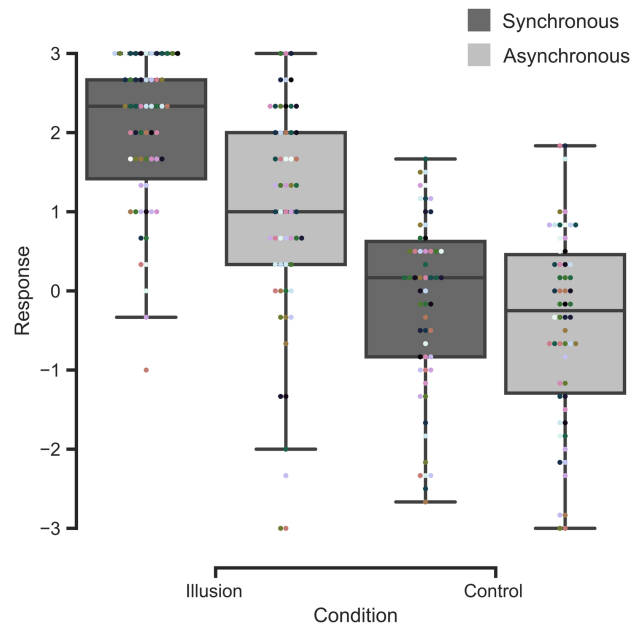
There was a statistically significant difference between Illusion scores in the synchronous and asynchronous conditions ( $W = 1260$ ,  $p < .001$ ,  $r = .761$ , 95% CI = [.597, .864], Figure 1). 72% of participants had stronger expectations for the Illusion statements in the synchronous condition compared to the asynchronous condition ( $n = 42$ ). This effect was most pronounced in statement S2 (referral of touch, 62%,  $n = 36$ ), with smaller effects in statements S1 (referral of touch, 57%,  $n = 33$ ) and S3 (ownership, 50%,  $n = 29$ ). Post hoc comparisons confirmed that expectations for each of these statements were significantly greater in the synchronous condition: S1 ( $W = 676.5$ ,  $p < .001$ ,  $r = .735$ , 95% CI = [.522, .861]), S2 ( $W = 766$ ,  $p < .001$ ,  $r = .697$ , 95% CI = [.473, .836]), S3 ( $W = 610.5$ ,  $p < .001$ ,  $r = .648$ , 95% CI = [.386, .813]).

There was also a statistically significant difference between Illusion and Control scores in the synchronous condition ( $W = 1708$ ,  $p < .001$ ,  $r = .996$ , 95% CI = [.994, .998], Figure 1). 97% of participants had stronger expectations for the Illusion statements than the Control statements ( $n = 56$ ). Figure 2 displays group data for participant responses to all questionnaire items.

Of the 36 participants who saw the synchronous condition first, 8% ( $n = 3$ ) explicitly mentioned expecting referral of touch in the free response for the synchronous condition, and 22% ( $n = 8$ ) expected to experience a sense of ownership over the fake hand. For the asynchronous condition, which they viewed second, 6% ( $n = 2$ ) of participants expected to experience referral of touch and 17% ( $n = 6$ ) expected to experience a sense of ownership. A post hoc McNemar test performed in Jamovi (The Jamovi Project, 2021) revealed that for the referral of touch statement, there was no statistically significant change in reporting between the synchronous and asynchronous condition ( $\chi^2(1, N = 36) = 0.333$ ,  $p = .564$ ). A non-significant result was also observed when examining expectations of the sense of ownership ( $\chi^2(1, N = 36) = 0.333$ ,  $p = .564$ ). Jamovi output files for this analysis can be accessed at <https://doi.org/10.17605/OSF.IO/3T9QK>.

Of the 22 participants who saw the asynchronous condition first, none of them expected to experience referral of touch in the asynchronous condition, and 23% ( $n = 5$ ) expected to experience a sense of ownership over the fake hand. For the synchronous condition, which they viewed second, 9% ( $n = 2$ ) expected referral of touch and 59% ( $n = 13$ ) expected a sense of ownership. A post hoc McNemar test revealed that for the ownership statement this difference in reporting between the synchronous and asynchronous conditions was statistically significant ( $\chi^2(1, N = 22) = 5.33$ ,  $p = .0209$ ).

In the final free response, presented after participants observed both the synchronous and asynchronous procedure, only 5% of participants ( $n = 3$ ) explicitly reported that



**Figure 1. Participant expectations for Illusion and Control statements**

Illusion scores are the mean response to statements S1-S3, Control scores are the mean response to statements S4-S9. Responses reflect expectation on a scale from -3 ("I am certain I won't feel any effect") to +3 ("I am certain I will feel some effect"). Boxplots indicate median and interquartile range.

they would expect to experience a referral of touch in both conditions. 17% of participants ( $n = 10$ ) explicitly reported that they would expect to experience a sense of ownership over the fake hand in both conditions. The only other commonly expected sensation was a feeling of confusion, reported by 14% of participants ( $n = 8$ ).

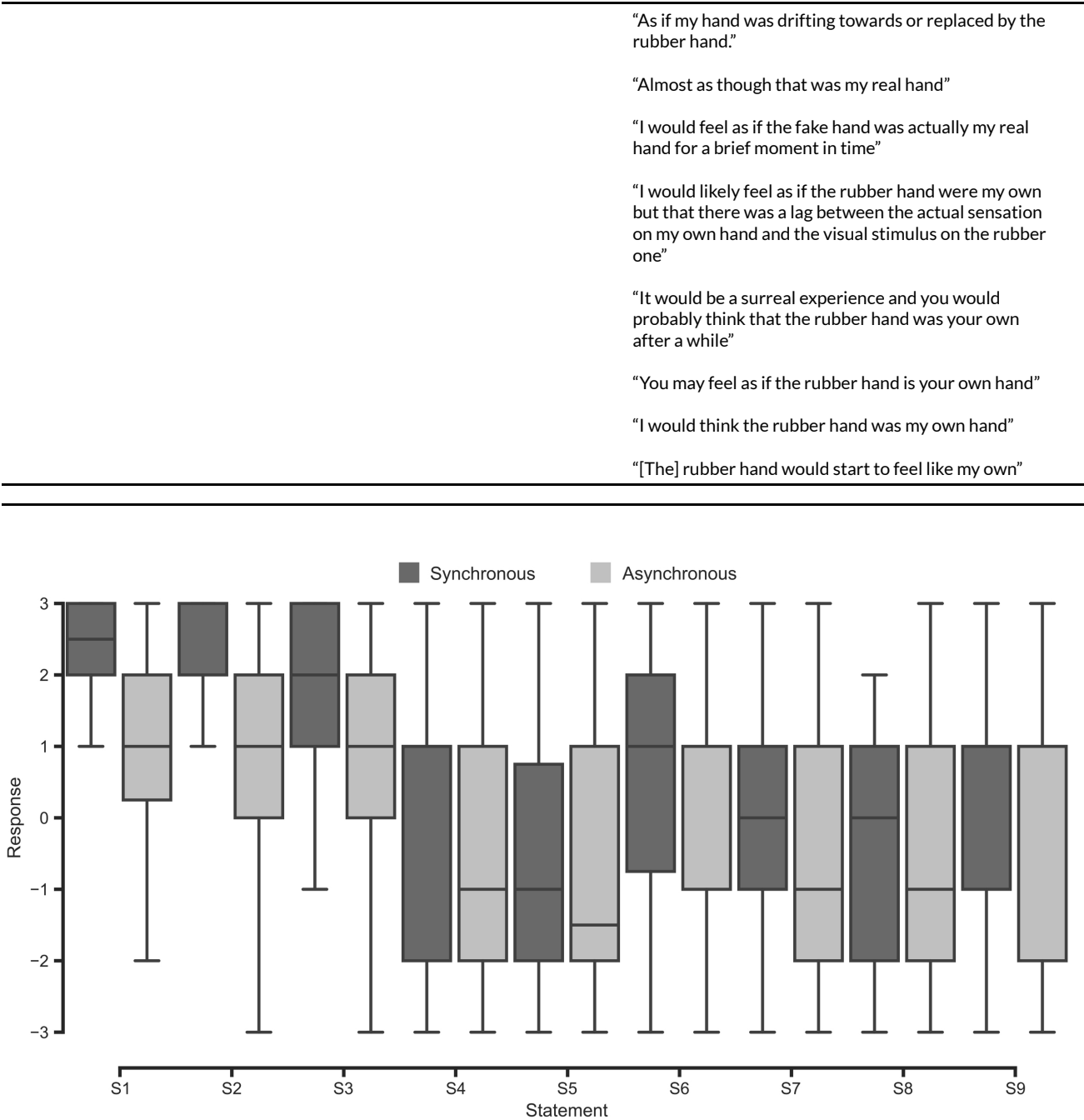
## Discussion

A conceptual replication of Lush (2020) was performed to examine the degree to which participants expect certain experiences when presented with details of the RHI procedure. In keeping with Lush (2020) the results suggest that participants may have stronger expectations for RHI questionnaire statements capturing illusory experience in the synchronous condition compared to the asynchronous condition, and for illusion statements compared to control statements. However, free responses suggest that these expectations could be at least partially driven by exposure to the questionnaire.

Questionnaire responses mirror the results of Lush (2020), suggesting that methodological limitations may not explain their findings. In their data the median ratings for illusion and control scores in those who had not heard of or participated in the RHI were as follows: synchronous illusion = 2, asynchronous illusion = 0.67, synchronous control = -0.33, asynchronous control = -0.83. The current results also show that expectation for illusion-related items in the synchronous condition was greater than that in the asynchronous condition. Similarly, whilst responses to the control items were varied (Figure 2), and several statements had a median rating of expectancy above zero in the synchronous condition (S4, S6, S9), participants also expected

**Table 2. Free response expectations of referral of touch and sense of ownership for synchronous and asynchronous conditions**

Condition	Expected experience	
	Referral of touch	Sense of ownership
Synchronous	"I might feel as if the brush strokes on the rubber hand induced the sensation of my actual hand being stroked"	"It might feel like the rubber hand was my real hand"
		"[I] might perceive the rubber hand as if it was mine"
	"I would think that the brush strokes on the fake hand were on my real hand even if the brush strokes have different patterns on each hand"	"I'd probably think my hand and the rubber hand were the same"
	"You may experience a sense of disassociation from your own hand, as the participant potentially believes they can feel the brush strokes on the fake hand."	"It may begin to (psychologically) feel as if that was my hand"
		"Feeling like the rubber hand is my own hand"
	"I would probably think that I feel my hand stroked only because I see the rubber hand being stroked."	"[I] would start to think the fake hand was my real hand"
	"Probably I would think that I can feel the strokes on the fake hand."	"I might imagine that the fake hand is my own as the exact same area is being stimulated but I can only see the fake hand"
		"I might experience the illusion of the fake hand being my real"
		"[I] think you would think the rubber hand felt like your real hand. So even though you can see the rubber hand you might eventually start to think it's your real hand"
		"I would feel as if the rubber hand was my own"
		"I might think the rubber hand is my hand"
		"[It] would feel like the rubber hand was your own as you feel the strokes from the paintbrush"
		"I would feel weirded out by the sensation of the rubber hand "becoming" my own"
		"Like the rubber hand started to feel like my own"
		"I would be slightly confused (if the strokes were simultaneous), and maybe start to assume that the fake hand was my own"
		"I would imagine that I would think the rubber hand was my real hand"
		"[As] though the fake hand was my hand"
Asynchronous	"I would feel the brushes of the fake hand even though they weren't stroking it at the same time as mine"	"I may believe that the rubber hand is own my hand"
		"I would feel like the rubber hand was my own hand through an empathetic connection"
	"I think I would feel the strokes when the rubber hand was stroked, not my own"	"To perceive the rubber hand as if it was your own"



**Figure 2. Participant expectations for all questionnaire items**

Illusion statements S1-S3, control statements S4-S9. Responses reflect expectation on a scale from -3 ("I am certain I won't feel any effect") to +3 ("I am certain I will feel some effect"). Boxplots indicate median and interquartile range.

the illusion-related items more than the control items. These results may therefore support the claims by Lush (2020) that expectancy is not well matched in the classic questionnaire statements used to assess subjective experience in the RHI (Botvinick & Cohen, 1998).

Lush (2020) and colleagues (2020, 2021) proposed that differences in reported experience between control and illusion measures in published RHI studies may reflect differences in expectancies. That is, increased responses to the illusion statements in the synchronous condition compared to the asynchronous condition (or control statements) may arise through participant expectations driving suggestibility or compliance (Lush et al., 2020). If participants expect

certain experiences in an experimental condition, but less so in a control, then those who are suggestible or complying with demand characteristics may respond in line with these expectations. For example, a sample with a high proportion of compliant participants could result in data indicating the presence of the illusion even if it rarely occurred. If expectations do drive reported experience in the RHI, then the common interpretation of the illusion as reflecting multisensory mechanisms underlying body ownership may be untenable. In order to address this possibility, further research is now essential for a better understanding of demand characteristics in the RHI and their influence on reported experience.

Firstly, it is necessary to understand the degree to which the current findings are applicable to the real RHI. This study examined visual depictions and relatively detailed verbal descriptions of the RHI induction procedure, the latter of which is not provided to participants in typical RHI studies. There are clearly different experiences afforded by the scenario presented here and the real RHI (particularly in terms of sensory experience). For example, it is possible that in the video stimuli used it *looks* like the fake hand could be one's own, and this visual impression may play a role in driving responses, rather than expectations of a *feeling* of ownership. Some free responses may support this interpretation. In addition, the information provided to participants about synchronous and asynchronous stimulation was more detailed than that available to participants in normal RHI studies (although this would not readily explain differences in expectation between illusion and control statements). It may be possible that experiencing the actual induction procedure affords greater or lesser expectations, with implications for how one interprets reported subjective experience. Perhaps the best way to probe expectations for the real illusion would be to briefly apply synchronous and asynchronous stroking in the real illusion setup, but stopping prior to typical illusion induction (likely less than 11 seconds, Ehrsson et al., 2004).

On a related note, there are clear differences between the magnitude of expectations and the experiences typically reported in the RHI. An increased agreement to illusion statements in the synchronous condition compared to the asynchronous condition is commonly observed in the RHI. So is increased agreement to the illusion statements compared to the control statements. However, whilst these differences are evident in the current data, the pattern of responses is not always consistent with responses to the real RHI. For example, participants rarely agree with illusion statements in the asynchronous condition (Reader et al., 2021), whereas expectations were surprisingly high in the current data. One possible explanation for this finding is the extent of asynchrony portrayed in the video stimuli, where touches applied to the real and fake hands were not perfectly out of phase (unlike in many RHI experiments, e.g., Ehrsson et al., 2004; Longo et al., 2008). This means that the brushes were occasionally touching both hands at some points (albeit in different locations in hand-centred space), and so this less salient asynchrony may have resulted in increased expectations for the illusion in that condition (and could also be the reason why some participants did not detect the asynchrony). However, there was also a surprisingly high level of expectation for control statements in the synchronous condition, which cannot be explained by the content of the asynchronous video stimuli. The median response to S6 ("It seemed as if the touch I was feeling came from somewhere between my own hand and the rubber hand") was positive, despite participants in real RHI induction tending to disagree that they experienced this sensation (Botvinick & Cohen, 1998). Whilst unmatched expectancy between experimental and control conditions/statements is enough to warrant concern about demand characteristics, differences in methods and results between the current experiment and real RHI induction also suggest an examination of expectations in the real illusion would be beneficial.

A second route for further research is to establish whether participant expectations (assuming that they are similar for the real illusion) do actually influence subjective responses. Lush (2020) proposed that this may be the case, pointing to findings indicating that expectations for feelings of ownership in the RHI predict participant responses to the illusion (Lush et al., 2020). However, even though Lush et al. (2020) observed that individuals who expect to experience the RHI are more likely to do so, in typical RHI experiments it is not normally the case that participants are presented with descriptions of both conditions or sensations they might experience before taking part in the experiment. It may be that this exposure drove some participant responses to the RHI (either through compliance or suggestibility) in the results reported by Lush et al. (2020), contributing to a statistically significant regression. Furthermore, it is not guaranteed that participants will respond in line with demand characteristics in all experimental paradigms. Evidence in favour of participant alignment with demand characteristics is mixed, and such behaviour may rely on other factors such as individual differences, experimental context, and information provided to participants (Corneille & Lush, 2021; Nichols & Maner, 2008; Sharpe & Whelton, 2016).

Thirdly, more work will be needed to ascertain the degree to which expectations are driven by exposure to the illusion induction procedure or by exposure to the questionnaire. This is an important distinction, because even though questionnaires are the main method for assessing subjective experience in the illusion, they are performed with the assumption that participants are experiencing similar sensations prior to knowing what they will be asked about. The current results might suggest that questionnaires play a role in driving expectations for a feeling of ownership. Whilst only 22% of participants who saw the synchronous condition first expected to experience a sense of ownership over the fake hand in the synchronous condition (i.e., before seeing the questionnaire items), 59% of participants who saw the asynchronous condition first expected this sensation (after they had seen the questionnaire items for the asynchronous condition). This might suggest that exposure to the questionnaire could play a key role in driving procedure-naïve participant expectations for illusion statements between synchronous and asynchronous conditions. Participants may not strongly expect such experiences until they read about and reflect on them. Of course, there are limitations to the use of free responses in the current study. Namely, motivation to respond to these questions may be more limited, and participants may not always adequately verbalise their expectations. It would be worthwhile to compare free responses of expectation to free responses for the real RHI in the absence of a questionnaire. If free responses of expectation are matched across both conditions, but free report of ownership and referral of touch are greater in the synchronous condition than the asynchronous condition during the real illusion, then this could indicate support for an illusory experience primarily driven by multisensory integration.

A fourth area of research that will be beneficial is to better understand the difference between participant expectations of experience and what they believe the *experimenter*



expects them to report. In this experiment and those of Lush (2020) and Lush et al. (2021), participants were asked to report the degree to which *they* would expect to experience the questionnaire items, not whether they think the *experimenter* expects them to occur. It is not yet clear if participant views converge in these cases, or if either of them actually contribute to reported experience during the RHI. It may be that compliance is more likely to be driven by beliefs about what the experimenter expects than participant expectations of experience. Further study could provide a more nuanced understanding of the factors that might influence reported experience in the RHI.

Regardless of the need for further work, it is still possible to address potential confounds if one assumes that the current results are at least partially reflective of participant expectations during the real RHI. One way of addressing the potential issue of unmatched expectancies could be to provide a cover story suggesting that experimenters are expecting participants to experience either the control events in the synchronous condition, or the illusion itself in the asynchronous condition. However, previous attempts to manipulate expectations of experience for the synchronous and asynchronous condition have been unsuccessful (Lush et al., 2020), meaning that this approach may be unsuitable. A further solution for comparing illusion and control items is to generate new control items that are matched for expectancy with illusion statements. Unfortunately, the final free responses collected for the current experiment did not provide any consistent perceptual experiences that could be used for this. Recording free responses for expectation in the real RHI may also be useful in this context.

Furthermore, the current findings might suggest that questionnaire exposure could bias participant responses if they are presented with either the synchronous or asynchronous condition, then the questionnaire, before completing the second of the two conditions. For example, if they take part in the asynchronous condition first they may expect that during the following (synchronous) condition they will experience referral of touch and a feeling of ownership (but not the control items). This could potentially lead to an increase in the magnitude of illusion statement responses, either through compliance or suggestibility. This situation could nullify counterbalancing if participants consistently provide greater responses to illusion statements in the synchronous condition when they experience the asynchronous condition first, and lower responses in the asynchronous condition when they experience the synchronous condition first. Recent evidence, albeit taken from a non-naïve sample, suggests that this could feasibly happen (Lush, 2021). Taking the order of condition presentation into account when analysing RHI data may resolve this issue when comparing illusion statements between conditions (at least for experimental procedures in line with that described above).

Finally, the limitations of the current study must be addressed. Notably, all participants were studying psychology at undergraduate level. Even if they were unfamiliar with the RHI, they are aware of the principles of experimental design (e.g., control conditions), which may have guided their responses. The current experiment is therefore not without its own set of demand characteristics that could

differ from the true RHI. A replication with individuals who are naïve to psychological experiment design is likely to be informative. Furthermore, the subjective interpretation of free responses by the experimenter must be considered. Care was taken to accurately categorise statements that reflected referral of touch or feeling of ownership, excluding statements that may have more than one interpretation. For example, one participant reported that they would “associate the strokes on the fake hand with feeling it on my own”. This could potentially be taken to reflect referral of touch, but could also reflect cognitive association of the timing of the two touches (i.e., that seeing a touch is always accompanied by feeling a touch). Similarly, regarding the sense of body ownership, one participant stated that they “might feel a connection to the rubber hand, almost as if it was my own”. Whilst they refer to experiencing the hand as if it was their own, the exact nature of the ‘connection’ they expect is not clear. It could be that they are referring to affective or cognitive aspects of experience, rather than sensory. In sum, it is possible that participant expectations for referral of touch and ownership are greater than expressed in free response, but interpretation is limited by participant phrasing.

In addition, this experiment can only inform us about the ‘classic’ visuotactile RHI. It remains to be seen whether similar expectations are present in versions of the RHI where touching is spatially incongruent rather than temporally asynchronous, or in versions that use different multi-sensory stimuli such as the somatic (Ehrsson et al., 2005) or moving RHI (Kalckert & Ehrsson, 2012). Similarly, the experiment can only inform us about expectations for the phenomena described in the original RHI questionnaire created by Botvinick and Cohen (1998). The questionnaire developed by Longo et al. (2008), which is also frequently used in experiments studying the RHI, splits RHI experience into several components (affect, deafference, loss of own hand, movement, and embodiment, which itself includes ownership, location, and agency) which might elicit different expectations from participants. It would be beneficial to study this questionnaire in a similar fashion (and, preferably, in a real induction scenario).

In conclusion, this study replicates the results of Lush (2020), indicating that when exposed to information about the RHI procedure participants may have greater expectations for illusion statements in the synchronous condition compared to the asynchronous condition, and for the illusion statements compared to the control statements. However, for comparing illusion statements between synchronous and asynchronous conditions, such expectations could possibly be driven by exposure to the questionnaire items rather than exposure to the illusion procedure. The role of expectations on reported experience in the RHI need to be further examined and better accounted for in experimental design to verify how well the illusion is explained by a multisensory integration model of body ownership.

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## Competing Interests

The author is an associate editor at Collabra: Psychology. Editors play no role during the review process of their spe-

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## Data Accessibility

Raw data associated with this article are available at <http://hdl.handle.net/11667/178>.

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# References

- Abdulkarim, Z., & Ehrsson, H. H. (2016). No causal link between changes in hand position sense and feeling of limb ownership in the rubber hand illusion. *Attention, Perception, & Psychophysics*, 78(2), 707–720. <https://doi.org/10.3758/s13414-015-1016-0>
- Abdulkarim, Z., Hayatou, Z., & Ehrsson, H. H. (2021). Sustained rubber hand illusion after the end of visuotactile stimulation with a similar time course for the reduction of subjective ownership and proprioceptive drift. *Experimental Brain Research*. <http://doi.org/10.1007/s00221-021-06211-8>
- Bekrater-Bodmann, R., Foell, J., Diers, M., & Flor, H. (2012). The perceptual and neuronal stability of the rubber hand illusion across contexts and over time. *Brain Research*, 1452, 130–139. <https://doi.org/10.1016/j.brainres.2012.03.001>
- Botvinick, M., & Cohen, J. (1998). Rubber hands ‘feel’ touch that eyes see. *Nature*, 391(6669), 756–756. <http://doi.org/10.1038/35784>
- Brozzoli, C., Gentile, G., & Ehrsson, H. H. (2012). That’s Near My Hand! Parietal and Premotor Coding of Hand-Centered Space Contributes to Localization and Self-Attribution of the Hand. *Journal of Neuroscience*, 32(42), 14573–14582. <https://doi.org/10.1523/JNEUROSCI.2660-12.2012>
- Chancel, M., & Ehrsson, H. H. (2020). Which hand is mine? Discriminating body ownership perception in a two-alternative forced-choice task. *Attention, Perception, & Psychophysics*, 82(8), 4058–4083. <http://doi.org/10.3758/s13414-020-02107-x>
- Chancel, M., Ehrsson, H. H., & Ma, W. J. (2021). *Uncertainty-based inference of a common cause for body ownership* [Preprint]. Open Science Framework. <https://doi.org/10.31219/osf.io/yh2z7>
- Chancel, M., Hasenack, B., & Ehrsson, H. H. (2021). Integration of predictions and afferent signals in body ownership. *Cognition*, 212, 104722. <https://doi.org/10.1016/j.cognition.2021.104722>
- Corneille, O., & Lush, P. (2021). *Sixty years after Orne’s American Psychologist article: A conceptual analysis of “Demand Characteristics”* [Preprint]. PsyArXiv. <https://doi.org/10.31234/osf.io/jqyvx>
- Costantini, M., & Haggard, P. (2007). The rubber hand illusion: Sensitivity and reference frame for body ownership. *Consciousness and Cognition*, 16(2), 229–240. <https://doi.org/10.1016/j.concog.2007.01.001>
- Costantini, M., Robinson, J., Migliorati, D., Donno, B., Ferri, F., & Northoff, G. (2016). Temporal limits on rubber hand illusion reflect individuals’ temporal resolution in multisensory perception. *Cognition*, 157, 39–48. <https://doi.org/10.1016/j.cognition.2016.08.010>
- Crucianelli, L., Paloyelis, Y., Ricciardi, L., Jenkinson, P. M., & Fotopoulou, A. (2019). Embodied Precision: Intranasal Oxytocin Modulates Multisensory Integration. *Journal of Cognitive Neuroscience*, 31(4), 592–606. [https://doi.org/10.1162/jocn\\_a\\_01366](https://doi.org/10.1162/jocn_a_01366)
- Ehrsson, H. H. (2020). Multisensory processes in body ownership. In *Multisensory Perception* (pp. 179–200). Elsevier. <https://doi.org/10.1016/B978-0-12-812492-5.00008-5>
- Ehrsson, H. H., Fotopoulou, A., Radziun, D., Longo, M. R., & Tsakiris, M. (2022). No specific relationship between hypnotic suggestibility and the rubber hand illusion. *Nature Communications*, 13(1), 564. <https://doi.org/10.1038/s41467-022-28177-z>
- Ehrsson, H. H., Holmes, N. P., & Passingham, R. E. (2005). Touching a Rubber Hand: Feeling of Body Ownership Is Associated with Activity in Multisensory Brain Areas. *Journal of Neuroscience*, 25(45), 10564–10573. <https://doi.org/10.1523/JNEUROSCI.0800-05.2005>
- Ehrsson, H. H., Rosen, B., Stocksli, A., Ragnö, C., Kohler, P., & Lundborg, G. (2008). Upper limb amputees can be induced to experience a rubber hand as their own. *Brain*, 131(12), 3443–3452. <https://doi.org/10.1093/brain/awn297>
- Ehrsson, H. H., Spence, C., & Passingham, R. E. (2004). That’s My Hand! Activity in Premotor Cortex Reflects Feeling of Ownership of a Limb. *Science*, 305(5685), 875–877. <https://doi.org/10.1126/science.1097011>
- Fahey, S., Charette, L., Francis, C., & Zheng, Z. (2018). Multisensory integration of signals for bodily self-awareness requires minimal cognitive effort. *Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale*, 72(4), 244–252. <https://doi.org/10.1037/cep0000152>
- Fang, W., Li, J., Qi, G., Li, S., Sigman, M., & Wang, L. (2019). Statistical inference of body representation in the macaque brain. *Proceedings of the National Academy of Sciences*, 116(40), 20151–20157. <https://doi.org/10.1073/pnas.1902334116>
- Germine, L., Benson, T. L., Cohen, F., & Hooker, C. I. (2013). Psychosis-proneness and the rubber hand illusion of body ownership. *Psychiatry Research*, 207(1–2), 45–52. <https://doi.org/10.1016/j.psychres.2012.11.022>
- Graziano, M. S. A. (2000). Coding the Location of the Arm by Sight. *Science*, 290(5497), 1782–1786. <https://doi.org/10.1126/science.290.5497.1782>
- Guterstam, A., Collins, K. L., Cronin, J. A., Zeberg, H., Darvas, F., Weaver, K. E., Ojemann, J. G., & Ehrsson, H. H. (2019). Direct Electrophysiological Correlates of Body Ownership in Human Cerebral Cortex. *Cerebral Cortex*, 29(3), 1328–1341. <https://doi.org/10.1093/cercor/bhy285>
- Holle, H., McLatchie, N., Maurer, S., & Ward, J. (2011). Proprioceptive drift without illusions of ownership for rotated hands in the “rubber hand illusion” paradigm. *Cognitive Neuroscience*, 2(3–4), 171–178. <https://doi.org/10.1080/17588928.2011.603828>
- JASP Team. (2020). *JASP* (0.10.0.0). [Computer software].

- Kalckert, A., Bico, I., & Fong, J. X. (2019). Illusions With Hands, but Not With Balloons – Comparing Ownership and Referral of Touch for a Corporal and Noncorporal Object After Visuotactile Stimulation. *Perception*, 48(5), 447–455. <https://doi.org/10.1177/0301006619839286>
- Kalckert, A., & Ehrsson, H. H. (2012). Moving a Rubber Hand that Feels Like Your Own: A Dissociation of Ownership and Agency. *Frontiers in Human Neuroscience*, 6. <https://doi.org/10.3389/fnhum.2012.00040>
- Kalckert, A., & Ehrsson, H. H. (2014). The spatial distance rule in the moving and classical rubber hand illusions. *Consciousness and Cognition*, 30, 118–132. <https://doi.org/10.1016/j.concog.2014.08.022>
- Kilteni, K., & Ehrsson, H. H. (2017). Body ownership determines the attenuation of self-generated tactile sensations. *Proceedings of the National Academy of Sciences*, 114(31), 8426–8431. <https://doi.org/10.1073/pnas.1703347114>
- Kilteni, K., Maselli, A., Kording, K. P., & Slater, M. (2015). Over my fake body: Body ownership illusions for studying the multisensory basis of own-body perception. *Frontiers in Human Neuroscience*, 9. <http://doi.org/10.3389/fnhum.2015.00141>
- Limanowski, J., & Blankenburg, F. (2015). Network activity underlying the illusory self-attribution of a dummy arm: Network Activity of Illusory Self-Attribution. *Human Brain Mapping*, 36(6), 2284–2304. <https://doi.org/10.1002/hbm.22770>
- Lloyd, D. M. (2007). Spatial limits on referred touch to an alien limb may reflect boundaries of visuo-tactile peripersonal space surrounding the hand. *Brain and Cognition*, 64(1), 104–109. <https://doi.org/10.1016/j.bandc.2006.09.013>
- Longo, M. R., Schüür, F., Kammers, M. P. M., Tsakiris, M., & Haggard, P. (2008). What is embodiment? A psychometric approach. *Cognition*, 107(3), 978–998. <https://doi.org/10.1016/j.cognition.2007.12.004>
- Lush, P. (2020). Demand Characteristics Confound the Rubber Hand Illusion. *Collabra: Psychology*, 6(1), 22. <https://doi.org/10.1525/collabra.325>
- Lush, P. (2021). *Order effects in the rubber hand illusion* [Preprint]. PsyArXiv. <https://doi.org/10.31234/osf.io/amsrp>
- Lush, P., Botan, V., Scott, R. B., Seth, A. K., Ward, J., & Dienes, Z. (2020). Trait phenomenological control predicts experience of mirror synaesthesia and the rubber hand illusion. *Nature Communications*, 11(1), 4853. <https://doi.org/10.1038/s41467-020-18591-6>
- Lush, P., Seth, A., & Dienes, Z. (2021). Hypothesis awareness confounds asynchronous control conditions in indirect measures of the rubber hand illusion. *Royal Society Open Science*, 8, 210911. <https://doi.org/10.1098/rsos.210911>
- Marotta, A., Tinazzi, M., Cavedini, C., Zampini, M., & Fiorio, M. (2016). Individual Differences in the Rubber Hand Illusion Are Related to Sensory Suggestibility. *PLOS ONE*, 11(12), e0168489. <https://doi.org/10.1371/journal.pone.0168489>
- Nichols, A. L., & Maner, J. K. (2008). The Good-Subject Effect: Investigating Participant Demand Characteristics. *The Journal of General Psychology*, 135(2), 151–166. <https://doi.org/10.3200/GENP.135.2.151-166>
- Perepelkina, O., Boboleva, M., Arina, G., & Nikolaeva, V. (2017). Higher Emotional Intelligence Is Associated With a Stronger Rubber Hand Illusion. *Multisensory Research*, 30(7–8), 615–637. <https://doi.org/10.1163/2134808-00002577>
- Petkova, V. I., & Ehrsson, H. H. (2009). When Right Feels Left: Referral of Touch and Ownership between the Hands. *PLoS ONE*, 4(9), e6933. <https://doi.org/10.1371/journal.pone.0006933>
- Preston, C. (2013). The role of distance from the body and distance from the real hand in ownership and disownership during the rubber hand illusion. *Acta Psychologica*, 142(2), 177–183. <https://doi.org/10.1016/j.actpsy.2012.12.005>
- Pyasik, M., Ronga, I., Burin, D., Salatino, A., Sarasso, P., Garbarini, F., Ricci, R., & Pia, L. (2021). I'm a believer: Illusory self-generated touch elicits sensory attenuation and somatosensory evoked potentials similar to the real self-touch. *NeuroImage*, 229, 117727. <https://doi.org/10.1016/j.neuroimage.2021.117727>
- Pyasik, M., Salatino, A., & Pia, L. (2019). Do movements contribute to sense of body ownership? Rubber hand illusion in expert pianists. *Psychological Research*, 83(1), 185–195. <https://doi.org/10.1007/s00426-018-1137-x>
- Reader, A. T., Trifonova, V. S., & Ehrsson, H. H. (2021). The Relationship Between Referral of Touch and the Feeling of Ownership in the Rubber Hand Illusion. *Frontiers in Psychology*, 12, 629590. <https://doi.org/10.3389/fpsyg.2021.629590>
- Riemer, M., Trojan, J., Beauchamp, M., & Fuchs, X. (2019). The rubber hand universe: On the impact of methodological differences in the rubber hand illusion. *Neuroscience & Biobehavioral Reviews*, 104, 268–280. <https://doi.org/10.1016/j.neubiorev.2019.07.008>
- Romano, D., Maravita, A., & Perugini, M. (2021). Psychometric properties of the embodiment scale for the rubber hand illusion and its relation with individual differences. *Scientific Reports*, 11(5029). <https://doi.org/10.1038/s41598-021-84595-x>
- Samad, M., Chung, A. J., & Shams, L. (2015). Perception of Body Ownership Is Driven by Bayesian Sensory Inference. *PLOS ONE*, 10(2), e0117178. <https://doi.org/10.1371/journal.pone.0117178>
- Sharpe, D., & Whelton, W. J. (2016). Frightened by an Old Scarecrow: The Remarkable Resilience of Demand Characteristics. *Review of General Psychology*, 20(4), 349–368. <https://doi.org/10.1037/gpr0000087>
- Shimada, S., Fukuda, K., & Hiraki, K. (2009). Rubber Hand Illusion under Delayed Visual Feedback. *PLoS ONE*, 4(7), e6185. <https://doi.org/10.1371/journal.pone.0006185>

- Shimada, S., Suzuki, T., Yoda, N., & Hayashi, T. (2014). Relationship between sensitivity to visuotactile temporal discrepancy and the rubber hand illusion. *Neuroscience Research*, 85, 33–38. <https://doi.org/10.1016/j.neures.2014.04.009>
- Tamè, L., Linkenauger, S. A., & Longo, M. R. (2018). Dissociation of feeling and belief in the rubber hand illusion. *PLOS ONE*, 13(10), e0206367. <https://doi.org/10.1371/journal.pone.0206367>
- The Jamovi Project. (2021). *Jamovi* (1.6). [Computer software]. <https://www.jamovi.org>
- Tidoni, E., Grisoni, L., Liuzza, M. T., & Aglioti, S. M. (2014). Rubber hand illusion highlights massive visual capture and sensorimotor face-hand remapping in a tetraplegic man. *Restorative Neurology and Neuroscience*, 32(5), 611–622. <https://doi.org/10.3233/RNN-130385>
- Tsakiris, M. (2010). My body in the brain: A neurocognitive model of body-ownership. *Neuropsychologia*, 48(3), 703–712. <https://doi.org/10.1016/j.neuropsychologia.2009.09.034>
- Tsakiris, M., Carpenter, L., James, D., & Fotopoulou, A. (2010). Hands only illusion: Multisensory integration elicits sense of ownership for body parts but not for non-corporeal objects. *Experimental Brain Research*, 204(3), 343–352. <https://doi.org/10.1007/s00221-009-2039-3>
- Tsakiris, M., & Haggard, P. (2005). The Rubber Hand Illusion Revisited: Visuotactile Integration and Self-Attribution. *Journal of Experimental Psychology: Human Perception and Performance*, 31(1), 80–91. <https://doi.org/10.1037/0096-1523.31.1.80>
- Tsakiris, M., Hesse, M. D., Boy, C., Haggard, P., & Fink, G. R. (2007). Neural Signatures of Body Ownership: A Sensory Network for Bodily Self-Consciousness. *Cerebral Cortex*, 17(10), 2235–2244. <https://doi.org/10.1093/cercor/bhl131>
- Tsakiris, M., Jiménez, A. T., & Costantini, M. (2011). Just a heartbeat away from one's body: Interoceptive sensitivity predicts malleability of body-representations. *Proceedings of the Royal Society B: Biological Sciences*, 278(1717), 2470–2476. <https://doi.org/10.1098/rspb.2010.2547>
- Walsh, E., Guilmette, D. N., Longo, M. R., Moore, J. W., Oakley, D. A., Halligan, P. W., Mehta, M. A., & Deeley, Q. (2015). Are You Suggesting That's My Hand? The Relation Between Hypnotic Suggestibility and the Rubber Hand Illusion. *Perception*, 44(6), 709–723. <https://doi.org/10.1177/0301006615594266>
- Ward, J., Mensah, A., & Jünemann, K. (2015). The rubber hand illusion depends on the tactile congruency of the observed and felt touch. *Journal of Experimental Psychology: Human Perception and Performance*, 41(5), 1203–1208. <https://doi.org/10.1037/xhp0000088>
- Zeller, D., Gross, C., Bartsch, A., Johansen-Berg, H., & Classen, J. (2011). Ventral Premotor Cortex May Be Required for Dynamic Changes in the Feeling of Limb Ownership: A Lesion Study. *Journal of Neuroscience*, 31(13), 4852–4857. <https://doi.org/10.1523/JNEUROSCI.5154-10.2011>
- Zopf, R., Savage, G., & Williams, M. A. (2013). The Crossmodal Congruency Task as a Means to Obtain an Objective Behavioral Measure in the Rubber Hand Illusion Paradigm. *Journal of Visualized Experiments*, 77, 50530. <https://doi.org/10.3791/50530>
- Zopf, R., Truong, S., Finkbeiner, M., Friedman, J., & Williams, M. A. (2011). Viewing and feeling touch modulates hand position for reaching. *Neuropsychologia*, 49(5), 1287–1293. <https://doi.org/10.1016/j.neuropsychologia.2011.02.012>

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