Short Report

PERCEPTION

Are You Suggesting That's My Hand? The Relation Between Hypnotic Suggestibility and the Rubber Hand Illusion

Perception
2015, Vol. 44(6) 709–723

DOI: 10.1177/0301006615594266
pec.sagepub.com
SAGE

E. Walsh
Cultural and Social Neuroscience Research Group, Forensic and Neurodevelopmental Sciences, Institute of Psychiatry, Psychology & Neuroscience, Kings College London, UK
Department of Psychological Sciences, Birkbeck, University of London, UK

D. N. Guilmette
Stonehill College, MA, USA

M. R. Longo
Department of Psychological Sciences, Birkbeck, University of London, UK

J. W. Moore
Department of Psychology, Goldsmiths, University of London, UK

D. A. Oakley
Division of Psychology and Language Sciences, University College London, UK
School of Psychology, Cardiff University, UK

P. W. Halligan
School of Psychology, Cardiff University, UK

M. A. Mehta*
Cultural and Social Neuroscience Research Group, Centre for Neuroimaging Sciences, Institute of Psychiatry, Psychology & Neuroscience, Kings College London, UK

Q. Deeley*
Cultural and Social Neuroscience Research Group, Forensic and Neurodevelopmental Sciences, Institute of Psychiatry, Psychology & Neuroscience, Kings College London, UK

* These authors contributed equally to this work.

Corresponding author:
E. Walsh, Cultural and Social Neuroscience Research Group, Forensic and Neurodevelopmental Sciences, Institute of Psychiatry, Psychology & Neuroscience, Kings College London, London, UK.
Email: eamonn.walsh@kcl.ac.uk

Abstract

Hypnotic suggestibility (HS) is the ability to respond automatically to suggestions and to experience alterations in perception and behavior. Hypnotically suggestible participants are also better able to focus and sustain their attention on an experimental stimulus. The present study explores the relation between HS and susceptibility to the rubber hand illusion (RHI). Based on previous research with visual illusions, it was predicted that higher HS would lead to a stronger RHI. Two behavioral output measures of the RHI, an implicit (proprioceptive drift) and an explicit (RHI questionnaire) measure, were correlated against HS scores. Hypnotic suggestibility correlated positively with the implicit RHI measure contributing to 30% of the variation. However, there was no relation between HS and the explicit RHI questionnaire measure, or with compliance control items. High hypnotic suggestibility may facilitate, via attentional mechanisms, the multisensory integration of visuoproprioceptive inputs that leads to greater perceptual mislocalization of a participant's hand. These results may provide insight into the multisensory brain mechanisms involved in our sense of embodiment.

Keywords

individual differences, proprioception, Harvard Group Scale, hypnotizability, multisensory integration, embodiment, body image

Introduction

The sense of one's own body is intimately related to our sense of self. Body image and physical appearance is central in medical and health contexts (e.g., cosmetic and reconstructive surgery, physical therapy, and rehabilitation), acquired physical diseases or injuries (e.g., skin diseases or burns), and psychopathology in relation to eating disorders, body dysmorphic disorder, social phobia, and mood disorders (Cash, 2004). Many treatments can dramatically change the functioning and appearance of the body, which in turn can alter the person's body image and well-being. Our sense of embodiment is rich and complex, yet elusive and hard to measure (Longo, Schüür, Kammers, Tsakiris, & Haggard, 2008). Experimental approaches make it possible to perceptually incorporate an external object into the representation of the body. A prime example is the so-called *rubber hand illusion* (RHI; Botvinick & Cohen, 1998), where a prosthetic hand is perceived as being incorporated by the participant. There are considerable individual differences in the extent to which the illusion is experienced. Much debate continues about the necessary and sufficient conditions eliciting the RHI. Here, we investigate whether hypnotic suggestibility (HS) contributes to people's experience of the illusion.

HS refers to an individual's ability to experience suggested alterations in physiology, sensations, emotions, thoughts, or behavior following a hypnotic induction procedure (Elkins, Barabasz, Council, & Spiegel, 2014) and to respond in an automatic way to direct verbal suggestions (Braffman & Kirsch, 1999; Weitzenhoffer & Hilgard, 1962). Importantly, HS is also a strong predictor of an individual's responsiveness to suggestion outside a hypnotic context (Braffman & Kirsch, 1999) and is measured using scales such as the Harvard Group Scale of Hypnotic Susceptibility: Form A (HGSHS:A; Shor & Orne, 1962). Scores on the HGSHS:A are normally distributed and remain stable over a person's lifetime (Hilgard, 1965; Piccione, Hilgard, & Zimbardo, 1989).

The RHI (Botvinick & Cohen, 1998) is an intriguing illusion used in research to investigate body ownership, awareness, and body image (e.g., Ehrsson, Spence, & Passingham, 2004;

Longo et al., 2008; Longo, Schüür, Kammers, Tsakiris, & Haggard, 2009; Tsakiris & Haggard, 2005). In the RHI, participants view a prosthetic (rubber) hand, which is stroked simultaneously with their own adjacent hidden hand (see Method section; Figure 3). Under such conditions, most people attribute the rubber hand to their own body and report that "it feels like the rubber hand is my hand" (Botvinick & Cohen, 1998; Ehrsson et al., 2004). In contrast, asynchronous stimulation, where tactile stimulation is out of phase, typically does not elicit the illusion to the same extent. The *difference* in performance between the synchronous (experimental) and the asynchronous (control) conditions gives a measure of the magnitude of the illusion. The synchronous stimulation condition, in particular, arguably presents a strong implicit suggestion to participants that the rubber hand is to be experienced as their own. Direct verbal suggestions given in a hypnotic context have previously been shown to be effective in creating alterations in the sense of ownership and awareness of body parts (Deeley, Walsh, et al., 2013; Oakley & Halligan, 2013; Walsh, Mehta, et al., 2014; Walsh, Oakley, et al., 2015).

HS individuals are characterized by heightened attentional focus (Crawford & Gruzelier, 1992; Rainville, Hofbauer, Bushnell, Duncan, & Price, 2002; Tellegen & Atkinson, 1974) and can block out sources of distraction better than low HS participants (Fehr & Stern, 1970; Jamieson & Sheehan, 2004; Mitchell, 1970; Nuys, 1973); an ability that is strengthened by a hypnotic induction procedure (Deeley et al., 2012). The capacity to strongly focus on the salient cues of an experimental stimulus facilitates the production of illusions (Power & Day, 1973). Previous research has indicated that highly hypnotically suggestible participants report more direction changes of a stationary light source (autokinetic effect; Wallace, Knight, & Garrett, 1976), a greater illusory effect to the Ponzo illusion (Miller, 1975), and a greater frequency of reversals with Necker cube and Schroeder staircase illusions (Wallace, 1988; Wallace et al., 1976). These effects were observed in the absence of any hypnotic induction. Individual differences in HS, in terms of suggestibility itself and attentional focus, might therefore explain some of the variance observed in the magnitude of response to the RHI.

Here, two widely used methods, one implicit and the other explicit, were adopted to measure the RHI. The implicit *proprioceptive drift* method (Ionta, Sforza, Funato, & Blanke, 2013; Schütz-Bosbach, Avenanti, Aglioti, & Haggard, 2009; Schütz-Bosbach, Tausche, & Weiss, 2009; Tsakiris & Haggard, 2005) measures how the perceived location of the participant's hand shifts toward the rubber hand during the illusion. The second explicit method uses an *RHI questionnaire* (Botvinick & Cohen, 1998) to measure the participants' conscious experience of the illusion by asking them to agree or disagree to statements relating to ownership and location of the rubber hand (Table 1; Longo et al., 2008). While original research has suggested common brain mechanisms for illusory hand ownership and proprioceptive drift (Botvinick & Cohen, 1998), more recent behavioral (e.g., Kammers, de Vignemont, Verhagen, & Dijkerman, 2009; Rohde, Di Luca, & Ernst, 2011) and neuroimaging (Ehrsson et al., 2004; Tsakiris, Hesse, Boy, Haggard, & Fink, 2007) findings have established that distinct multisensory mechanisms underlie the two phenomena (Blanke, 2012), and that the two measures assess related, but distinct, aspects of the experience of the RHI (Fiorio et al., 2011; Rohde et al., 2011). A number of conceptual models (Figure 1; Makin, Holmes, & Ehrsson, 2008; Rohde et al., 2011; Tsakiris, Longo, & Haggard, 2010) have proposed that proprioceptive drift relies on integration of visual and proprioceptive information (Visuoproprioceptive stream, Figure 1(a); Rohde et al., 2011), while the illusory feeling of ownership toward the rubber hand is thought to rely on integration of visual and tactile information (Visuotactile stream, Figure 1(b); Ehrsson et al., 2004).

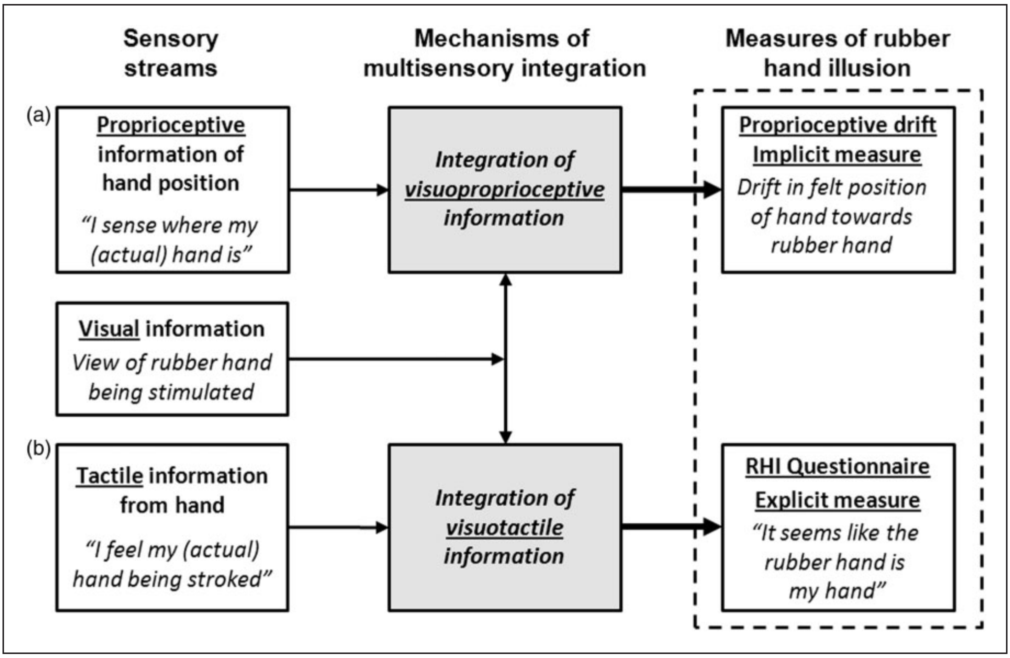

Figure 1. Theoretical model showing how different sensory streams are integrated via two related but distinct multisensory mechanisms (gray boxes) during the rubber hand illusion (RHI). The original rubber hand illusion (Botvinick & Cohen, 1998) has suggested common brain mechanisms for explicit illusory hand ownership and explicit proprioceptive drift measures (dashed box). However, more recent research (see text) indicates that *distinct* multisensory mechanisms underlie the two phenomena. (a) Visual and proprioceptive information are integrated leading to mislocalization of actual hand position, as measured implicitly using proprioceptive drift, and (b) visual and tactile information are integrated leading to an illusory feeling of ownership over the hand, as measured explicitly using the RHI questionnaire.

The aim of the present study was to measure the relation between HS and susceptibility to the RHI, while controlling for compliance. We predicted that HS would be associated with greater response to the RHI, as measured both implicitly (proprioceptive drift) and explicitly (RHI questionnaire).

Results

There were no significant correlations between HS as measured by the HGSHS:A score and estimates of prestimulation index finger position (see Method section); Pearson's $r = .174$; $p = .440$. Just viewing the rubber hand prior to stimulation did not appear to influence felt finger position in relation to HS (Pavani, Spence, & Driver, 2000). Consistent with previous studies (e.g., Longo et al., 2008), there was significant proprioceptive drift in both the synchronous (2.2 cm, $SD = 2.8$), $t(21) = 3.643$, $p < .001$ (one tailed) and the asynchronous condition (1.1 cm, $SD = 2.8$), $t(21) = 1.895$, $p < .05$ (one tailed), revealing an overall proprioceptive bias toward the body midline (Ghilardi, Gordon, & Ghez, 1995). Critically, proprioceptive drift was significantly larger in the synchronous than the asynchronous condition, $t(21) = 1.990$, $p < .05$ (one tailed), indicating that participants experienced the RHI as measured implicitly.

To explore if HS was associated with a greater response to the RHI, a Pearson correlation was performed. When tested separately, no significant correlations were observed for the synchronous (Pearson's $r = .20$, $p = .371$) or the asynchronous (Pearson's $r = -.29$, $p = .190$) conditions. Importantly, a moderate strength positive correlation (Pearson's $r = .55$, $p = .008$)

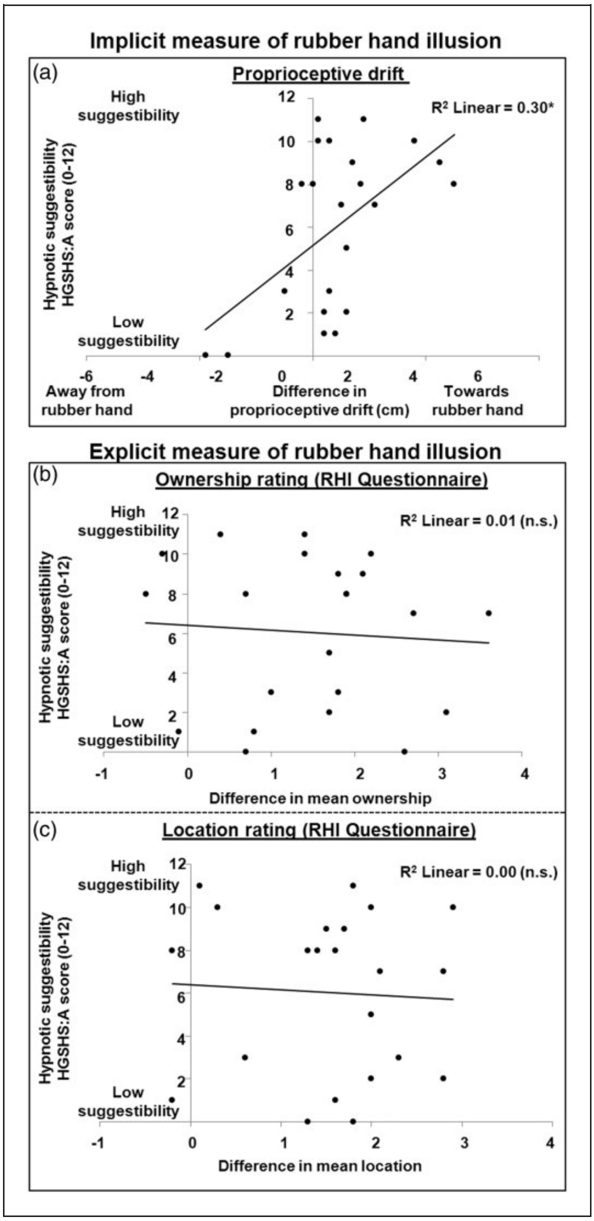

Figure 2. Pearson correlations between hypnotic suggestibility (Harvard Group Scale of hypnotic suggestibility HGSHS:A) score and (a) implicit (proprioceptive drift; significant positive correlation; $^*p = .008$) and (b, c) explicit measures of the rubber hand illusion (RHI questionnaire; negative correlations, both nonsignificant [n.s.]; $p > .194$).

was observed between HS (HGSHS:A score) and the magnitude of the illusion as measured by the difference between the experimental and the control (i.e., synchronous minus asynchronous) conditions in proprioceptive drift (Figure 2(a)); the observed statistical power was 0.80 (Ellis, 2010; two-tailed test at $\alpha = 0.05$). While the standard HGSHS:A score is the main index of HS, an additional *subjective* score applied to the same scale to measure how suggestive effects are experienced is thought to provide a more complete assessment of HS (Kirsch, Council, & Wickless, 1990). The subjective score showed a strong correlation with the difference in proprioceptive drift (Pearson's $r = .70$, $p < .001$), with an observed statistical power of 0.98 (Ellis, 2010; two-tailed test at $\alpha = 0.05$). Thus as predicted, significant relationships between HS and the implicit proprioceptive drift measure of the RHI were observed.

For the RHI questionnaire items, there was stronger agreement with the overall Ownership ratings in the synchronous condition (see Table 1; mean rating = 0.5, $SD = 1.8$) than in the asynchronous condition (mean rating = −1.0; $SD = 1.8$); $t(21) = 6.499$; $p < .0001$. Likewise, for the overall Location ratings, agreement was stronger in the synchronous condition (mean rating = 0.5; $SD = 1.6$) than in the asynchronous condition (mean rating = −1.1; $SD = 1.8$); $t(21) = 7.758$; $p < .0001$. Therefore, the mean difference in ratings between the experimental (synchronous) and the control (asynchronous) conditions was 1.5 ($SD = 1.8$) for mean Ownership and 1.6 ($SD = 1.7$) for mean Location ratings (Table 1),

Table 1. Mean (*SD*) Ratings (*N* = 22) for RHI Questionnaire Items Across Synchronous (Synch) and Asynchronous (Asynch) Tactile Stimulation Conditions.

Item no.	"During the experiment there were times when . . .	Synch	Asynch	Synch − Asynch
	Ownership items			
1	. . . it seemed like the rubber hand was my hand"	0.8 (1.6)	−1.0 (1.8)	1.8 (1.7)
2	. . . it seemed like the rubber hand was part of my body"	0.1 (1.9)	−1.1 (1.8)	1.2 (1.8)
3	. . . it seemed like I was looking directly at my own hand, rather than at a rubber hand"	0.4 (1.9)	−0.9 (1.8)	1.3 (1.8)
4	. . . it seemed like the rubber hand belonged to me"	0.4 (1.8)	−1.2 (1.7)	1.8 (1.7)
5	. . . it seemed like the rubber hand began to resemble my real hand"	0.7 (1.6)	−0.7 (1.8)	1.4 (1.8)
	Ownership overall mean	0.5 (1.8)	−1.0 (1.8)	1.5 (1.8)
	Location items			
6	. . . it seemed like the touch I felt was caused by the paintbrush touching the rubber hand	1.4 (1.3)	−0.9 (2.0)	2.3 (1.6)
7	. . . it seemed like the rubber hand was in the location where my hand was	−0.3 (1.8)	−1.2 (1.6)	0.9 (1.7)
8	. . . it seemed like my hand was in the location where the rubber hand was	0.3 (1.7)	−1.0 (1.8)	1.3 (1.7)
	Location overall mean	0.5 (1.6)	−1.1 (1.8)	1.6 (1.7)
	Compliance items			
9	. . . it seemed like I couldn't really tell where my hand was	−0.4 (1.3)	−1.2 (1.2)	0.8 (1.2)
10	. . . it seemed like my hand was normal	0.8 (1.2)	1.0 (1.2)	−0.2 (1.2)
11	. . . it seemed like I had three hands	−2.1 (1.0)	−1.9 (1.4)	−0.2 (1.2)

Note. Participants used a 7-point Likert scale (−3 = *strongly disagreed*; 0 = *neither agreed nor disagreed*; +3 = *strongly agreed*). Compliance items were included to detect any suggestibility-related role play during the illusion.

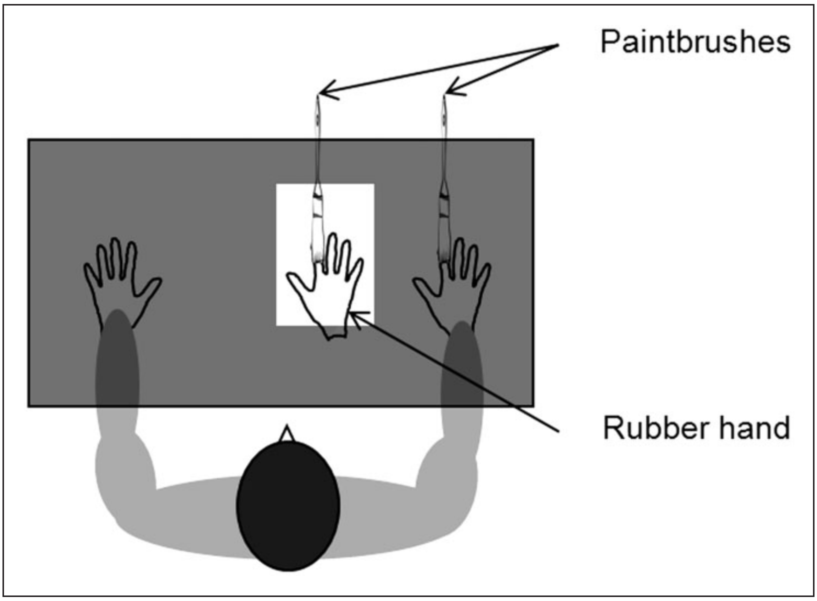

Figure 3. Schematic of experimental setup as viewed from above. No mirror was used during these procedures. The participant sat at a table and placed both hands inside a black box (top of box shown transparent here for illustration). When a lid on top of the box was raised, the participant could view a rubber hand through an aperture cut into the top of the box. Then the participant's hidden (to them) right hand and visible rubber hand were stroked with identical paintbrushes by the experimenter. In this way, participants could *feel* their right hand being stroked, while *seeing* the rubber hand being stroked. Stroking was either synchronous (as shown) or asynchronous depending on the experimental condition. The *difference* in performance between the experimental (synchronous) and the control (asynchronous) conditions gives a measure of the magnitude of the illusion.

confirming that participants experienced the RHI as measured explicitly via the RHI questionnaire.

There were no significant correlations for either standard or subjective HGSHS:A scores with the overall Ownership ratings (see Method section) for the separate synchronous (Pearson's $r = .195$) and asynchronous (Pearson's $r = .184$) conditions, nor for their difference (synchronous – asynchronous; Figure 2(b); Pearson's $r = -.068$; all $p > .373$). Likewise, there was no significant relation, for the difference (synchronous – asynchronous; Figure 2(c); Pearson's $r = -.036$ all $p > .632$) for the overall Location questionnaire data. Thus, contrary to our prediction, there was no relationship between HS and the explicit RHI questionnaire measure.

Importantly, the correlation observed between proprioceptive drift and HGSHS:A score ($r = .55$; Figure 2(a)) was significantly greater than the mean overall Ownership (Figure 2(b); $Z = 2.14493$; $p = .032$ [two tailed]) and Location (Figure 2(c); $Z = 2.1005$; $p = .036$ [two tailed]) questionnaire correlations (Steiger, 1980), demonstrating a clear dissociation between implicit and explicit measures of the RHI. Furthermore, there was no correlation between the proprioceptive drift (implicit) and RHI questionnaire (explicit) overall Ownership (Pearson's $r = .231$; $p = .301$) and Location (Pearson's $r = .216$; $p = .334$) ratings.

To control for experimental demand effects, we included compliance items (Ehrsson et al., 2004; Table 1; item numbers 9 to 11) in the RHI questionnaire. Pearson correlations indicated no significant relation with the HGSHS:A score for the first two compliance items (all $p > .283$). The correlation for the final compliance item (''It seemed like I had three hands''; Table 1; item number 11) tended toward but did not reach significance (Pearson's $r = -.387$; $p = .076$; two tailed). Twenty-one out of 22 participants disagreed with this item (the remaining participant neither agreed nor disagreed); however, participants with lower HS scores disagreed slightly more. Thus, there was no evidence that participants engaged in role-playing or compliant behavior during the RHI.

Discussion

The present study measured the relation between HS and susceptibility to the RHI. Results confirmed that participants experienced the classic illusion as measured implicitly, using mislocalization of felt finger position (proprioceptive drift), and explicitly using the RHI questionnaire (Botvinick & Cohen, 1998). As predicted, HS correlated positively with proprioceptive drift. Contrary to prediction, however, HS did not correlate with feelings of ownership and location for the rubber hand (RHI questionnaire). Furthermore, there is no evidence that participants engaged in role-playing or compliant behavior during the experimental procedures.

The finding that HS correlates with proprioceptive drift, but not the RHI questionnaire ratings, casts light on the potential mechanisms underlying both HS and the RHI. According to conceptual accounts (Blanke, 2012; Makin et al., 2008; Rohde et al., 2011; Tsakiris et al., 2010), separate mechanisms of multisensory integration underlie the spatial update of hand position (proprioceptive drift) and feeling of ownership (Longo et al., 2008; Rohde et al., 2011). Proprioceptive drift is thought to rely on visuoproprioceptive integration alone (Figure 1(a); Rohde et al., 2011), whereas the feeling of ownership is associated with visuotactile integration (Figure 1(b); Holmes, Snijders, & Spence, 2006; Rohde et al., 2011).

High HS is the propensity to respond to direct verbal suggestions for alterations in perceptual experiences and behavior (Shor & Orne, 1962), and an increased attentional capacity (Rainville et al., 2002; Tellegen & Atkinson, 1974), which may facilitate the integration of multisensory inputs and lead to a spread of attention across sensory modalities (Ramakonar, Franz, & Lind, 2011; Talsma, Senkowski, Soto-Faraco, & Woldorff, 2010). Interestingly, this facilitation seems to only occur for the visuoproprioceptive stream (Figure 1(a)), which may relate to the subjective involuntariness of ideomotor responses (e.g., ''my hand feels as if it is moving by itself'') observed during hypnotic procedures (Deeley, Walsh, et al., 2013; Oakley & Halligan, 2013; Santarcangelo, Scattina, Carli, Macerata, & Manzoni, 2008; Wallace & Hoyenga, 1980; Walsh, Mehta, et al., 2014; Walsh, Oakley, et al., 2015).

Conversely, the mechanism for visuotactile integration does not seem to interact with HS during the illusion (Figure 1(b)). Stimulus-driven, bottom-up mechanisms induced by crossmodal visuotactile interactions can automatically capture attention toward multisensory events (Tsakiris & Haggard, 2005). Previous research has mapped the visuotactile and proprioceptive integration mechanisms onto anatomically distinct neuronal regions (Ehrsson et al., 2004; Fiorio et al., 2011; Kammers et al., 2009; Tsakiris et al., 2007; Zeller, Gross, Bartsch, Johansen-Berg, & Classen, 2011). Neural activity in premotor cortex is thought to reflect the phenomenal effect of the illusion, that is, the feeling of ownership of the rubber hand (Ehrsson, 2007; Ehrsson et al., 2004; Ehrsson, Holmes, & Passingham, 2005; Limanowski & Blankenburg, 2015), whereas proprioceptive drift is associated with distinct brain areas including right posterior insula (Tsakiris et al., 2007), left inferior parietal lobule (Kammers et al., 2009), and left extrastriate body area (EBA; Wold, Limanowski, Walter, & Blankenburg, 2014). This neuroimaging evidence indicates that separate processes are involved in the feeling of ownership and in proprioceptive drift.

A rubber hand is a suggestive stimulus and may involve strong social pressure to comply by *performing* in line with the perceived demands of the experimental task (Spanos, Burgess, Cross, & MacLeod, 1992; Wagstaff, 1981). The explicit RHI questionnaire measure with its subjective character might therefore be more prone to demand characteristics (Bowers, 1966; Hilgard, 1965; Sheehan & Perry, 1977). However, no correlation was observed between HS and the RHI questionnaire or the compliance items explicitly designed to control for these effects (Table 1; Ehrsson et al., 2004). In contrast, the implicit proprioceptive drift measure, which relies on a perceptual judgement of felt finger position, and does not involve leading questions, showed the predicted association with HS. Also, there was no evidence of proprioceptive drift being automatically driven by visual dominance over somatosensation prior to stimulation (Botvinick & Cohen, 1998; Hagura et al., 2007; Pavani et al., 2000). Collectively, these findings indicate that the greater implicit response to the RHI is neither due to social compliance nor visual capture but rather may be attributable to the greater attentional abilities associated with HS. They also imply that responsiveness to direct verbal suggestions, as measured by the HGSHS:A, does not play a significant role in the RHI using the experimental procedures employed here.

Botvinick and Cohen's (1998) seminal work suggests common brain mechanisms for illusory hand ownership and proprioceptive drift. Therefore, it could be argued that the lack of a relationship between one aspect of the RHI (i.e., the explicit questionnaire) and HS implies no relationship between HS and the RHI, as classically proposed. However, recent behavioral (Holle, McLatchie, Maurer, & Ward, 2011; Kammers et al., 2009; Wold et al., 2014) and neuroimaging (Tsakiris et al., 2007) findings have indicated that the RHI is a multifacetted and complex illusion which can be broken down into separate constructs (e.g., Figure 1) and that separate cognitive multisensory mechanisms underlie different aspects of the illusion (Blanke, 2012; Makin et al., 2008; Rohde et al., 2011; Tsakiris et al., 2010). Our results indicate that HS, impacts at least one key aspect (implicit proprioceptive drift) of the illusion but not another (explicit RHI questionnaire). Another interpretation of the current finding is that participants may have perceived a change in judged location of their hand that was induced merely by tactile stimulation of their hand finger and vision of the rubber hand (i.e., visuotactile input), but that participants did not actually experience any *illusion*. However, there are a number of reasons why we believe this is not the case. First, for the Ownership questionnaire item previously shown to have the largest component loading in the experience of body-ownership during the RHI (Longo et al., 2008), that is, "it seemed like the rubber hand was my hand," participants reported a difference in rating between with the synchronous and asynchronous conditions of 1.8 (7-point scale; see Table 1, item 1; Synch − Asynch). This difference is consistent with the experience of an illusion and is comparable to other studies employing similar experimental designs (e.g., Holle et al., 2011; Tsakiris, Tajadura-Jiménez, & Costantini, 2011). Second, conceptual models (e.g., Makin et al., 2008) would predict a resultant change in explicit *ownership* ratings resulting from the integration of tactile and visual (i.e., visuotactile) input (Figure 1(b)), whereas the present results clearly show the effect is in the implicit drift data. Finally, participants' descriptions of their experience recorded immediately after the experiment are consistent with the experience of an illusion. During synchronous stimulation, representative participants reported that "It was uncanny—the rubber hand does not particularly look like my hand—it plainly is not my hand—yet it felt like she [the experimenter] was stroking my hand" or "I felt that it [the rubber hand] was my hand the instant the paintbrush touched my [real] hand.'' Together, these lines of evidence suggest that the perceived change in judged location of the hand was not due to *visuotactile* (but rather visuoproprioceptive) integration, and that participants experienced a compelling RHI.

We argue that superior attentional ability associated with high HS may facilitate the multisensory integration, which leads to perceptual mislocalization of a limb. However, an alternative and not incompatible explanation of our results proposes that HS, which can facilitate automatic response to direct verbal suggestions (Elkins et al., 2014), may have lead to hand mislocalization via implicit processes. Implicit learning is the acquisition of complex information in an incidental manner and without awareness of what has been learned (Reber, 2013). Thus, highly HS participants may have shown a greater response on the implicit localization (i.e., proprioceptive drift) measure merely because they are more susceptible to implicit cues. Indeed, improved performance in a hypnotic setting has previously been demonstrated in a procedural-based sequence learning task (Nemeth, Janacsek, Polner, & Kovacs, 2013). This line of reasoning leads to a testable hypothesis for future research: If the RHI involves implicit learning, then repeated exposures to the rubber hand paradigm should lead to change in hand localization estimates for highly suggestible participants over time.

Some caution is appropriate when considering our results in relation to HS. While the HGSHS:A (Shor & Orne, 1962) is commonly considered the *gold standard*, there are other measures of HS (e.g., Barnier & McConkey, 2004; Bowers, 1993; Spanos et al., 1983; Weitzenhoffer & Hilgard, 1962). Any one measure of HS does not necessarily produce a completely reliable measure and does not correlate perfectly with other single measures, of HS (Halligan & Oakley, 2013). Furthermore, there is clear phenomenological and behavioral evidence of two subtypes of highly suggestible individuals (McConkey & Barnier, 2004; Sheehan & McConkey, 1982; Terhune & Cardeña, 2010). Distinct subtypes of highly HS individuals have been identified (Barber, 1999; Terhune & Cardeña, 2010), including *dissociative* participants who, in response to a hypnotic induction, exhibit pronounced distortions in awareness, relative to a second subtype of highly HS participants, who are characterized by endogenously directed attention. The dissociative subtype may be more prone to experiences of greater distortion in *bodily* awareness and may therefore prove to be more susceptible to the RHI.

Future work could examine the relation of HS with other behavioral and physiological correlates of the RHI, for example, skin temperature, which cools during the illusion (Moseley et al., 2008). Skin temperature correlates with an explicit *subjective* rating of illusion, that is, *vividness* (Moseley et al., 2008), hinting that no relationship may exist between HS and thermal measures of limb ownership. However, the insula which is implicated in proprioceptive drift (see earlier) is also associated with the sensation of cooling (Hua, Strigo, Baxter, & Johnson, 2005); this region could be involved in the cooling of the counterpart real hand that can accompany feelings of ownership of a rubber hand (Moseley et al., 2008). Further research could also explore whether individual differences in HS extend to the perceptual illusion of body swapping (Petkova et al., 2011; Salomon, Lim, Pfeiffer, Gassert, & Blanke, 2013). An interesting research question is whether hypnotic procedures (Deeley, Oakley, et al., 2013; Walsh, Oakley, et al., 2015) would further modulate performance during the RHI. First, a formal hypnotic induction procedure which can help participants ''to enter a hypnotic state'' (Mazzoni, Venneri, McGeown, & Kirsch, 2013) is predicted to enhance attentional focus thereby increasing the implicit response to the RHI. Second, *targeted* suggestions given after a hypnotic induction procedure could be employed to create additional specific changes in perceptual experience or behavior, for example, ''at the sound of a tone, you will, ('or will not', dependent on the experimental condition) experience the 'hand' you see in front of you as your hand." Direct verbal suggestions targeting hand ownership have previously been shown to manipulate subjective ratings relating to the hand (Deeley, Walsh, et al., 2013; Walsh, Mehta, et al., 2014; Walsh, Oakley, et al., 2015) and may therefore indirectly affect explicit RHI questionnaire ratings. Such research could have experimental and clinical significance given the potential role of suggestion in the etiology and treatment of clinical symptoms involving body image and embodiment.

In conclusion, HS scores predicted differences in proprioceptive drift but not in subjective experience. These findings help clarify what distinguishes participants who exhibit proprioceptive drift toward the rubber hand during the illusion from those who do not. The superior attentional ability associated with high HS may facilitate the multisensory integration of visuoproprioceptive inputs leading to a greater perceptual mislocalization of an experimental participant's real hand toward the rubber hand. A better understanding of the experiences and conditions underlying our rich and complex, yet elusive, sense of embodiment may have far-reaching effects on human development and quality of life.

Method

Twenty-three healthy, English-speaking participants (all right-handed as assessed by the Edinburgh Handedness Inventory; 14 female) were recruited randomly from a pool of approximately 350 volunteers, who were screened 12 to 24 months previously for suggestibility in a hypnotic context using the Harvard Group Scale (HGSHS:A; Shor & Orne, 1962). Participants' mean HGSHS:A score was 6.2 ($SD = 3.8$; range 0–11) and their mean age was 34.0 ($SD = 13.4$) years. The study was approved by the King's College London ethics committee and conducted in accordance with the Helsinki Declaration (2008). All participants provided written informed consent.

Briefly, participants sat at a table wearing a smock that concealed their arms and placed both hands inside a black box (Figure 3). No mirror was used during these procedures. A lid on top of the box could be raised to reveal the rubber hand to the participant, while simultaneously concealing the experimenter from view. At the start of each block, participants placed both hands inside the box and were instructed not to move. Next participants reported their felt right index finger position using a random offset ruler (prestimulation finger position). The lid was raised and a 2-min stimulation phase began in which the index and middle fingers of the participant's right hand (not visible to the participant) and the (visible) rubber hand were stroked using identical paintbrushes, at a rate of one stroke per second. In the synchronous condition, the participant's right hand and the visible rubber hand were stroked simultaneously, while in the asynchronous condition stroking was 180° out of phase. At the end of 2 min, tactile stimulation ceased, the lid of the box was lowered concealing the rubber hand, and a postinduction proprioceptive location of the participant's right index finger was taken (poststimulation finger position). Participants then removed their hands from the box to complete an 11-item pen and paper questionnaire (see Table 1). Items in the questionnaire were based on those from Longo et al. (2008); five items relate to the component of Ownership (Table 1; numbers 1–5), and three items to the component of Location (Table 1; numbers 6–8) associated with the RHI. The last three items served as controls for suggestibility and task compliance (Table 1; numbers 9 to 11; Ehrsson et al., 2004). The experiment consisted of eight blocks (four synchronous and four asynchronous), lasting 2 min each. The order of presentation of the synchronous and asynchronous blocks was randomized across participants. Participants completed a questionnaire at the end of each block. The order of questionnaire items was randomized for each participant from block to block. Experimenter DNG, a visiting United States researcher, conducted the experiment, was unknown to all participants and blind to their HS scores during testing. No hypnotic induction or targeted suggestions were used and the terms *hypnosis* or *illusions* were not mentioned throughout (Gandhi & Oakley, 2005).

Pearson correlations were performed for HGSHS:A scores for all participants ($N = 23$) to explore the linear relation of HS with both the implicit (proprioceptive drift) and explicit (RHI questionnaire) outcome measures. The Cook's distance (D_i) statistic was used to identify outliers and influential points. Cook's D was calculated using the cutoff of $D_i = 0.174$ (4/n; where n is the sample size; Bollen & Jackman, 1990). Twenty-two of the 23 observations were less than the cutoff (mean Cook's distance = 0.025; $SD = 0.025$; range 0.002 to 0.079). However, one observation point had a Cook's distance of 0.333, in excess of the cutoff, and was removed from the analysis. The significant correlation of the difference (i.e., synchronous minus asynchronous) did not change when the regression was performed with ($r = .49$; $p = .019$) or without ($r = .70$; $p < .001$) this outlying data point. For the RHI questionnaire items, ratings from the five ownership and three location questions were collapsed to form overall Ownership and Location difference scores (Table 1).

Conflict of interest

None declared.

Funding

This work was supported by grants from the Psychiatry Research Trust (to E. W. and Q. D.) and the Panacea Society (to Q. D. and M. M.).

References

Barber, T. X. (1999). A comprehensive three-dimensional theory of hypnosis. In I. Kirsch, A. Capafons, E. Cardeña-Buelna, & S. Amigó (Eds.), *Clinical Hypnosis and Self-regulation: Cognitive-behavioral Perspectives* (pp. 21–48). Washington, DC: American Psychological Association.

Barnier, A. J., & McConkey, K. M. (2004). Defining and identifying the highly hypnotizable person. In M. Heap, R. J. Brown, & D. A. Oakley (Eds.), *The highly hypnotizable person: Theoretical, experimental and clinical issues* (pp. 30–61). London, UK: Routledge.

Blanke, O. (2012). Multisensory brain mechanisms of bodily self-consciousness. *Nature Reviews Neuroscience*, *13*, 556–571.

Bollen, K. A., & Jackman, R. W. (1990). Regression diagnostics: An expository treatment of outliers and influential cases. In J. Fox, & J. Scott Long (Eds.), *Modern methods of data analysis* (pp. 257–291). Newsbury Park, CA: SAGE.

Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel' touch that eyes see. *Nature*, *391*, 756–756.

Bowers, K. (1966). Hypnotic behavior: The differentiation of trance and demand characteristic variables. *Journal of Abnormal Psychology*, *71*, 42.

Bowers, K. S. (1993). The Waterloo-Stanford Group C (WSGC) scale of hypnotic susceptibility: Normative and comparative data. *International Journal of Clinical and Experimental Hypnosis*, *41*, 35–46.

Braffman, W., & Kirsch, I. (1999). Imaginative suggestibility and hypnotizability: An empirical analysis. *Journal of Personality and Social Psychology*, *77*, 578.

Cash, T. F. (2004). Body image: Past, present, and future. *Body Image*, *1*, 1–5.

Crawford, H. J., & Gruzelier, J. H. (1992). A midstream view of the neuropsychophysiology of hypnosis: Recent research and future directions. In E. Fromm, & M. R. Nash (Eds.), *Contemporary hypnosis research*. New York, NY: Guildford Press.

Deeley, Q., Oakley, D. A., Toone, B., Bell, V., Walsh, E., Marquand, A. F., . . . Halligan, P. W. (2013). The functional anatomy of suggested limb paralysis. *Cortex*, *49*, 411–422.

Deeley, Q., Oakley, D. A., Toone, B., Giampietro, V., Brammer, M. J., Williams, S. C., . . . Halligan, P. W. (2012). Modulating the default mode network using hypnosis. *The International Journal of Clinical and Experimental Hypnosis*, *60*, 206–228.

Deeley, Q., Walsh, E., Oakley, D. A., Bell, V., Koppel, C., Mehta, M. A., . . . Halligan, P. W. (2013). Using Hypnotic Suggestion to Model Loss of Control and Awareness of Movements: An Exploratory fMRI Study. *PLoS One*, *8*, e78324.

Ehrsson, H. H. (2007). The experimental induction of out-of-body experiences. *Science*, *317*, 1048.

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. *The Journal of Neuroscience*, *25*, 10564–10573.

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*, 875–877.

Elkins, G. R., Barabasz, A. F., Council, J. R., & Spiegel, D. (2014). Advancing Research and Practice: The Revised APA Division 30 Definition of Hypnosis. *International Journal of Clinical and Experimental Hypnosis*, *63*, 1–9.

Ellis, P. D. (2010). *The essential guide to effect sizes: Statistical power, meta-analysis, and the interpretation of research results*. New York, NY: Cambridge University Press.

Fehr, F. S., & Stern, J. A. (1970). Peripheral physiological variables and emotion: The James-Lange theory revisited. *Psychological Bulletin*, *74*, 411.

Fiorio, M., Weise, D., Önal-Hartmann, C., Zeller, D., Tinazzi, M., Classen, J. (2011). Impairment of the rubber hand illusion in focal hand dystonia. *Brain*, *134*, 1428–37.

Gandhi, B., & Oakley, D. A. (2005). Does 'hypnosis' by any other name smell as sweet? The efficacy of 'hypnotic'inductions depends on the label 'hypnosis'. *Consciousness and Cognition*, *14*, 304–315.

Ghilardi, M. F., Gordon, J., & Ghez, C. (1995). Learning a visuomotor transformation in a local area of work space produces directional biases in other areas. *Journal of Neurophysiology*, *73*, 2535–2539.

Hagura, N., Takei, T., Hirose, S., Aramaki, Y., Matsumura, M., Sadato, N., . . . Naito, E. (2007). Activity in the posterior parietal cortex mediates visual dominance over kinesthesia. *The Journal of Neuroscience*, *27*, 7047–7053.

Halligan, P. W., & Oakley, D. A. (2013). Hypnosis and cognitive neuroscience: Bridging the gap. *Cortex*, *49*, 359–364.

Hilgard, E. R. (1965). *Hypnotic susceptibility*. New York, NY: Harcourt, Brace & World.

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*, 171–178.

Holmes, N. P., Snijders, H. J., & Spence, C. (2006). Reaching with alien limbs: Visual exposure to prosthetic hands in a mirror biases proprioception without accompanying illusions of ownership. *Perception & Psychophysics*, *68*, 685–701.

Hua, L. H., Strigo, I. A., Baxter, L. C., & Johnson, S. C. (2005). Anteroposterior somatotopy of innocuous cooling activation focus in human dorsal posterior insular cortex. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, *289*, R319–R325.

Ionta, S., Sforza, A., Funato, M., & Blanke, O. (2013). Anatomically plausible illusory posture affects mental rotation of body parts. *Cognitive, Affective, & Behavioral Neuroscience*, *13*, 197–209.

Jamieson, G. A., & Sheehan, P. W. (2004). An empirical test of Woody and Bowers's dissociated-control theory of hypnosis. *The International Journal of Clinical and Experimental Hypnosis*, *52*, 232–249.

Kammers, M., de Vignemont, F., Verhagen, L., & Dijkerman, H. C. (2009). The rubber hand illusion in action. *Neuropsychologia*, *47*, 204–211.

Kirsch, I., Council, J. R., & Wickless, C. (1990). Subjective scoring for the Harvard Group Scale of Hypnotic Susceptibility, Form A. *The International Journal of Clinical and Experimental Hypnosis*, *38*, 112–124.

Limanowski, J., & Blankenburg, F. (2015). Network activity underlying the illusory self-attribution of a dummy arm. *Human Brain Mapping*, *36*, 2284–2304.

Longo, M. R., Schüür, F., Kammers, M. P., Tsakiris, M., & Haggard, P. (2008). What is embodiment? A psychometric approach. *Cognition*, *107*, 978–998.

Longo, M. R., Schüür, F., Kammers, M. P., Tsakiris, M., & Haggard, P. (2009). Self awareness and the body image. *Acta Psychologica*, *132*, 166–172.

McConkey, K., & Barnier, A. (2004). High hypnotisability: unity and diversity in behaviour and experience. In M. Heap, R. J. Brown, & D. A. Oakley (Eds.), *The highly hypnotizable person: Theoretical, experimental and clinical issues* (pp. 61–84). London: Routledge.

Makin, T. R., Holmes, N. P., & Ehrsson, H. H. (2008). On the other hand: Dummy hands and peripersonal space. *Behavioural Brain Research*, *191*, 1–10.

Mazzoni, G., Venneri, A., McGeown, W. J., & Kirsch, I. (2013). Neuroimaging resolution of the altered state hypothesis. *Cortex*, *49*, 400–410.

Miller, R. J. (1975). Response to the Ponzo illusion as a reflection of hypnotic susceptibility. *The International Journal of Clinical and Experimental Hypnosis*, *23*, 148–157.

Mitchell, M. B. (1970). Hypnotizability and distractibility. *American Journal of Clinical Hypnosis*, *13*, 35–45.

Moseley, G. L., Olthof, N., Venema, A., Don, S., Wijers, M., Gallace, A., . . . Spence, C. (2008). Psychologically induced cooling of a specific body part caused by the illusory ownership of an artificial counterpart. *Proceedings of the National Academy of Sciences*, *105*, 13169–13173.

Nemeth, D., Janacsek, K., Polner, B., & Kovacs, Z. A. (2013). Boosting human learning by hypnosis. *Cerebral Cortex*, *23*, 801–805.

Nuys, D. V. (1973). Meditation, attention, and hypnotic susceptibility: A correlational study. *The International Journal of Clinical and Experimental Hypnosis*, *21*, 59–69.

Oakley, D. A., & Halligan, P. W. (2013). Hypnotic suggestion: Opportunities for cognitive neuroscience. *Nature Reviews Neuroscience*, *14*, 565–576.

Pavani, F., Spence, C., & Driver, J. (2000). Visual capture of touch: Out-of-the-body experiences with rubber gloves. *Psychological Science*, *11*, 353–359.

Petkova, V. I., Bjornsdotter, M., Gentile, G., Jonsson, T., Li, T. Q., & Ehrsson, H. H. (2011). From part- to whole-body ownership in the multisensory brain. *Current Biology*, *21*, 1118–1122.

Piccione, C., Hilgard, E. R., & Zimbardo, P. G. (1989). On the degree of stability of measured hypnotizability over a 25-year period. *Journal of Personality and Social Psychology*, *56*, 289.

Power, R., & Day, R. (1973). Constancy and illusion of apparent direction of rotary motion in depth: Tests of a theory. *Perception & Psychophysics*, *13*, 217–223.

Rainville, P., Hofbauer, R. K., Bushnell, M. C., Duncan, G. H., & Price, D. D. (2002). Hypnosis modulates activity in brain structures involved in the regulation of consciousness. *Journal of Cognitive Neuroscience*, *14*, 887–901.

Ramakonar, H., Franz, E. A., & Lind, C. R. (2011). The rubber hand illusion and its application to clinical neuroscience. *Journal of Clinical Neuroscience*, *18*, 1596–1601.

Reber, P. J. (2013). The neural basis of implicit learning and memory: A review of neuropsychological and neuroimaging research. *Neuropsychologia*, *51*, 2026–2042.

Rohde, M., Di Luca, M., & Ernst, M. O. (2011). The rubber hand illusion: feeling of ownership and proprioceptive drift do not go hand in hand. *PLoS One*, *6*, e21659.

Salomon, R., Lim, M., Pfeiffer, C., Gassert, R., & Blanke, O. (2013). Full body illusion is associated with widespread skin temperature reduction. *Frontiers in Behavioral Neuroscience, 7*. doi: 65 10.3389/fnbeh.2013.00065

Santarcangelo, E. L., Scattina, E., Carli, G., Macerata, A., & Manzoni, D. (2008). Hypnotizability-dependent modulation of postural control: Effects of alteration of the visual and leg proprioceptive inputs. *Experimental Brain Research*, *191*, 331–340.

Schütz-Bosbach, S., Avenanti, A., Aglioti, S. M., & Haggard, P. (2009). Don't do it! Cortical inhibition and self-attribution during action observation. *Journal of Cognitive Neuroscience*, *21*, 1215–1227.

Schütz-Bosbach, S., Tausche, P., & Weiss, C. (2009). Roughness perception during the rubber hand illusion. *Brain and Cognition*, *70*, 136–144.

Sheehan, P. W., & McConkey, K. M. (1982). *Hypnosis and experience: The exploration of phenomena and process*. Hillsdale, NJ: Erlbaum.

Sheehan, P. W., & Perry, C. W. (1977). *Methodologies of hypnosis: A critical appraisal of contemporary paradigms of hypnosis*. Hillsdale, New Jersey: Erlbaum.

Shor, R. E., & Orne, E. C. (1962). *Harvard Group Scale of Hypnotic Susceptibility*. Palo Alto, CA: Consulting Psychologists Press.

Spanos, N. P., Burgess, C. A., Cross, P. A., & MacLeod, G. (1992). Hypnosis, reporting bias, and suggested negative hallucinations. *Journal of Abnormal Psychology*, *101*, 192.

Spanos, N. P., Radtke, H. L., Hodgins, D. C., Bertrand, L. D., Stam, H. J., & Dubreuil, D. L. (1983). The carleton university responsiveness to suggestion scale: Stability, reliability, and relationships with expectancy and ‘‘hypnotic experiences’’. *Psychological Reports*, *53*, 555–563.

Steiger, J. H. (1980). Tests for comparing elements of a correlation matrix. *Psychological Bulletin*, *87*, 245.

Talsma, D., Senkowski, D., Soto-Faraco, S., & Woldorff, M. G. (2010). The multifaceted interplay between attention and multisensory integration. *Trends in Cognitive Sciences*, *14*, 400–410.

Tellegen, A., & Atkinson, G. (1974). Openness to absorbing and self-altering experiences (‘‘absorption’’), a trait related to hypnotic susceptibility. *Journal of Abnormal Psychology*, *83*, 268.

Terhune, D. B., & Cardeña, E. (2010). Differential patterns of spontaneous experiential response to a hypnotic induction: A latent profile analysis. *Consciousness and Cognition*, *19*, 1140–1150.

Tsakiris, M., & Haggard, P. (2005). The rubber hand illusion revisited: Visuotactile integration and self-attribution. *Journal of Experimental Psychology: Human Perception and Performance*, *31*, 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*, 2235–2244.

Tsakiris, M., Longo, M. R., & Haggard, P. (2010). Having a body versus moving your body: Neural signatures of agency and body-ownership. *Neuropsychologia*, *48*, 2740–2749.

Tsakiris, M., Tajadura-Jiménez, A., & Costantini, M. (2011). Just a heartbeat away from one's body: interoceptive sensitivity predicts malleability of body-representations. *Proceedings of the Royal Society of London B: Biological Sciences*, *278*, 2470–2476.

Wagstaff, G. F. (1981). *Hypnosis, compliance and belief*. New York, NY: St. Martin's Press.

Wallace, B. (1988). Hypnotic susceptibility, visual distraction, and reports of Necker Cube apparent reversals. *The Journal of General Psychology*, *115*, 389–396.

Wallace, B., & Hoyenga, K. B. (1980). Production of proprioceptive errors with induced hypnotic anesthesia. *The International Journal of Clinical and Experimental Hypnosis*, *28*, 140–147.

Wallace, B., Knight, T. A., & Garrett, J. B. (1976). Hypnotic susceptibility and frequency reports to illusory stimuli. *Journal of Abnormal Psychology*, *85*, 558.

Walsh, E., Mehta, M., Oakley, D., Guilmette, D., Gabay, A., Halligan, P., . . . Deeley, Q. (2014). Using suggestion to model different types of automatic writing. *Consciousness and Cognition*, *26*, 24–36.

Walsh, E., Oakley, D. A., Halligan, P. W., Mehta, M. A., & Deeley, Q. (2015). The functional anatomy and connectivity of thought insertion and alien control of movement. *Cortex*, *64*, 380–393.

Weitzenhoffer, A. M., & Hilgard, E. R. (1962). *Stanford hypnotic susceptibility scale, form C*. Palo Alto, CA: Consulting Psychologists Press.

Wold, A., Limanowski, J., Walter, H., & Blankenburg, F. (2014). Proprioceptive drift in the rubber hand illusion is intensified following 1 Hz TMS of the left EBA. *Frontiers in Human Neuroscience*, *8*, 390.

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. *The Journal of Neuroscience*, *31*, 4852–4857.