The Body-ownership is Unconsciously Distorted in the Brain: An Event-related Potential Study of Rubber Hand Illusion[*]

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Many studies have reported that bottom-up multisensory integration of visual, tactile, and proprioceptive information can distort our sense of body-ownership, producing rubber hand illusion (RHI). There is less evidence about when and how the body-ownership is distorted in the brain during RHI. To examine whether this illusion effect occurs preattentively at an early stage of processing, we monitored the visual mismatch negativity (vMMN) component (the index of automatic deviant detection) and N2 (the index for conflict monitoring). Participants first performed an RHI elicitation task in a synchronous or asynchronous setting and then finished a passive visual oddball task in which the deviant stimuli were unrelated to the explicit task. A significant interaction between Deviancy (deviant hand vs. standard hand) and Group (synchronous vs. asynchronous) was found. The asynchronous group showed clear mismatch effects in both vMMN and N2, while the synchronous group had such effect only in N2. The results indicate that after the elicitation of RHI bottom-up integration could be retrieved at the early stage of sensory processing before top-down processing, providing

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evidence for the priority of the bottom-up processes after the generation of RHI and revealing the mechanism of how the body-ownership is unconsciously distorted in the brain.

Keywords: rubber hand illusion, body-ownership, visual mismatch negativity, ERP

Highlights:

- Bottom-up integration could be retrieved at the early stage of sensory processing.
- Bottom-up processes precede top-down process when generating RHI.
- RHI can automatically affect bodily and social perception.

The sense of body-ownership, a critical component of self-consciousness, refers to how we feel our bodies as our own (Evans & Blanke, 2013). Recent evidence has suggested that numerous brain regions could contribute to the sense of body-ownership (Grivaz et al., 2017), including the parietal cortex (e.g., Apps et al., 2015; Guterstam et al., 2015; Isayama et al., 2019), premotor cortex (e.g., Apps et al., 2015; Bekrater-Bodmann et al., 2014; Gentile et al., 2013; Lee & Chae, 2016), and insula (e.g., Apps et al., 2015; Limanowski et al., 2014). Other neuroscience research has also shown that these brain regions hold the mental models of one's own body perception (e.g., Kanayama et al., 2009; Preston, 2013). In order to successfully interact with the environment, body perception is constantly updated in response to sensory input from inside and outside the body.

Our understanding of body-ownership has increased significantly after the discovery of the rubber hand illusion (RHI; Botvinick & Cohen, 1998). The RHI refers to the illusory sense of ownership of a dummy hand that is stroked while one's unseen hand is stroked synchronously. So far, a variety of models have been proposed to clarify the underlying mechanisms of RHI. Model favoring top-down processing has posited that the strength of RHI was modulated by the pre-existing body model. In other words, the greater the difference between the to-be-integrated object and the pre-existing body model (such as space, posture, and texture), the weaker, even disappear, the sense of ownership over the to-be-integrated object (e.g., Haans et al., 2008; Ide, 2013; Lloyd, 2007). For example, Lloyd (2007) revealed that RHI became stronger and stronger as the rubber hand and the subject's hand became more and more structurally similar when their distance was within 30 cm. Ide (2013) found that participants perceived higher ownership of the stimulated rubber hand when the angles were at 0°, 45°, 90°, and 315° (easy to mimic with the actual hand) than at 180°, 225°, and 270° (difficult to mimic with the actual hand), suggesting that the occurrence of RHI was affected by anatomical plausibility. Haans et al. (2008) reported that a natural skin texture increased the strength of the RHI for a hand-shaped object, but not for a non-hand-shaped object.

However, the model favoring purely bottom-up processing has suggested that the changed body ownership was simply constructed based on the temporal congruency between different sensory modalities (Armel & Ramachandran, 2003). That is, the detection of visuo-tactile temporal congruency is sufficient for the objects to be fully incorporated into the internal body model (Braun et al., 2018). The findings of RHI (Botvinick & Cohen, 1998), rubber foot illusion (Flögel et al., 2016), cat claw illusion (Chen et al., 2017), and the illusion based on things without visual resemblance with the body such as a table (Armel & Ramachandran, 2003) and the virtual balloon and square (Ma & Hommel, 2015) support this model.

Recently, Tsakiris (2010) put forward the Neurocognitive Model of body-ownership and proposed that the occurrence of RHI depended on the interaction between current multisensory inputs and internal models of the body. First, a pre-existing internal body model differentiates whether the to-be-integrated objects are part of one's body (top-down processing). Second, on-line anatomical and postural representations of the body regulate the integration of multisensory information, leading to the recalibration of visual and tactile coordinate systems (the interaction between top-down and bottom-up processing). Finally, the resulting tactile associations produce the subjective body-ownership experience of the to-be-integrated object.

There is a general consensus that certain semantic top-down constraints affect how the objects may be incorporated. That is, to-be-integrated objects should be structurally similar to the visual representations in the internal body model. However, empirical evidence has shown that the sense of ownership may extend to objects strikingly distinct in morphology and structure (e.g., balloon) and the hypothesis about the relevance of appearance cannot exclude the involvement of bottom-up constraints on the production of body-ownership over to-be-integrated objects. Thus, bottom-up processing could be a more promising model for revealing the mechanism of body-ownership. Following this line, one critical issue remains to be addressed: whether sensory illusion is activated rapidly and influences early visual processing during RHI. Specifically, could bottom-up integration be achieved at the early stage of sensory processing before top-down processing? The answer to this question could help explain whether body-ownership is unconsciously distorted in the brain.

Recently, RHI has received increasing attention in cognitive neural research (e.g., Bekrater-Bodmann et al., 2014; Lee & Chae, 2016; Rao & Kayser, 2017; Zeller et al., 2015). For example, Rao and Kayser (2017) observed that a consistent illusion-related attenuation of ERP (event-related potential) occurred around 330 ms over frontocentral areas with frontal alpha and beta power decreasing during the illusion. Lee and Chae (2016) using fMRI (functional magnetic resonance imaging) showed that tactile and visual afferent inputs could affect the connectivity patterns driven by disowned bodily states. That is, tactile information changed the brain network by directly influencing activity in the secondary somatosensory cortex, whereas visual information changed the brain

network by influencing both the secondary somatosensory cortex and the lateral occipitotemporal cortex. Other studies found that the visual cortex played an important role in the re-instantiation of body-ownership (e.g., Faivre et al., 2017; Kanayama et al., 2017; Zeller et al., 2016).

In addition to revealing the neural substrates underlying mechanisms of the RHI, it is also important to examine the mechanism that how the body-ownership is distorted in the brain during RHI. The current study focused on whether the body-ownership could be distorted at the early, preattentive perceptual processing stage. Visual mismatch negativity (vMMN) is an event-related brain potential component that is typically elicited by stimuli with infrequent (deviant) features embedded among frequent (standard) stimuli, outside the focus of attention.

It is a tool to probe the mechanisms of automatic change detection in various aspects of human cognition (Czigler, 2014). For example, Mo et al., (2011) showed the amplitude of the vMMN evoked by the within-category deviant was significantly smaller than that evoked by the between-category deviant, suggesting that the Whorfian effect per se occurs out of awareness and at an early stage of processing. Stefanics and Czigler (2012) used a visual oddball paradigm and found mismatch responses to hands with unexpected laterality in the periphery of the visual field, suggesting the automatically continuous monitoring of the left or right identity of hands in the observer's ego-centric spatial reference frame. Briefly, these studies showed that vMMN could reflect the brain's early and automatic change in response to a deviant stimulus and serve as an electrophysiological index of preattentive change detection.

In the present study, we used ERP techniques and examined the dynamic processing of RHI, focusing on whether bottom-up integration could be retrieved at the early stage of sensory processing before top-down processing RHI. To our knowledge, there has been no study on the issue of whether the RHI could take place early, automatically, and out of awareness. Adapting Botvinick and Cohen's paradigm (1998), we first elicited Chinese participants' RHI with a black rubber hand as the to-be-integrated object in a synchronous or asynchronous setting. Following two short measurements of RHI, participants immediately completed a passive visual oddball task which is widely used to detect the vMMN component (e.g., Mo et al., 2011). We compared the vMMN elicited by the yellow hand to that elicited by the black hand between the synchronous setting (experimental group) and the asynchronous setting (control group).

We expected that if RHI was successfully elicited only in the synchronous setting (i.e., black rubber hand is incorporated into the participants' pre-existing internal body model) but not in the asynchronous setting, a typical vMMN effect would be found in the asynchronous condition rather than in the synchronous condition. After the successful elicitation of RHI, the black hand is embodied as a part of the internal body model. Thus, the different black hand deviants elicit a smaller vMMN response in synchronous condition than in asynchronous condition, revealing that RHI could incur bottom-up distortion at the early, preattentive perceptual processing stage.

Method

Participants

Forty-six Chinese undergraduate students participated in this study for monetary compensation. All were right-handed and had a normal or corrected-to-normal vision. They had no neurological disorders or any major heading injury and were ethnic Chinese. Written informed consent was obtained from each participant. The Institutional Review Board of the South China Normal University (Guangzhou, China) approved this study. Data from two participants in the asynchronous group were eliminated due to excessive EEG (electroencephalogram) artifacts. The final sample consisted of forty-four participants (mean age: 21.16 ± 1.87 years, 24 males and 20 females).

Materials and Procedure

As shown in Figure 1a, the yellow/black hands were used in the current study. Based on Botvinick and Cohen's (1998) early work about RHI, numerous studies have used hand-based procedures to elicit RHI (Isayama et al., 2019; Maister et al., 2013; Zeller et al., 2016). For example, Maister et al. (2013) found that light-skinned participants (e.g., Caucasian participants) could experience body-ownership illusion over a dark-skinned virtual body (e.g., a black rubber hand). Since the skin of the Chinese participants was yellow, we used yellow hands, which were perceived as a part of their own body, and black hands which were perceived as a part of a foreign body. The yellow and black feet were used as fillers.

The experimental session consisted of two successive parts: the first part was a replication of the procedure used in Botvinick and Cohen (1998) in which RHI was elicited with synchronous or asynchronous timing of stimulation, while in the second part we used the oddball paradigm with four types of stimuli (i.e., black-skin hand, yellow-skin hand, black-skin foot, and yellow-skin foot). Participants were randomly allocated to one of two different timing stimulation groups: (a) the synchronous timing stimulation group ($n = 23$ subjects, 13 males) and (b) the asynchronous timing stimulation group ($n = 21$ subjects, 11 males).

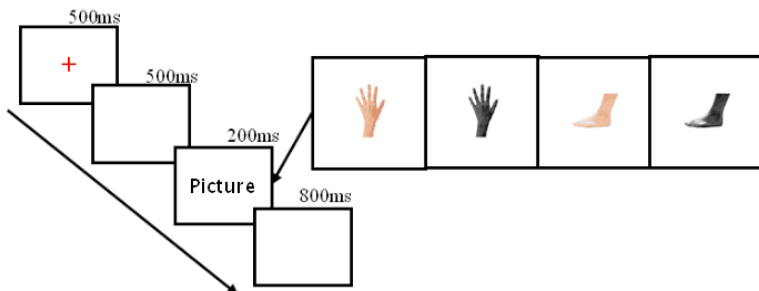**Figure 1a**
Experimental design and sample of stimulus sequences presented in the experimental blocks

Figure 1b
Stimuli and structure of a trial in the vMMN paradigm in Part 2. Stimuli were flashed for 200 ms with an interval of 800 ms

For RHI induction, participants placed their left and right hands on the table, about 30 cm apart from each other. A black lifelike rubber hand was positioned close to the left hand which was behind a barrier, rendering the left hand hidden from the participant's view but the rubber hand being seen. An experimenter placed a towel over the participant's shoulder to cover his/her upper arm, making the rubber hand seem attached to the body. The participants were instructed to watch the rubber hand with their fingers being brushed for 3 minutes, either synchronously or asynchronously (180 degrees out-of-phase).

Similar to Petkova et al. (2012), before and after tactile stimulation, the measurement of proprioceptive drift was taken. A 60 cm long ruler was placed 10 cm in front of and perpendicular to the participant's right hand. Participants were asked to place their right index finger on the ruler and slide it towards their left index finger along the ruler with their eyes being closed and covered by a blinder. The proprioceptive drift was calculated as the difference in pointing before and after the rubber hand illusion. To reduce the random error, we asked participants to point with their right index finger towards their left index finger twice and took the average as the pre-test or post-test performance of proprioceptive drift.

After the proprioceptive drift measure, participants completed five items measuring bodily self-consciousness adopted from the research of Longo et al. (2008). They introspectively reported the RHI by rating the degree to which they thought to own the rubber hand on a 7-point Likert scale from -3 = *strongly disagree* to +3 = *strongly agree* with 0 indicating neither agreed nor disagreed. The ownership score was computed by averaging five items.

Immediately following the first part, participants completed an oddball task that allowed one to obtain vMMN in a short time. During each trial, a cross was first presented as a fixation mark at the center of the screen for 500 ms. After a 500 ms blank screen, a left hand or a left foot was flashed for 200 ms against a white background with an inter-stimulus interval of 800 ms (see Figure 1b). Participants were asked to press the spacebar with the left or right index finger when "target" stimuli (a yellow or a black foot) appeared. The finger responses were counterbalanced across participants.

The participants viewed two blocks of trials with each consisting of 380 trials. Within a block, a yellow or black hand served as the standard throughout. That is, there was one block with a yellow-hand standard and a black-hand deviant, and another block with a black-hand standard and a yellow-hand deviant. Within each block, 70% of the trials were "standard (e.g., a yellow hand)", 10% of the trials were deviant trials (e.g., a black hand), 20% were "target" trials (i.e., 10% for yellow foot and 10% for black foot). The presentation order was pseudorandomized within each block, such that the first ten trials were standard, two deviants or targets never appeared in immediate succession, and there were at least two standards in a row between two deviant stimuli. The block order was counterbalanced across participants.

EEG Recording and Analysis

EEGs were recorded from the scalp with a 64-channel Ag–AgCl electrode cap (10–20 system) with a 1000 Hz sampling rate and a 0.05–250 Hz band-pass filter, and refiltered offline with a 30-Hz low-pass zero phase shift digital filter (slope 24 dB/Oct). All the electrodes were referenced off-line to the mean of two mastoids. Vertical eye movements were monitored via supra- to sub-orbital bipolar montage. EEG and EOG data were amplified with a BrainAmp MR plus EEG amplifier. The impedance of the electrodes was maintained below 5 kΩ throughout the recording session.

Eye movement artifacts were corrected using regression-based weighting coefficients. Epochs were from -200 to 800 ms time-locked to the onset of standard and deviant hands, with artifact rejection threshold set at ± 80 µV. Average waveforms were calculated off-line excluding the hand stimuli trials immediately following targets and separated by the trial condition. A passive visual oddball task often elicits a vMMN along with other ERP components (e.g., N2). Mean ERP amplitudes were then computed for each participant for the 130-180 ms time window for the vMMN component and 220-300 ms time window for the N2 component. According to the previous studies (e.g., Mo et al., 2011), the vMMN and N2 were maximal over the lateral parietal-occipital scalp. So electrodes O1, O2, PO3, PO4, PO7, PO8, P7, and P8 were chosen for further analysis in the current study.

Results

Results in Ownership Score and Proprioceptive Drift

One-way analyses of variance (ANOVA) on ownership score and proprioceptive drift were conducted with Group (synchronous vs. asynchronous) as the between-subject factor. There was a significant difference in ownership score between synchronous and asynchronous conditions ($F(1, 42) = 58.96$, $p < .001$, $\eta_p^2 = .58$), with participants in the synchronous group yielding higher ownership score (1.37) than those in the asynchronous group (-0.95). Additionally, participants in synchronous group showed a significantly greater proprioceptive drift compared to those in the asynchronous group (2.93 vs. -0.31; $F(1, 42) = 24.45$, $p < .001$, $\eta_p^2 = .37$). These results confirmed the successful manipulation of synchronous and asynchronous settings.

Results in Detection Task

The behavioral results are presented in Table 1. The mean accuracy of target stimuli was at ceiling (> 99%) and the reaction time was less than 200 ms in synchronous and asynchronous groups, indicating that participants were attentive to the target stimuli and could easily distinguish foot from hand. Additionally, the reaction time showed no significant effect for Group. Figure 2 showed a summary of the grand-averaged ERP waveforms time-locked to the standard and deviant hands onset.

Table 1
The Mean (SDs) of accuracy and reaction times (ms) of target stimuli in synchronous and asynchronous groups

	Accuracy	Reaction Times
Synchronous group	0.991 (0.011)	181 (53)
Asynchronous group	0.998 (0.005)	172 (45)

Figure 2a

Grand average ERP waveforms over bilateral parietooccipital electrodes (linear derivation of O1, O2, PO3, PO4, PO7, PO8, P7, P8) for all conditions
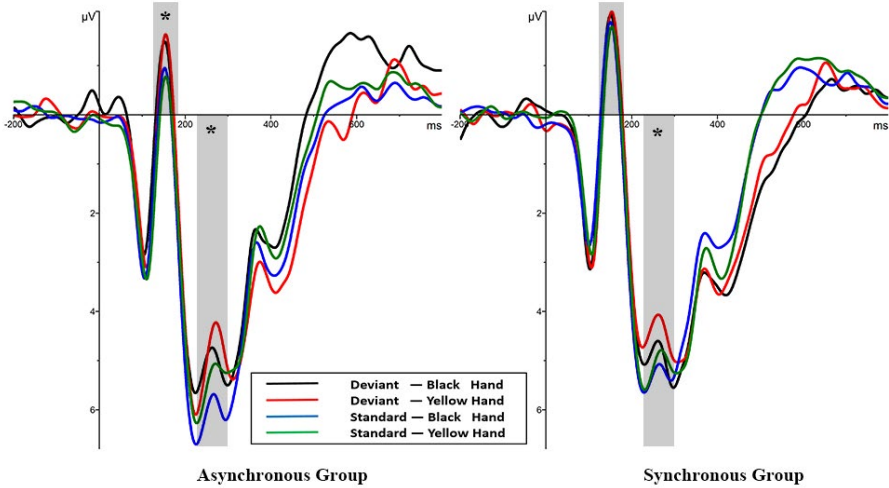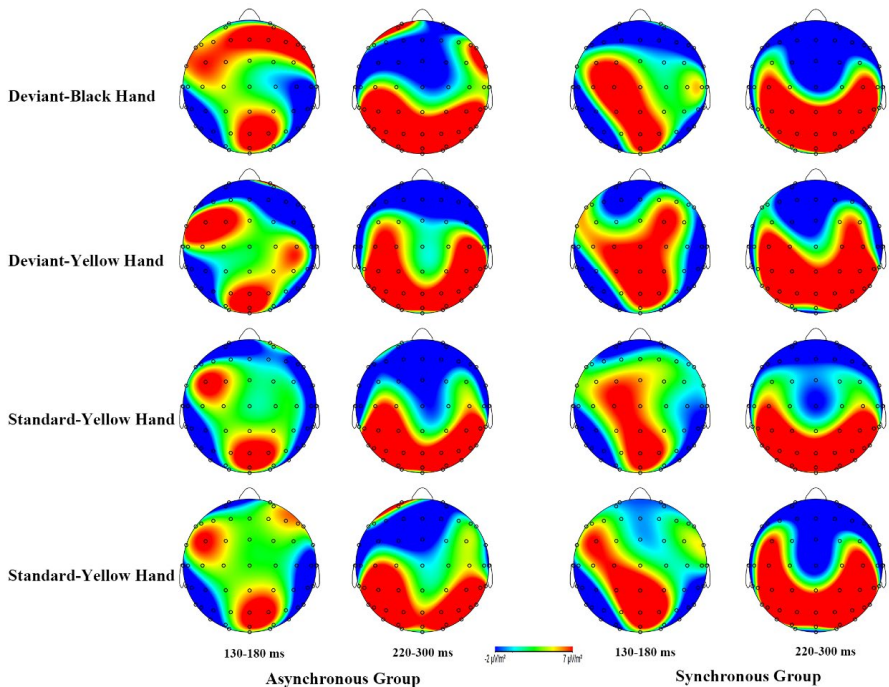

Figure 2b

Scalp topographical maps displaying the topographic distributions of the mean amplitude in time windows of 130-180 ms and 220-300 ms

vMMN (*130–180 ms time window*)*.* Mean amplitude was submitted to a 2 (Deviancy: Deviant hand vs. Standard hand) × 2 (Hand Type: Yellow hand vs. Black hand) × 2 (Group: Synchronous vs. Asynchronous) repeated measures analysis of variance (ANOVA) with Deviancy and Hand Type as within-subject factors and Group as a between-subject factor. The main effect of Deviancy was statistically significant (F(1, 42) = 19.65, p < .001, η_p^2 = .32), with the deviant stimuli eliciting larger negative effect (-1.33 μV) than standard stimuli (-0.75 μV). However, the main effect of Hand Type was not statistically significant (F(1, 42) = .57, p = .48), and neither was the main effect of Group (F(1, 42) = .663, p = .42).

More importantly, the Deviancy × Group interaction effect was significant (F(1, 42) = 4.87, p = .03, η_p^2 = .10). The deviant hand significantly differed from the standard hand in both black-hand-as-the-standard condition (F(1, 20) = 7.54, p = .01, η_p^2 = .27) and yellow-hand-as-the-standard condition (F(1, 20) = 4.72, p = .04, η_p^2 = .19) in the asynchronous stimulation group, but not in the synchronous stimulation group (black-hand-as-the-standard condition: F(1, 22) = .73, p = .40; yellow-hand-as-the-standard condition: F(1, 22) = 1.10, p = .31; see Figure 2). The Hand Type × Group interaction effect was not statistically significant (F(1,42) = .05, p = .82), nor was the Deviancy × Hand Type × Group interaction effect (F(1,42) = .01, p = .92).

N2 (220-300ms time window). The three-way ANOVA on mean signal amplitudes showed a significant main effect of Deviancy (F(1, 42) = 21.01, p < .001, η_p^2 = .33), with the deviant hand eliciting more negativity (4.58 μV) than the standard hand (5.39 μV). There was no significant main effect of Hand Type (F(1, 42) = 2.92, p = .10) or Group (F(1, 42) = 0.19, p = .66).

Different from the results of vMMN, the interaction of Deviancy × Group was not significant (F(1, 42) = 1.20, p = .28). Specifically, in the asynchronous group the deviant hand significantly differed from the standard hand (i.e., deviancy effect) in yellow-hand-as-the-standard condition (F(1, 20) = 4.38, p < .05, η_p^2 = .18) and black-hand-as-the-standard condition (F(1, 20) = 8.49, p < .01, η_p^2 = .30). In the synchronous group the deviant hand also significantly differed from the standard hand in yellow-hand-as-the-standard condition (F(1, 22) = 4.78, p = .04, η_p^2 = .18) and achieved marginal significant level in black-hand-as-the-standard condition (F(1, 22) = 4.21, p = .052, η_p^2 = .16). That is, similar deviancy effect occurred in both synchronous and asynchronous groups. Additionally, there were no significant interaction effects of Hand Type × Group, or Hand Type × Deviancy × Group (all p > .05).

Discussion

The present study addressed the question about how the body-ownership was distorted in the brain during RHI by examining whether the distortion could occur at the early, preattentive perceptual processing stage. The results indicated

that a significant vMMN effect was elicited by the deviant hand relative to the standard hand in the asynchronous group but not in the synchronous group. In contrast, there was no such difference in the time window of N2, although the deviant hand provoked a reliable deviancy effect compared with the standard stimuli in both asynchronous and synchronous groups. These results are consistent with Ehrsson et al.'s (2004) claim that RHI arises from bottom-up processes involved.

The experiment reported here contributes to a burgeoning literature, which suggests that the sense of bodily self involves an ongoing integration of multisensory experiences (e.g., Kilteni et al., 2015; Petkova et al., 2011; Tsakiris & Haggard, 2005). For instance, our findings fit nicely with previous studies showing that the perceived size of a body part can be increased by modifying visual inputs (Farmer et al., 2012; Suzuki et al., 2013). Also, the study by Ambron et al. (2018) has shown that magnifying lenses improve motor function in subjects with stroke. Similarly, there is evidence showing that body-ownership influences visual perceptual processes such as visual size (van der Hoort & Ehrsson, 2016).

Additionally, previous research, based on a variety of paradigms such as continuous flash suppression (CFS), has found that the congruency between visual information and signals from other sensory modalities can alter the time it takes for the visual stimulus to enter awareness (e.g., Lunghi et al., 2014; Salomon et al., 2016; van der Hoort et al., 2017). These results suggest that body-ownership can promote visual awareness, helping to explain the central role of body-ownership in conscious awareness. As a supplement, our experiment is the first to directly address whether body-ownership can also be unconsciously distorted in the brain. Even in an off-line experimental setting, the generation of RHI had a reliable effect on the perception of a body part in a passive oddball task which indicated the automatic processing in the visual sensory input. Therefore, the present study provides an important new role for ownership in sensory processing.

Our results also constitute a new example of how body-ownership unconsciously shaded the integration of different visual hands (yellow hand and black hand), which is an indicator of a change in self-orientation perception. It has been found by other studies that embodiment of light-skinned participants in a dark-skinned virtual body significantly reduced implicit racial bias against dark-skinned people (e.g., Banakou et al., 2016; Farmer et al., 2012; Hasler et al., 2017; Maister et al., 2013). This finding suggests that illusory ownership over a hand or a full-body induced by multisensory integration can change the implicit racial bias of participants. Similarly, the present study showed that yellow-skinned Chinese participants in the synchronous group could produce a relocation of the sensed position of their own hand towards the black hand, and unconsciously mixed the black hand with the yellow hand. Together with previous studies, the present study indicates that RHI can automatically affect bodily and social perception.

It is thought that the RHI arises from bottom-up and top-down processes involved in multisensory integration (e.g., Costantini & Haggard, 2007). For example, the illusion disappeared when the object to be integrated was morphologically different from a part of the body although visual and tactile stimuli were temporally congruent (e.g., Tsakiris et al., 2010). Similarly, the illusion disappeared when the visual and tactile stimuli were temporally incongruent, although the visual image of the rubber hand was similar to the participant's own hand (e.g., Botvinick and Cohen, 1998). The current study used the black hand and conducted synchronous stimulation in the synchronous group. The results showed that participants in the synchronous group yielded higher ownership scores and greater proprioceptive drift than those in the asynchronous group, which is in line with the previous findings.

Other research showed that the visuo-tactile illusion could be produced by top-down projections from brain areas involved in memory and visual imaging (e.g., prefrontal cortex; Tomita et al., 1999), which affects the function of bottom-up (i.e., more perceptual) brain areas (e.g., primary somatosensory cortex; Otsuru et al., 2014). That is, there is a sequence of processes where top-down processes precede bottom-up processes when generating RHI. However, the current study showed that the bottom-up integration during RHI was retrieved at an early stage of sensory processing before top-down processing, suggesting that RHI exert an automatic effect on 'low-level' bottom-up processing without the monitor of the 'high-level' top-down processing, which is different from its generation mechanism.

Additionally, the deviancy effect was observed in both synchronous and asynchronous groups in the time window of N2 which occurred later than vMMN. This would indicate that the bottom-up effect of RHI has a short duration. Later, driven by the pre-existing body model, the top-down processing begins to affect participants' rubber hand experience, leading to a decline in RHI in the synchronous group. With regard to the RHI, the tactile and visual stimuli are integrated into a coherent, but physiologically impossible, percept: tactile and visual stimuli have a common source. However, although the visible rubber hand is sensed as part of the body, it indeed does not replace the hidden yellow hand in the body model. The connection between tactile and visual black hand stimuli would become weaker over time. As an effect, the internal model of the body could easily drive the top-down processing to distinguish a black hand from a yellow one in a later time window.

Although our findings suggest meaningful insights, the study had limitations that must be addressed in future research. First, we here focused on the illusion of the black hand after the induction of RHI, but the perception of the black hand before the induction of RHI should also be measured as a baseline. Thus, future research could conduct a within-subject comparison on the perception of the black hand between before and after RHI induction, which could be more sensitive to detect the RHI effect by reducing the amount of error arising from the natural variance between individuals. Based on the RHI effect

observed here, we hypothesize that the black hand after RHI induction would elicit significantly less negativity as compared with the black hand before RHI induction. Second, following the first limitation, future studies could make the conclusion based on the significant difference in the perception of black hand between before and after RHI induction, instead of on the non-significant difference between black hand and yellow hand in the current study, which could provide stronger evidence to support that the body-ownership could be unconsciously distorted in the brain.

Third, previous studies have found that RHI can also occur in special populations, such as stroke patients (e.g., Llorens et al., 2018) and persons with autism spectrum disorder (e.g., Paton et al., 2012). It is important to note that a clinical sample was not involved in the current study. This would affect the generalizability of our results. Future research should expand the scope of sample selection. Finally, Lush (2020) argued that reports of experiences of ownership over a fake hand following simple multisensory stimulation might reflect suggestion effects. On the one hand, although insightful, the explicit nature of these self-report questions makes the results hard to interpret, as there is often no clear baseline measurement. On the other hand, due to the suggestion effects, demand characteristics are usually controlled for by contrasting agreement ratings for "illusion" and "control" conditions. That is, demand characteristics are not matched across conditions. Because demand characteristics have not been controlled in the illusion report in the current study and the previous existing studies, future research should propose methods to develop robust control.

Conclusions

This study demonstrates for the first time that after the induction of RHI bottom-up integration could be retrieved at an early stage of sensory processing before top-down processing by demonstrating that there was a salient vMMN effect of deviant hand in the asynchronous group but not in the synchronous group. Our results provide evidence for the priority of the bottom-up processes after the generation of RHI and reveal the mechanism of how body-ownership is unconsciously distorted in the brain.

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Vlasništvo nad telom je nesvesno iskrivljeno u mozgu: studija iluzije gumene ruke na osnovu događajima evociranih potencijala

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Mnoge studije su ukazale da mulitsenzorna integracija vizuelnih, taktilnih i proprioceptivnih informacija odozdo naviše može da iskrivi naš osećaj vlasništva nad telom stvarajući iluziju gumene ruke (eng. rubber hand illusion, RHI). Ima manje dokaza o tome kada i kako se ovaj osećaj iskrivljuje u mozgu za vreme pomenute iluzije. Da bismo ispitali da li se efekti ove iluzije pojavljuju pre dejstva pažnje, na ranom stadijumu obrade pratili smo komponentu negativnosti vizuelnog neslaganja (eng. visual mismatch negativity (vMMN) component), odnosno indeks automatske detekcije devijacija. Ispitanici su najpre radili zadatak koji je trebao da izazove javljanje iluzije gumene ruke u sinhronom ili asinhronom okruženju, a nakon toga završavali pasivni vizuelni zadatak pronalaženja "uljeza" (eng. visual oddball task) u kojem stimulusi koji su se razlikovali od ostalih u nizu nisu bili povezani sa pomenutim zadatkom. Dobijena je statistički značajna interakcija između devijacije (toga da li je učesnicima u istraživanju izlagana gumena ruka koja se vidno razlikovala po boji od ruke ispitanika ili "standardna" gumena ruka koja je po boji slična pravoj ruci ispitanika) i grupe (sinhrona ili asinhrona grupa). U asinhronoj grupi se pokazalo jasno neslaganje i u komponenti vMMN i u N2 komponenti koja je takođe praćena, dok je u sinhronoj grupi ovaj efekat utvrđen samo za N2 komponentu. Rezultati pokazuju da se, nakon izazivanja iluzije gumene ruke, integracija odozdo-naviše može dobiti u ranoj fazi senzorne obrade, pre javljanja obrade odozgo-naniže, što ukazuje na prioritet koji obrada odozdo-naviše ima nakon javljanja iluzije gumene ruke. Ovo ukazuje na mehanizam kojim se percepcija vlasništva nad telom nesvesno iskrivljuje u mozgu.

Ključne reči: iluzija gumene ruke, vlasništvo nad telom, negativnost vizuelnog neslaganja, događajima evocirani potencijali