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Research report

Oscillatory brain mechanisms of the hypnotically-induced out-of-body experience

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ABSTRACT

One of the most challenging questions regarding the nature and neural basis of consciousness is the embodied dimension of the phenomenon, that is, feeling located within the body and viewing the world from that spatial perspective. Current theories in neurophysiology highlight the active role of multisensory and sensorimotor integration in supporting self-location and self-perspective, and propose the right temporal-parietal-junction (rTPJ) as a key area for such function. These theories are based mainly on findings from two experimental paradigms: manipulation of bottom-up multisensory information integration regarding one's body location (full-body illusion), or direct and invasive manipulation disrupting brain activity at the rTPJ. In this study we take a different approach by using hypnotic suggestion – a non-invasive top-down technique – to manipulate the subjective experience of self-location. The brain activity of 18 right-handed participants was recorded using magnetoencephalography (MEG) while their subjective experience of self-location was hypnotically manipulated. Spectral analyses were conducted on the spontaneous MEG data before and during an induction of an out-of-body experience (OBE) by a trained psychiatrist. The results indicate high correlations between power at alpha and high-gamma frequency-bands and the degree of perceived change in self-location. Regions exhibiting such correlations include temporal-occipital regions, the rTPJ, as well as frontal and midline regions. These findings are in line with an oscillatory-based predictive coding framework.

1. Introduction

Current neurobiological theories highlight the active role of multisensory and sensorimotor integration in inducing fundamental states of consciousness, such as the experience of being a self, localized within the space of a physical body (Aspell, Lenggenhager, & Blanke, 2012; Ehrsson, 2007). Much of the data regarding the mediating neural mechanisms involved in consciousness comes from neurological patients (Blanke &

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Mohr, 2005) suffering from out-of body experience (OBE) and similar types of experiences, and highlights the role of the right temporo-parietal-junction (rTPJ) (Blanke, Ortigue, Landis, & Seeck, 2002; Ionta et al., 2011; Ridder, Laere, Dupont, Menovsky, & Heyning, 2007). The development of the 'full body illusion' paradigm (Blanke & Metzinger, 2009; Ehrsson, 2007; Lenggenhager, Tadi, Metzinger, & Blanke, 2007), where virtual reality and robotics technology are used to provide ambiguous multisensory information about the location of one's own body, has made it possible to manipulate self-location and -perspective in healthy participants under rigorous experimental settings, including neuroimaging settings such as functional Magnetic Resonance Imaging (fMRI) (i.e., Ionta et al., 2011) and electroencephalogram (EEG) (Lenggenhager, Halje, & Blanke, 2011). fMRI results confirm the privileged role of multisensory mechanisms in the TPJ in supporting self-location and -perspective (Blanke, 2005, 2012; Ionta et al., 2011), but have suggested the involvement of other regions, including the precuneus (Guterstam, Björnsdotter, Gentile, & Ehrsson, 2015), extrastriate cortex (including the extrastriate body area), the insula and ventral premotor areas (Arzy, Thut, Mohr, Michel, & Blanke, 2006; Gentile, Björnsdotter, Petkova, Abdulkarim, & Ehrsson, 2015; Heydrich & Blanke, 2013; Petkova et al., 2011; Urgesi, Candidi, Ionta, & Aglioti, 2007). In terms of neurophysiology, the only EEG study examining oscillatory-based modulation of self-location implicates alpha band power in sensorimotor and premotor regions, and has shown that the strength of induced-self-location-change correlates positively with frontal alpha and negatively with right parietal gamma (Lenggenhager et al., 2011).

The neurocognitive mechanism underlying the 'full body illusion' involves the mismatching of low-level sensory processing of visual and tactile representations. This mismatch in the bottom-up processing of different sensory modalities 'surprises' the brain, leading it to change its habitual top-down predictive tendency (Carhart-Harris & Friston, 2010; Limanowski & Blankenburg, 2013; Seth, 2013) of placing the self within the confines of the physical body, giving precedence to visual representations over tactile representations, and aligning self-location with the former. Our understanding regarding the neural coding of such feedback and feedforward, top-down and bottom-up processes has been greatly advanced in recent years. A number of influential intracranial EEG and magnetoencephalography (MEG) studies in humans have shown that alpha and beta oscillations encode top-down modulations of predictions, while gamma oscillations encode bottom-up 'surprise' due to prediction violation (Bauer, Stenner, Friston, & Dolan, 2014; Brodski, Paasch, Helbling, & Wibral, 2015; Friston, 2012; Michalareas et al., 2016; Sedley et al., 2016). Thus, the alpha-gamma oscillatory results mentioned above (Lenggenhager et al., 2011) are very much in line with an oscillatory-based predictive coding account (Arnal & Giraud, 2012; Arnal, Wyart, & Giraud, 2011; Clark, 2013; Friston, 2009). Specifically regarding the alpha band, there is substantial evidence that supports the role of alpha as a top-down control mechanism for inhibiting conflicting information (Jensen & Mazaheri, 2010; Klimesch, 2012). An increase in alpha power may reflect inhibitory processes affecting sensory and vestibular regions which anchor the self to its habitual body-based location.

While an oscillatory-based predictive coding account of self-location is plausible, it lacks support from the literature in two important respects: First, there is no information regarding the prospects, and neural mechanisms, of producing altered self-location states using top-down strategies rather than by manipulating bottom-up sensory information. From a predictive coding account this should be possible. Second, there is very little evidence to show that the mediating neural mechanisms underlying the production of altered self-location states (regardless of induction method) are in line with the oscillatory predictive-coding framework. The present study addresses both of these issues by (i) inducing altered self-location states using hypnotic suggestion, in which incoming tactile-visual (or other sensory) information is not manipulated, thus necessarily involving top-down mechanisms; and (ii) doing so while recording brain activity using MEG, a direct measure of the brain's neurophysiology ideally suited to mapping fast brain rhythms.

In recent years there has been a growing interest in hypnosis from a cognitive neuroscience perspective (Kihlstrom, 2013; Oakley & Halligan, 2009, 2013). This 'instrumental' approach utilizes hypnotic suggestion to study a range of normal and abnormal psychological processes. Hypnotic suggestion has been used to study a range of cognitive processes such as limb anesthesia, vision, volition, control, pain and attention (Deeley et al., 2013; Derbyshire, Whalley, Stenger, & Oakley, 2004; Kosslyn, Thompson, Costantini-Ferrando, Alpert, & Spiegel, 2000; Lifshitz, Aubert Bonn, Fischer, Kashem, & Raz, 2013; Ludwig et al., 2013; Magalhães De Saldanha da Gama, Slama, Caspar, Gevers, & Cleeremans, 2013; Zeev-Wolf, Goldstein, Bonne, & Abramowitz, 2016). The idea of studying OBEs by way of hypnotic suggestion is not a new one (Alvarado, 1992; Blackmore, 1982). Manipulating subjective awareness via hypnotic suggestion in conjunction with neuroimaging allows probing some of the deeper and more challenging questions relating to the nature and neural basis of consciousness, and in particular its attribute of being an embodied phenomenon: localized within the body and viewing the world from that spatial perspective (Bertossa, Besa, Ferrari, & Ferri, 2008).

For a hypnotic suggestion of an alternate self-location to succeed two processes are hypothesized to occur. First, the brain would need to adopt the suggested top-down world-model regarding the self's altered location; and second, error signals indicating the incompatibility of the suggested world-model with the self's embodiment would need to attenuate. Thus, we hypothesized that the strength of perceived change in self-location would (i) correlate positively with alpha/beta band power, and (ii) correlate negatively with gamma band power. In addition, in line with the fMRI full-body-illusion literature, (iii) we hypothesized these processes would involve, among other regions, the TPJ.

2. Method

2.1. *Participants*

Twenty five right-handed participants with no prior OBEs were recruited for the experiment. Exclusion criteria included current or past neurological, physical and mental disorders