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Excitatory stimulation of the right inferior parietal cortex lessens implicit religiousness/spirituality

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ABSTRACT

Although religiousness and spirituality (RS) are considered two fundamental constituents of human life, neuroscientific investigation has long avoided the study of their neurocognitive basis. Nevertheless, recent investigations with brain imaging and brain damaged patients, and more recently with brain stimulation methods, have documented important associations between RS beliefs and experiences and frontoparietal neural activity. In this study, we further investigated how individuals' implicit RS self-representations can be modulated by changes in right inferior parietal lobe (IPL) excitability, a key region associated to RS. To this end, we combined continuous theta burst stimulation (cTBS), intermittent TBS (iTBS), and sham TBS with RS-related, Implicit Association Test (IAT) and with a control self-esteem (SE) IAT in a group of fourteen healthy adult individuals. A specific decrease of implicit RS, as measured with the IAT effect, was induced by increasing IPL excitability with iTBS; conversely cTBS, which is supposedly inhibitory, left participants' implicit RS unchanged. The performance in the control SE-IAT was left unchanged by any TBS stimulation. These data showed the causative role of right IPL functional state in mediating plastic changes of implicit RS. Implications of these results are also discussed in the light of the variability of behavioral effects associated with TBS.

1. Introduction

Religiousness and spirituality are a central part of our meaning systems. About 90% of people worldwide have some types of religious/spiritual beliefs, arguing that religious entities or some other spiritual power may exist, and reporting the subjective feeling of their presence in life (Inzlicht et al., 2009; Zuckerman, 2005). Thus, religiousness and spirituality (hereafter RS in keeping with LaBouff et al., 2010 and Crescentini et al., 2014) are ubiquitous in people's lives; they influence the latter both positively, via the many beneficial effects on mental and physical health (Koenig et al., 2001; Cobb et al., 2012), and negatively, for instance in terms of religious fanaticism (Harris, 2004). Despite their universal nature, however, the study of RS has long been avoided by scientific investigation: the neural basis for the different mechanisms involved in RS experiences/beliefs remains underspecified.

RS involve extremely complex and varied neuropsychological processes; more specifically, they are multidimensional constructs that include the thoughts, subjective feelings, and behaviors arising from a search for the ultimate truth, or the transcendent nature of the world (Emmons and Paloutzian, 2003; Zinnbauer and Pargament, 2005). Scholars interested in the investigation of the neurocognitive bases of the three major components of RS (namely beliefs, experiences, and practices) have mostly considered self-report questionnaires, prayer and meditation practice (Cahn and Polich, 2006; Fingelkurts and Fingelkurts, 2009; Boyer, 2003; Harris et al., 2009; Kapogiannis et al., 2009a, 2009b). Accordingly, several electrophysiological and neuroimaging studies in people of different faith or expert in different forms of meditation or prayer (Azari et al., 2001; Beauregard and Paquette, 2006; Brefczynski-Lewis et al., 2007; Cahn and Polich, 2006; Lazar et al., 2000; Lutz et al., 2008; Newberg and Iversen, 2003; Newberg et al., 2001; Schjoedt et al., 2009) have recently indicated that a large cortical and subcortical brain network, including prefrontal, temporal and parietal regions, are involved in RS.

In particular, many neuroimaging studies have hinted at a relationship between decreased parietal lobe activity and increased RS beliefs and experiences (e.g., Brefczynski-Lewis et al., 2007; Cahn and Polich, 2006; Herzog et al., 1990; Newberg et al., 2001, 2003; Newberg and Iversen, 2003; Tomasino et al., 2013). Moreover, adding causal evidence to the relationship between neural

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activity in specific neural structures and RS feelings and beliefs, a few clinical investigations in brain damaged patients (i.e., cranial trauma or surgical ablation; Johnstone and Glass, 2008; Johnstone et al., 2012; Urgesi et al., 2010) have shown that selective lesions in left and right inferior parietal regions increase the explicit self-transcendental representation of the patients. Overall, these findings have been held to reflect an altered sense of awareness of the self in space (Newberg and Iversen, 2003; Paloutzian and Park, 2005; Fuller, 2008), as the basic involvement of the posterior parietal cortex in the cognitive representation of different aspects of bodily knowledge (e.g., Berlucchi and Aglioti, 1997, 2010; Previc, 2006) has been put into relation with the transcendental representations of the self that often accompany RS experiences. Indeed, it has been argued that RS-related changes in self-awareness may lead one to experience a sense of detachment of the self from spatiotemporal contingencies of the physical body that may increase feelings of connection with religious entities or spiritual power, nature and other individuals at large (Paloutzian and Park, 2005; Fuller, 2008).

More recently, we were able to provide corroborative evidence of fast RS changes in healthy subjects undergoing non-invasive stimulation procedures, namely repetitive transcranial magnetic stimulation (rTMS), for reversibly interfering with neural activity in dorsolateral prefrontal cortex (DLPFC) and inferior parietal lobe (IPL) regions (Crescentini et al., 2014). Specifically, interfering with IPL neural activity reflected in an increase in participants' automatic RS self-representations, whereas no changes were obtained in other self-representations not linked to RS, such as self-esteem (SE). RS and SE representations were measured by implicit rather than explicit measures (i.e., implicit association tests for RS, RS-IAT, and for SE, SE-IAT) (LaBouff et al., 2010; Greenwald and McGhee, 1998; Greenwald and Farnham, 2000). This was meant to ameliorate the problems with the use of self-report measures of RS that, notoriously, are subjective in nature and susceptible to desirable responding (LaBouff et al., 2010; Schwarz, 1999; Sedikides and Gebauer, 2010).

More in particular, the RS-IAT was used to indirectly infer people's implicit RS while they were receiving TMS by measuring the strength of automatic concept–attribute associations between the self and RS dimensions. This was done by having participants categorize word stimuli, by pressing one of two response keys. In each trial, words from one out of four categories were presented: Two target categories (referring to the concept of self and other) and two attribute categories (RS and non-RS words). The participants' task was to press one of two response keys to categorize each word; what is relevant for the IAT measure is that, in separate blocks defined as congruent and incongruent according to the expected tendency to associate the self with RS attributes (and with good attributes in the SE-IAT), the response key corresponding to a target category (e.g., self) may be the same as that corresponding to one (e.g., RS; congruent blocks) or the other (e.g., non-RS; incongruent blocks) attribute category. Generally, the main tenet of the IAT is that strongly associated concept–attribute pairs are easier to classify together (i.e. by pressing the same response key) than are weakly associated pairs. Thus, an RS-IAT effect suggesting that a person automatically perceives the self as more religious–spiritual than non-religious-non-spiritual is found when a person is faster and/or more accurate in responding in congruent blocks, in which RS words are associated (i.e., are categorized using the same response key) with self-related terms and non-RS words are associated with other-related terms, as compared to incongruent blocks, in which non-RS words are associated with self-related terms and RS words are associated with other-related terms (LaBouff et al., 2010; Crescentini et al., 2014). Analogously, an SE-IAT effect indicating that a person automatically associates the self with positive rather than with negative valence is obtained when a person shows better performance in responding in congruent blocks, in which good words are associated with self-related terms and bad words with other-related terms, than in incongruent blocks in which bad words are associated with self-related terms and good words with other-related terms (Greenwald and Farnham, 2000; Crescentini et al., 2014).

In Crescentini et al. (2014), the application of two TMS pulses over IPL at the onset of each stimulus word, a stimulation which is thought to add neural noise and thus disrupt neural activity in the area underlying the coil (Cattaneo et al., 2011; Walsh and Pascual-Leone, 2003), appeared to increase the response difficulty when non-RS and self-related words (and RS and other-related words) were associated to the same response key. No performance changes were obtained on an analogous IAT designed to measure implicit self-esteem representations (SE-IAT). These findings were interpreted as evidence that altering neural activity in IPL strengthens RS representations of the self. The specific feature of the on-line TMS protocol that was used, however, prevented any specific claim about the direction of the neural activity change (facilitation or inhibition), thus leaving unresolved the question of whether RS is associated to lower or higher activity of IPL.

The aim of the present research is to take benefit of related hypotheses from multiple areas of research on RS including, as mentioned above, functional imaging of healthy individuals, neuropsychological analysis of brain lesion patients, and TMS research, to further investigate how individuals' RS implicit self-representations, as compared to implicit SE representations, can be modulated by specific IPL activity changes, either increased or decreased excitability, induced by non-invasive focal stimulation in normal healthy individuals. To this aim, we applied theta burst stimulation (TBS) over right IPL before participants performed the RS-IAT, and its control SE-IAT, designed by Crescentini et al. (2014) (see also LaBouff et al., 2010 for the only pre-existing RS-IAT). As in previous studies on TBS of non-motor brain regions (e.g., Cho et al., 2010), participants underwent three different offline TBS stimulation paradigms involving: (i) continuous TBS (cTBS), which is held to produce a long-lasting inhibition of the underlying cortex (e.g., Huang et al., 2005), (ii) intermittent TBS (iTBS), which should result into a long-lasting excitation of the underlying cortex, and (iii) sham stimulation. All subjects performed the two IATs after the completion of TBS or sham in each stimulation condition (Fig. 1).

The particular TBS experimental design used in the current study has two main advantages: first, it allows controlling for any exogenous influence of both the somatic unpleasant sensation and the sound typical of the TMS machinery during task performance; secondly, and more critically, it offers the unique opportunity to complement the above-mentioned findings linking specific decreased (after cTBS) or increased (after iTBS) activation of the parietal lobe with increased or decreased RS representations, respectively. In keeping with previous research (e.g., Crescentini et al., 2014), one could thus expect that inhibiting the excitability level of the right IPL via cTBS should strengthen implicit RS representations, making the IAT blocks that associate non-RS and self-related words more difficult to perform. Conversely, boosting the excitability of right IPL via iTBS should weaken implicit RS representations either by making the IAT blocks that associate RS and self-related words more difficult or by making the blocks associating non-RS and self-related words easier. Nevertheless, it is known that translation of iTBS and cTBS modulatory effects on behavior from motor to non-motor regions may not be straightforward (e.g., Restle et al., 2012); thus we may (perhaps more realistically) assume that any potential significant modulatory effect on RS, but not on SE, dimensions of any of the TBS protocols applied in the current study to the right IPL would suggest a