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Research report

Dissociating cognitive from affective theory of mind: A TMS study

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ABSTRACT

Introduction: ‘‘Theory of Mind’’ (ToM), i.e., the ability to infer other persons’ mental states, is a key function of social cognition. It is increasingly recognized to form a multidimensional construct. One differentiation that has been proposed is that between cognitive and affective ToM, whose neural correlates remain to be identified. We aimed to ascertain the possible role of the right dorsolateral prefrontal cortex (DLPFC) for cognitive ToM as opposed to affective ToM processes.

Methods: 1 Hz repetitive transcranial magnetic stimulation (rTMS) was used to interfere offline with cortical function of the right DLPFC in healthy male subjects who subsequently had to perform a computerized task assessing cognitive and affective ToM.

Results: RTMS over the right DLPFC induced a selective effect on cognitive but not affective ToM. More specifically, a significant acceleration of reaction times in cognitive ToM compared to affective ToM and control items was observed in the experimental (right DLPFC) compared to the control (vertex) rTMS stimulation condition.

Conclusions: Our findings provide evidence for the functional independence of cognitive from affective ToM. Furthermore, they point to an important role of the right DLPFC within neural networks mediating cognitive ToM. Possible underlying mechanisms of the acceleration of cognitive ToM processing under rTMS are discussed.

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1. Introduction

Theory of mind (ToM) is defined as the ability to attribute mental states, such as desires, intentions and beliefs, to other people in order to explain and predict their behavior (Frith and Frith, 1999). It constitutes a central aspect of social cognition which is regarded to be a highly specialized, human-specific skill that forms a crucial prerequisite to function in social groups (Adolphs, 2003a, 2003c; Herrmann et al., 2007). ToM is commonly regarded to be mediated by a complex neural network including the medial prefrontal cortex (mPFC), the superior temporal sulcus region, the temporal pole (Frith and Frith, 2003; Siegal and Varley, 2002), and the amygdalae (Adolphs, 2003b). Many lesion studies (e.g., Eslinger et al., 2007; Griffin et al., 2006; Happé et al., 1999; Siegal et al., 1996; Stuss et al., 2001; Winner et al., 1998) and functional imaging studies (e.g., Brunet et al., 2000; Gallagher et al., 2000; Sommer et al., 2007; Vogeley et al., 2001) suggest that ToM and other social cognitive functions are mediated predominantly by a network lateralized to the right hemisphere, although evidence for bilateral (e.g., Völlm et al., 2006; Hynes et al., 2006) and left-sided involvement also exists (e.g., Baron-Cohen et al., 1999; Calarge et al., 2003; Channon and Crawford, 2000; Fletcher et al., 1995; Goel et al., 1995), probably depending on task type and modality (Kobayashi et al., 2007).

Recent social cognitive neuroscience has begun to define subcomponents of the complex concept we refer to as ToM. One important differentiation is that of ‘affective’ versus ‘cognitive’ ToM, although different terms have been used for these and related concepts (overview in Baron-Cohen and Wheelwright, 2004; Kalbe et al., 2007). Whereas cognitive ToM, for example assessed with so-called false belief tasks, is thought to require cognitive understanding of the difference between the speaker’s knowledge and that of the listener (knowledge about beliefs), affective ToM, for example tested with faux pas and irony tasks, is supposed to require in addition an empathic appreciation of the listener’s emotional state (knowledge about emotions) (Shamay-Tsoory et al., 2006). Brothers (1995, 1997) had postulated a unitary social ‘editor’ which is specialized for processing others’ social intentions but which could not be dissociated into ‘hot’ social cognition (i.e., processing others’ emotional expressions) and ‘cold’ social cognition (i.e., attributing and processing cognitive mental states such as beliefs). However, Eslinger et al. (1996) reported a dissociation between affective and cognitive aspects of ‘empathy’ in brain damaged patients. Furthermore, Blair (2005) and Blair and Cipolotti (2000) argued that divergent results concerning ToM dysfunctions in sociopathy may be attributed to a selective deterioration of affective social cognition (‘emotional empathy’), while individuals with autism show more difficulties with cognitive than with emotional empathy. Recently, Shamay-Tsoory and colleagues found selective deficits of affective as opposed to cognitive ToM in various patients groups (Shamay-Tsoory and Aharon-Peretz, 2007; Shamay-Tsoory et al., 2006, 2005).

Already Eslinger (1998) suggested that different regions in the prefrontal cortex may be relevant for these distinct functions, with a dorsolateral prefrontal cortex (DLPFC) system mediating cognitive empathy and the orbitofrontal cortex mediating affective empathy. Shamay-Tsoory et al. (2005) confirmed the special role of the ventromedial prefrontal cortex (VMPFC) in processing affective ToM and argued that cognitive ToM may rather involve both the VMPFC and dorsal parts of the prefrontal cortex (Shamay-Tsoory and Aharon-Peretz, 2007). Further confirmation for partially differential mechanisms in processing affective and cognitive ToM was recently provided by functional magnetic resonance imaging (fMRI) studies (Hynes et al., 2006). These studies underline the particular role of medial and orbital PFC for affective perspective taking and show involvement of dorsolateral prefrontal structures for cognitive ToM. Kobayashi et al. (2007) and Sommer et al. (2007) found involvement especially of the right-hemispheric DLPFC in false belief tasks (which can be categorized as cognitive ToM tasks).

In summary, research so far (a) suggests a distinction between affective and cognitive ToM functions and (b) point to at least partly different neural correlates mediating these two subcomponents. However, while the role of the VMPFC for affective ToM is well documented, neural substrates of cognitive ToM are less well defined but may include the DLPFC.

On the basis of the aforementioned considerations, we aimed to further examine the dissociation of cognitive and affective ToM processes. We tried to elucidate neural correlates of cognitive as opposed to affective ToM and, more specifically, to investigate the functional relevance of the DLPFC for cognitive ToM performance. For this purpose, we applied 1-Hz repetitive transcranial magnetic stimulation (rTMS) to the DLPFC of 28 male right-handed healthy subjects prior to the performance of a computer-based ToM task that has previously been used to differentially assess cognitive versus affective ToM (Shamay-Tsoory and Aharon-Peretz, 2007). Although functional imaging studies have shown somewhat contradictory results regarding laterality of ToM functions (see above) we decided to perform rTMS over the right DLPFC for the following reasons: (i) We used the “Yoni” paradigm introduced by Shamay-Tsoory and Aharon-Peretz (2007) in which ToM has to be inferred on the basis of eye gaze and facial expression. According to Sabbagh (2004), a right-hemispheric mechanism mediates the decoding of mental states based on immediate information, such as eye expression, while a left-hemispheric network is responsible for complex reasoning about mental states. It can be speculated that the right-hemispheric decoding system is utilized when performing the Yoni task (Shamay-Tsoory and Aharon-Peretz, 2007). (ii) Executive functions have been conceptualized as a “co-opted” system for ToM processing (Siegal and Varley, 2002), and recent functional imaging research points to the central role of the right DLPFC in executive working memory operations and cognitive control functions (Lie et al., 2006).

TMS is a well-established tool for inducing transient changes in brain activity non-invasively in conscious human volunteers. Over the past couple of years, this ability of actively interfering with neural processing during behavioral performance has been increasingly used for the investigation of causal brain-behavior relations in higher cognitive functions (Pascual-Leone et al., 2000; Sack and Linden, 2003). RTMS has been applied to different areas within prefrontal cortex in