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Research report

Exploring theory of mind after severe traumatic brain injury

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ABSTRACT

Previous studies have reported a dissociation between social behavioral impairments after severe traumatic brain injury (TBI) and relatively preserved performances in traditional tasks that investigate cognitive abilities. Theory of mind (ToM) refers to the ability to make inferences about other's mental states and use them to understand and predict others' behavior. We tested a group of 15 patients with severe TBI and 15 matched controls on a series of four verbal and non-verbal ToM tasks: the faux pas test, the first-order and second-order false belief task, the character intention task and the Reading the Mind in the Eyes Test. Participants with severe TBI were also compared to controls on non-ToM inference tasks of indirect speech act from the Montreal Evaluation of Communication (M.E.C.) Protocol and empathy (Davis Interpersonal Reactivity Index – I.R.I.) and tests for executive functions. Subjects with TBI performed worse than control subjects on all ToM tasks, except the first-order false belief task. The findings converge with previous evidence for ToM deficit in TBI and dissociation between ToM and executive functions. We show that ToM deficit is probably distinct from other aspects of social cognition like empathy and pragmatic communication skills.

1. Introduction

Changes in the social behavior of an individual following severe traumatic brain injury (TBI) have long been noted (Levin and Eisenberg, 1991). Impairments of social behavior after severe TBI are often problematic and difficult to assess and manage, with few models addressing evaluation, treatment options and prognosis. The neuropsychological consequences of TBI (disorders of attention, executive functioning, and memory and information processing) are strongly related to poor social outcome (Ponsford et al., 1995). Previous studies have reported a dissociation between social behavioral impairments and relatively preserved performances in traditional tasks that investigate cognitive abilities (Eslinger and Damasio, 1985; Shallice and Burgess, 1991). There is therefore a need for more detailed examination of the ability of people with TBI to use social information.

Much of the research has focused on one aspect of social intelligence, namely ''theory of mind (ToM)''. ToM is a cognitive process which refers to the ability to make inferences about others' mental states (beliefs, intentions and desires) and use them to understand and predict others' behavior (Premack and Woodruff, 1978). Neuroimaging studies with healthy controls have reported that performance on ToM tasks is supported by a widely distributed neural system, involving frontal and temporal lobes (Gallagher et al., 2000;

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Brunet et al., 2000; Siegal and Varley, 2002; Vollm et al., 2006). This may explain why ToM judgments have been found to be impaired in adults with frontal focal lesions (Shallice, 2001; Stuss et al., 2001). As these regions are often damaged in TBI, deficits in ToM could be anticipated.

Previous studies have provided convincing evidence of a deficit in the capacity to infer others' mental states in patients with severe TBI. A range of tasks has been used to assess ToM in the TBI population. Bibby and McDonald (2005) reported that TBI subjects performed poorly in false belief tasks, which measure the ability of someone to understand that another person can hold a belief that is mistaken. Milders et al. (2003) found impairment in the faux pas detection task. A faux pas occurs when someone say something they should not have said, not knowing or not realizing that they should not say it. False belief and faux pas tasks are considered as "verbal" tasks, in the sense that they consist in short verbal stories. Other forms of ToM tasks have been developed with a view to minimizing the verbal component of ToM performance. These tasks with significantly reduced verbal demands are usually called "non-verbal" tasks, even if they require some spared language abilities to achieve them. Such tasks have been used to assess ToM following TBI. Havet-Thomassin et al. (2006) found impairments in the character intention task (Sarfati et al., 1997). This consisted of short comic strips which were designed to show a character performing an action motivated by an easily recognizable intention. Subjects were asked to design the correct ending that corresponded to the character's intention. Havet-Thomassin et al. (2006) and Henry et al. (2006) demonstrated that TBI subjects also performed poorly in the Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001), which is based on photographs of eyes.

Several reasons suggest the need to focus on the material used when studying ToM in TBI population. The first is that it appears particularly important to take account of the verbal/non-verbal material when investigating ToM in individuals with TBI. These patients often present language disorders and pragmatic communication skills deficits (Stemmer et al., 1994; Dahlberg et al., 2006), such as the ability to ignore the literal meaning of an utterance in order to comprehend conversational implicatures such as sarcasm, humor, irony, and ambiguous advertising slogans (Channon et al., 2005). The majority of researchers into ToM have emphasized that the relationship between language and the attribution of mental states is still unknown, but it is clear that performance on ToM tasks in severe TBI patients is influenced by the language demands of the tasks (Bibby and McDonald, 2005).

Secondly, these different ToM tasks are supposed to present various degrees of difficulty. ToM has a particular stereotyped developmental sequence whose acquisition starts in childhood and develops over several years (Wimmer and Perner, 1983; Perner and Wimmer, 1985; Baron-Cohen et al., 1999). According to the theory of Stone et al. (1998), impairment is more pronounced in tasks requiring abilities that develop later. Thus, performance on ToM tasks could be an index of how severe a person's ToM deficit is. The ability to understand first-order false belief corresponds to an early stage in the development of ToM. Between ages 3 and 4, children develop the ability to understand first-order false beliefs (Wimmer and Perner, 1983). Between ages 6 and 7, they begin to be able to understand second-order false beliefs, i.e., "beliefs about beliefs" (Perner and Wimmer, 1985). The faux pas test and the Reading the Mind in the Eyes Test represent the most developmentally advanced ToM tasks, so they are considered as good measures of subtle ToM deficit. Comprehension of social faux pas develops around 9–11 years (Baron-Cohen et al., 1999) and the Reading the Mind in the Eyes Test is used with adults (Baron-Cohen et al., 1997).

Although ToM is first considered as a cognitive ability, some authors have argued for a distinction between "cognitive" ToM and "affective" ToM (Shamay-Tsoory and Aharon-Peretz, 2007). Some ToM tasks may involve a more complex affective emotional dimension than others. The false belief tests could assess "cognitive ToM" because they do not involve complex emotional ToM. The faux pas task and the Reading the Mind in the Eyes test could assess "affective ToM" because they have both a strong emotional component. These cognitive and affective aspects of ToM raise the question of the relationship between ToM and another aspect of social behavior, namely "empathy". Whereas ToM refers to the attribution of mental states such as desires, intentions and beliefs, to others, empathy has been described as the ability to infer and share the emotional experiences of another (Davis, 1983; Spinella, 2005). It has been shown that the recognition of emotion in other people's speech and facial expressions are disturbed for people with TBI (McDonald and Flanagan, 2004; Milders et al., 2008) and some authors have reported impaired empathy following brain injury (Eslinger, 1998; Shamay-Tsoory et al., 2003). The relationships between ToM and empathy remain controversial and still to be determined. Some authors propose a theoretical model which postulates the possibility of shared processes between these two psychological concepts. In this model, there are both cognitive and emotional components of empathy (Davis, 1983; Spinella, 2005). The cognitive component of empathy is akin to ToM while the emotional component involves the actual emotional reaction. Shamay-Tsoory and Aharon-Peretz (2007) found that performances in "affective" ToM tasks of patients with lesions that involve the ventral medial and orbital frontal lobe were positively related to their empathic abilities, indicating that the ability to make affective representations of others' mental states is associated with the ability to empathize. In a recent functional magnetic resonance imaging (fMRI) study, Vollm et al. (2006) compared networks associated with both empathy and a ToM task using cartoon stories derived from Sarfati et al. (1997). They concluded that ToM and empathy stimuli are associated with overlapping as well as distinct neuronal networks. They both engage a common neuronal circuit including the medial prefrontal cortex, temporoparietal junction and temporal poles. However, empathic responding requires the additional recruitment of the amygdala and the cingulate cortex involved in emotional processing. Several authors have performed objective and subjective measurement of empathy in individuals with frontal lobe injury, in the context of acquired sociopathy and moral judgments (Tranel et al., 2005; Koenigs et al., 2007). According to Spinella (2005), the most developed scale psychometrically is Davis' Interpersonal Reactivity Index (I.R.I.) with scales rating both the cognitive and emotional components of empathy.

There has been debate over whether the ability to infer others' mental states is a true implicit "theory" or the result of