Theory of mind following traumatic brain injury: The role of emotion recognition and executive dysfunction

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Abstract

A number of studies have now documented that traumatic brain injury (TBI) is associated with deficits in the recognition of basic emotions, the capacity to infer mental states of others (theory of mind), as well as executive functioning. However, no study to date has investigated the relationship between these three constructs in the context of TBI. In the current study TBI participants ($N = 16$) were compared with demographically matched healthy controls ($N = 17$). It was found that TBI participants' recognition of basic emotions, as well as their capacity for mental state attribution, was significantly reduced relative to controls. Performance on both of these measures was strongly correlated in the healthy control, but not in the TBI sample. In contrast, in the TBI (but not the control) sample, theory of mind was substantially correlated with performance on phonemic fluency, a measure of executive functioning considered to impose particular demands upon cognitive flexibility and self-regulation. These results are consistent with other evidence indicating that deficits in some aspects of executive functioning may at least partially underlie deficits in social cognition following TBI, and thus help explain the prevalence of social dysfunction in TBI.
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1. Introduction

Theory of mind (ToM) refers broadly to the ability to understand others' emotions, motivations, and thoughts, and to understand their behavior accordingly (Bibby & McDonald, 2005; Channon, Pellijeff, & Rule, 2005; Martin & McDonald, 2005). Research on ToM in relation to traumatic brain injury (TBI) to date has concentrated on the understanding of emotions and social conventions, typically requiring participants to infer mental state from stories or cartoons (Bibby & McDonald, 2005; Martin & McDonald, 2005) or video vignettes (McDonald & Flanagan, 2004; Turkstra, Dixon, & Baker, 2004). All of these studies found ToM to be significantly impaired following TBI. However, these ToM measures resemble problem-solving tasks in that complex passages of text or video narrative are presented and have to be analyzed, and also have a memory component that may partially explain TBI effects (see Bibby & McDonald, 2005). These tasks, therefore, may not tap naturalistic ToM that people use from moment to moment to infer mental states.

A task which is relatively free of these cognitive demands was presented by Baron-Cohen, Jolliffe, Mortimore, & Robertson (1997). The nonverbal Eyes test taps "affective" not "cognitive" ToM, requiring participants to make inferences about the affective and motivational state of others, as opposed to their cognitive state, on the basis of a picture of their eyes. This task differs from identifying basic facial expressions of emotion in that the distinctions made involve more complex emotional terms and often concern social interaction (e.g., distinctions include attraction or repulsion, friendly or hostile, noticing you or ignoring you). Adults with autism show poorer ability than controls on this task (Baron-Cohen et al., 1997), as do individuals who have sustained localized amygdala damage (Adolphs, Baron-Cohen, & Tranel, 2002).

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In the only study to date to use the Eyes test in the context of TBI, Milders, Fuchs, & Crawford (2003) found that whilst TBI participants performed more poorly than controls (effect size [*d*] calculated by present authors = .68), this deficit was smaller than the deficit on a measure that required identification of basic facial emotions [Faces; *d* = 1.17], and indeed, only this latter effect size attained statistical significance. Although interpretation of this study's results is limited by the fact that multiple comparisons were made without correction for an inflated Type I error rate, these results are nevertheless of interest. This is because it has been argued by some that performance on ToM tasks is related to the ability to identify facial expressions of emotion (Buitelaar, van der Wees, Swaab-Barneveld, & van der Gaag, 1999). Thus, TBI participants may perform poorly on measures of ToM, not because of a specific ToM impairment, but because of more basic deficits in emotion recognition. Indeed, if Eyes and Faces do tap overlapping emotion recognition skills, and differ only in that the Eyes test additionally taps ToM, Milders et al.'s (2003) results may be construed as evidence that TBI is not associated with specific problems with ToM. This is because evidence for a specific ToM impairment would require showing that performance on Eyes is disproportionately impaired relative to performance on Faces; as noted, Milders et al. (2003) reported the *reverse* pattern of impairment on these two measures.

However, Frith and Frith (1999, 2001) have argued that there are two functionally separate neural networks which are important in social processing; a "ventral" stream which links the orbitofrontal cortex and regions next to the amygdala, and a "dorsal" stream which connects the medial prefrontal cortex, the anterior cingulate and the superior temporal sulcus. Whereas the former is argued to be implicated in recognition of differences in emotional expression, the latter is thought to be crucial for ToM (Frith & Frith, 1999, 2001). This perspective would therefore suggest that the emotional processes tapped by Eyes and Faces may be distinct. However, as Brune (2005b) noted, "The link of ToM to other social cognitive capacities such as emotion recognition represents an underexplored field of research" (p. 38), and indeed no study to date has assessed this relationship in the context of TBI.

Further, it remains unclear whether ToM ability following TBI is related to executive dysfunction. Hughes and Russell (1993) argue that deficits on measures of ToM simply reflect executive dysfunction as such measures impose substantial demands upon control processes such as response inhibition and cognitive flexibility. However, whilst some studies have suggested a specific link between executive functioning and ToM (Bora et al., 2005; Channon & Crawford, 2000), others suggest that these abilities may be dissociated (Lee, Farrow, Spence, & Woodruff, 2004; Lough & Hodges, 2002). As Bibby and McDonald (2005) noted, "the relationship between ToM performance and executive functioning remains controversial." (p. 111). Assessment of this issue is important, as it bears on whether similar brain areas are recruited by emotional and cognitive control processes, which has been identified as a key aim of the emerging field of 'social cognitive neuroscience' (Ochsner & Lieberman, 2001). In the context of TBI, no study to date has investigated the relationship between these constructs.

In the current study, we address the following research questions:

(1) Is TBI participants' performance on a measure of ToM (Eyes) related to their ability to decode basic emotions from facial expressions (Faces)?
(2) Is TBI participants' performance on a measure of ToM (Eyes) related to their scores on a measure of executive functioning?

2. Methods

2.1. Participants

For the TBI sample, outpatient records of the Department of Neurosurgery, Aberdeen Royal Infirmary were reviewed by the responsible neuropsychologist, who determined on a case by case basis whether each individual would be able to give informed written consent to participate, and would meet the eligibility criteria outlined below. Each potential participant was then sent a letter which provided a description of the purpose and procedure of the study. In total, 16 adults who had sustained a TBI (14 males, 2 females) between the ages of 20 and 61 (*M* = 44.4, S.D. = 13.36) were recruited in this manner. None reported a history of psychiatric disease or a premorbid history of alcohol or drug addiction. Subjects with comorbid neurological conditions (e.g., premorbid seizure disorders, stroke, etc.) were also excluded. Clinical features taken from the patients' medical records are shown in Table 1.

Seventeen healthy participants served as controls. Demographic, familial and occupational differences have been identified between individuals with head injuries and convenience samples (see, e.g., Lezak, Howieson, & Loring, 2004). Although some control participants were recruited from the Public Participation Panel at the University of Aberdeen (*N* = 6), to help minimise such differences the majority of control participants were friends or family members of TBI participants (*N* = 11). Controls did not differ significantly from TBI participants in terms of age (*t*(31) = .75, *p* = .459), education (*t*(31) = .62, *p* = 544) or gender (Fisher's Exact Test; *p* = .145). All participants received remuneration to cover travel expenses. TBI participants and controls did not differ significantly on the number of items correct on the National Adult Reading Test (NART), which

Table 1
Clinical features of the TBI participants

Participant number	Cause of injury	Injury site (CT or MRI scan)	GCS score	Time post-injury (years)
1	Assault	–	14	1.5
2	Assault	–	14	5
3	Fall	–	–	2
4	MVA	–	–	2
5	Fall	Left temporal	13	4
6	MVA	Subarachnoid	6	2.5
7	MVA	–	7	8
8	Explosion	–	14	5
9	MVA	Right frontal and parietal	8	2.5
10	MVA	Left cerebrum	7	11
11	Fall	Left temporal	14	2
12	Fall	Bilateral frontal	15	2.5
13	Uncertain[a]	–	–	3
14	MVA	–	–	1
15	Falling object	Right frontal	14	1
16	Fall	Bilateral frontal	14	2

GCS refers to Glasgow Coma Scale (Teasdale & Jennet, 1974); MVA refers to motor vehicle accident; – indicates that this information was not available.

[a] Participant does not recollect cause of injury and there were no witnesses to the injury.

provides an index of premorbid intelligence ($M = 33.2$, S.D. = 10.0 and $M = 36.1$, S.D. = 4.68, respectively; $t = 1.37$, df = 31, $p = .09$). Ethical approval to conduct this study was provided by the Grampian Research Ethics Committee, and all participants gave informed consent prior to their inclusion in the study.

2.2. Materials and procedure

The following tasks were administered in one of two counterbalanced orders.

2.2.1. Theory of mind

Eyes. Participants were presented with the 37 stimuli from Baron-Cohen, Wheelwright, Hill, Raste, & Plumb (2001) Eyes test designed to assess ToM. For each pair of eyes presented, they were asked to choose which of four words best assessed what the person in the picture was thinking or feeling (e.g., for the first stimulus the choice to be made was between 'jealous', 'panicked', 'arrogant' and 'hateful'). Most of the distinctions had an emotional dimension. Interested readers can access this test at the following url: http://www.autismresearchcentre.com/tests/eyes_test_adult.asp.

2.2.2. Emotional identification

Faces. Participants were presented with a sequence of 48 photographs from the black and white (Ekman & Friesen, 1976) set of faces, eight each of: (a) anger, (b) happiness, (c) fear, (d) disgust, (e) sadness, and (f) surprise. For each face, participants had to identify which of the six emotion labels best described the face.

2.2.3. Executive functioning

Verbal fluency (FAS). To tap executive functioning, each participant completed a test of phonemic fluency (using the probes: F, A and S). Tests of phonemic fluency are amongst the most sensitive measures of executive dysfunction (Crawford & Henry, 2005; Henry & Crawford, 2004a). Decety and Jackson (2004) argue that whilst executive functioning is a broader construct than ToM, mental flexibility and self-regulation (including inhibition) are critical in order to be able to take the perspective of another person, and thus ToM. In terms of specific executive demands, tests of fluency impose substantial demands upon both mental flexibility and self-regulation; in particular, performance is dependent on self-monitoring aspects of cognition, effortful self-initiation, inhibition of responses when appropriate, and mental switching between different search strategies (Crawford & Henry, 2005; Perret, 1974; Ruff, Light, Parker, & Levin, 1997). It is also important to note that tests of phonemic fluency have been shown to be very sensitive to the presence of TBI specifically (Henry & Crawford, 2004b). For each fluency probe, participants were given one minute to produce as many exemplars as possible. Participants' responses were recorded on an audio-cassette recorder. The dependent measure of interest was the total number of responses, minus repetitions and inappropriate responses.

2.3. Analysis

The two groups were compared on each measure of interest using *t*-tests. When conducting multiple comparisons, it is important to adequately control for Type I error rates. Because the analyses of interest in the present study used intercorrelated dependent variables, the appropriate way to apply a Bonferonni correction for multiple comparisons is to adjust the alpha level for each comparison in relation to both the number of comparisons made, and the intercorrelation between dependent variables. Thus, the reported *t*-tests took the level of intercorrelation into consideration, and used the Bonferroni Step-down (Holm) correction in which the *p*-values are ranked from the smallest to the largest.

3. Results

Table 2 summarises performance by the TBI and control groups on each of the measures, along with inferential statistical test results. As is often found in clinical relative to non-clinical groups, TBI participants' performance on each of the dependent measures was associated with greater variability than the controls'. Therefore, the results reported are based on inferential statistics that do not assume equal variances. For both the TBI and the control group, for each of the three dependent measures (Eyes, Faces and FAS fluency) there was no evidence of floor or ceiling effects, and the data passed tests for skewness and kurtosis. The effect sizes associated with each comparison are shown in Table 2. According to the criteria of Cohen (1977), the between-group differences represent medium or large effect sizes. Whilst both Eyes and Faces were moderately impaired, FAS fluency was associated with a deficit large in magnitude.

Taking the level of intercorrelation into consideration, and using the Bonferroni Step-down (Holm) correction, the corrected alpha level for the first comparison is .026 (FAS fluency), .033 for the second comparison (Faces), and .050 for the third comparison (Eyes). Thus, it can be seen that participants with TBI performed significantly more poorly than controls on all of the administered measures. No significant associations were found between injury severity, time since injury and the three dependent measures.

Table 3 presents Pearson Product–Moment correlations among Eyes, Faces, and FAS scores, separately for TBI participants and controls. Whereas in the control group, Eyes and Faces were very substantially and significantly inter-related ($r = .72$), the correlation between these measures in the TBI participant group was much smaller ($r = .29$) and failed to attain statistical significance. However, the magnitude of these two correlations did not differ significantly ($Z = 1.61$, $p = .11$). In the TBI group Eyes (but not Faces) was significantly correlated with perfor-

Table 2

Means, standard deviations, inferential statistics and effect sizes for group differences in the measures of theory of mind, emotional identification and executive functioning

Dependent measure	Control group		TBI group		Inferential statistics[a]		Effect size
	M	S.D.	M	S.D.	t	p	d[b]
Theory of mind							
Total Eyes	25.9	4.06	22.4	6.49	1.84	.038	.66
Emotional identification							
Total Faces	35.3	3.06	33.1	4.75	2.01	.027	.72
Executive functioning							
FAS	47.1	11.88	36.7	15.72	2.33	.014	.87

[a] Since the predictions for each of the measures reported are of TBI deficits, each of the inferential test results are based on one-tailed tests of significance.

[b] A positive value of *d* denotes a deficit for the TBI group.

Table 3
Correlations between measures of theory of mind, emotion recognition and executive functioning

	Faces	FAS
Control group		
Eyes	0.72[*]	0.16
Faces	–	0.18
TBI group		
Eyes	0.29	0.74[*]
Faces	–	−.26

[*] $p < .01$.

mance on the FAS, with the magnitude of the correlation between FAS and Eyes significantly greater in the TBI relative to the control group (rs = .74 versus .16, respectively; $Z = 2.02$, $p = .04$).

4. Discussion

4.1. Emotion recognition and ToM following TBI

TBI participants' scores were significantly lower than those of controls on a task that required detection of subtle differences in mental states from pictures of eyes, but there was a larger group difference in labeling facial expressions of emotion. Correlational analysis revealed that although the ability to label emotions correlated highly with making ToM judgements in the control group ($r = .72$), the corresponding correlation in the TBI group was substantially smaller and non-significant ($r = .29$). The group difference in the magnitude of the correlations failed to attain statistical significance, but the results are broadly consistent with the predictions of Frith and Frith's (1999, 2001) neurocognitive model, which posits that emotion recognition and ToM are subserved by distinct neural networks. Indeed, Brune (2005a) recently reported very similar findings in a study involving participants with schizophrenia. Whereas capacity for emotion recognition as indexed by Faces was strongly correlated with the total score collapsed across several measures of ToM in the control group ($r = .73$), the corresponding correlation in the patient group was substantially smaller ($r = .33$). On the basis of these results, Brune (2005a) suggested that: "It is conceivable that the disparate neural networks underlying 'behavior reading' and ToM are independently affected in schizophrenia, leading to a mosaic pattern of defective or preserved social perceptual and cognitive capacities." (p. 145). The present results suggest that this may also be true for individuals who have sustained a TBI, i.e., basic emotion recognition and ToM may have distinct neural substrates, and therefore be dissociably impaired.

4.2. Emotion recognition, ToM and executive functioning

Whereas in the control group neither ToM nor emotion recognition were substantially correlated with performance on phonemic fluency, in the TBI group ToM, but not emotion recognition, was substantially related to performance on this measure of executive function. The correlation between Faces and phonemic fluency was significantly larger in the TBI group than the con-

trol group, indicating that the relationship between executive functioning and ToM is specific to the TBI group. However, whilst the present study demonstrates evidence of a clear association between executive impairment and ToM ability in TBI, it is not able to address questions of causality. The present pattern of results might have arisen because executive function impairments lead to poor performance on measures of ToM, or because ToM and executive function depend on neuroanatomical systems which are close in proximity to one another. Nevertheless, as Snowden et al. (2003) noted, "It is reasonable to suppose that executive impairments will have a secondary impact on performance on theory of mind tasks." (p. 699), and we would also adopt this view.

Whilst there is considerable evidence that executive functioning and ToM may be dissociated (Bach, Happe, Fleminger, & Powell, 2000; Lough & Hodges, 2002; Varley, Siegal, & Want, 2001) and even when co-occurring, may not be causally related (Rowe, Bullock, & Polkey, 2001), Channon and Crawford (2000) have argued that there may be two distinct routes to deficits in theory of mind tasks. The first arises from impairment in a specific ToM ability, the second from disruption to broader executive abilities. We would suggest that for participants with TBI, this latter route may be more important than the former, given that deficits in executive functioning constitute one of the most prominent features of TBI (Henry & Crawford, 2004b; Stuss & Gow, 1992), possibly due to the diffuse network damage which is common in TBI.

A limitation of the present study is that each of the major constructs of interest (i.e., theory of mind, emotion recognition, executive function) are difficult to assess adequately using a single task. In particular, given the broad, multifaceted nature of executive functioning as a construct, future research is needed to explore the association between ToM and other executive processes that are not likely to be strongly tapped by measures of phonemic fluency (e.g., planning, reasoning, etc.). Nevertheless, the present results do suggest that the cognitive control processes responsible for mental flexibility and self-regulation may be implicated in reduced ToM following TBI. As noted previously, Decety and Jackson (2004) have argued that these particular cognitive control processes are an essential prerequisite for ToM, and measures of phonemic fluency are known to impose substantial demands upon both (see Crawford & Henry, 2005). Thus, the pervasive nature of phonemic fluency deficits following TBI, and the fact that these deficits cannot be ascribed to more generalized deficits in either intelligence or cognitive speed (see Henry & Crawford, 2004b), suggests that reduced cognitive flexibility and capacity for self-regulation may at least partially explain the association between TBI and problems with ToM.

Clearly conclusions from the present study are limited by the relatively small sample size. Using a two-tailed test of significance with an alpha level of .05 the power in the present study to detect a correlation of a small or a moderate magnitude was low. Thus, even though the power to detect a significant correlation of the magnitude actually identified between Eyes and FAS in the TBI sample ($r = .74$) was high (.82), a sample consisting of 16 TBI participants cannot provide reliable correlations.

The robustness of the pattern of correlations reported therefore remains to be demonstrated. In addition, it is difficult to gauge how representative the small group of TBI participants included in the present study is of the larger population of adults with TBI. This is because, in contrast to studies that recruit patients prospectively, as with most other retrospective investigations involving participants with TBI it is not possible to accurately estimate how many potential participants declined participation. Another reason why cross-validation of the present results is necessary is because of the heterogeneous nature of the TBI sample. As noted previously, because the variance in the dependent measures was higher in the TBI relative to the control group, the potential impact of the difference in group variances was taken into account in group comparisons. Nevertheless, the difference in variances could also help account for differences in the magnitude of correlations across groups (for instance, correlations may be more restricted in the comparison group). Again, this clearly points to the need to demonstrate that the present results are robust, which requires cross-validation in an independent sample.

In conclusion, whether arising as a primary disorder, or secondary to executive function impairment, it has long been recognised that deficits in the capacity to infer the mental states of others are likely to lead to serious problems in social functioning. There is considerable evidence that TBI is associated with changes in social relationships (Ponsford, Olver, & Curran, 1995; Weddell, Oddy, & Jenkins, 1980) and that these are considered to be one of the most distressing and disabling aspects of the disorder (Brooks, Campsie, Symington, Beattie, & McKinlay, 1986; Kinsella, Packer, & Olver, 1991). Importantly, McDonald, Flanagan, Martin, & Saunders (2004) found that TBI participants' performance on a measure which involves inferring mental state from videoed vignettes, was significantly associated with deficits in spontaneous social behavior, and particularly use of humour and partner-directed behavior. Thus, although studies typically focus on aspects of cognitive change following head injury, the present results add to growing evidence suggesting that more attention should be focused upon assessment of social and emotional problems, and specifically point to the need to further investigate the link between executive function and theory of mind, and to the implications this has for social functioning following TBI.

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