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Neuropsychological Impairments and Changes in Emotional and Social Behaviour Following Severe Traumatic Brain Injury

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ABSTRACT

Changes in emotional and social behaviour are relatively common following severe traumatic brain injury (TBI). Despite the serious consequences of these changes, little is known about the underlying neuropsychological deficits. In this study, we investigated which deficits might underlie these behavioural changes. The emotional and social behaviour of 17 patients with severe TBI was assessed with questionnaires, completed by the patient and a relative. Neuropsychological tests assessed recognition of emotional expressions, understanding of other people's mental states and cognitive fluency. Ratings from patients and relatives revealed changes in emotional and social behaviour after injury. Compared to matched healthy controls, the patients were impaired at recognising facial and vocal expressions of emotions, detecting social faux pas and nonverbal fluency. None of these impairments was significantly associated with the relatives' ratings of behavioural problems following TBI, although the correlation with detecting social faux pas was relatively high ($r = -.61$).

INTRODUCTION

Changes in emotional and social behaviour as expressed in, for example, indifference, emotional lability, poor social judgement and disinhibition, are among the most common and debilitating consequences of severe traumatic brain injury (TBI) (Kendall & Terry, 1996; Levin, 1995; Prigatano, 1992). Many patients fail to return to work or maintain meaningful social relationships as a result of these changes (Brooks, McKinlay, Symington, Beattie, & Campsie, 1987; Malia, Powell, & Torode, 1995). For relatives of patients with TBI these behavioural changes are often a greater burden than the physical or cognitive impairments (Brooks, Campsie, Symington, Beattie, & McKinlay, 1986; Kinsella, Packer, & Olver, 1991), even many years after the injury (Koskinen, 1998). Although the adverse consequences of changes in emotional and social behaviour are well documented, relatively little is known about the impairments that may underlie these changes.

Numerous studies in patients with TBI have tried to identify the factors that can best predict psychosocial outcome. Possible predictors of outcome reported in the literature included age at time of injury, level of education, injury severity, time since injury and performance on neuropsychological tests (see Bowman, 1996; Kendall & Terry, 1996; Tate & Broe, 1999 for overviews). However, the neuropsychological variables included as predictors of outcome were restricted to cognitive functions (memory, attention, executive functions), while variables that may be more directly related to social and emotional functioning were typically ignored as possible predictors. Studies that did include measures of emotional

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state (e.g., Bowman, 1996) found that these could predict aspects of psychosocial outcome, especially social activity. Another common limitation of studies into psychosocial outcome is that behavioural changes are assessed almost exclusively by means of self-report measures, i.e., questionnaires. Typically relatives or carers of the patient or, in some cases, patients themselves, rate various aspects of the patient's behaviour. A problem with such measures is their vulnerability to confounding variables such as poor memory or lack of insight in the patients or the personality structure and mood state of the patient's relative. As a result, there is a growing recognition of the need to develop alternative methods of measuring behavioural changes in TBI patients (Jackson et al., 1992; Tate, 1999), which rely less on relatives' or patients' reports of behaviour.

Possible candidates for such alternative measures of changes in emotional and social behaviour may be found among specific neuropsychological tests. Evidence for this comes from studies in patients with behavioural changes following localised lesions in the frontal lobes. Hornak, Rolls, and Wade (1996) found that patients with lesions in the ventral frontal lobes, who were rated as poor at interpreting other people's moods by nursing staff, were also impaired in a test of recognition of emotional expressions. In addition, Hornak et al. (1996) found a significant correlation between the ability to recognise emotional expressions and subjective ratings regarding emotional changes in these patients. Impaired recognition of expressions was associated with reports of larger changes in emotional experience. Cicerone and Tanenbaum (1997) also described impaired performance on tests assessing interpretation of social situations in a patient who showed changed emotional and social behaviour following traumatic injury to the left orbitofrontal lobe. More recently, Blair and Cipolotti (2000) reported a patient with behavioural disturbances described as "acquired sociopathy" following damage to the orbitofrontal cortex. This patient proved impaired on tests of recognising facial expressions and identifying socially inappropriate behaviour from stories of social situations. Reports like these suggest that behavioural changes may be related to impairments in abilities such as recognising emotional expressions or understanding of social situations, abilities that can be assessed with neuropsychological tests.

A number of studies in patients with TBI have investigated recognition of emotional expressions or understanding of social situations, although none of these studies explicitly related these abilities to the patients' behaviour postinjury. Impaired recognition of facial expressions in patients with TBI was reported in several studies (Braun, Baribeau, Ethier, Daigneault, & Proulx, 1989; Jackson & Moffat, 1987; Pettersen, 1991). Jackson and Moffat (1987) showed that the recognition impairment was not specific to faces as their patients were equally impaired at recognising emotions from body postures. Jackson and Moffat (1987) speculated "that a systematic impairment in the accurate recognition of such social cues may promote the maintenance, and possibly the genesis, of poor social skills and antisocial behaviour commonly found following severe closed head injury" (p. 298), but did not actually investigate this possibility. Pettersen (1991) noted that those head-injured children and adolescents who were impaired at recognising facial expressions were rated by their parents as showing less mature and socially appropriate behaviour than matched controls. However, Pettersen did not report correlations between the ratings and the expression recognition data. So, to date it is unclear whether impairments at recognising emotional expressions in TBI patients can be related to behavioural changes following injury.

Understanding of social situations and other people's intentions following TBI has been investigated by very few studies. Grattan and Eslinger (1989) tested empathy in patients with acquired brain injury, including TBI. According to Grattan and Eslinger (1989), empathy "refers to the capacity to apprehend another person's situation or state of mind in such a way that there is a potential for sharing and increased understanding through an interpersonal relationship" (p. 176). Patients with behavioural changes after brain injury scored lower on an empathy scale than healthy controls. Six months following injury, patients reported fewer empathic responses compared to the time before injury. These changes were confirmed by the patients' relatives (Eslinger, 1998). A requirement for empathy would be the ability to recognise the mental state of other people. The ability to recognise and make inferences about other people's intentions and mental states is often referred to as ''theory of mind,'' which is thought to be crucial for normal social communication. Most research into deficits in theory of mind has been done in developmental disorders such as autism and Asperger's syndrome, which are characterised by impaired social behaviour (Baron-Cohen, Leslie, & Frith, 1986; Baron-Cohen, Tager-Flusberg, & Cohen, 1999). Indications for acquired deficits in theory of mind have recently been reported in adult patients with frontal lobes lesions (Happé, Brownell, & Winner, 1999; Happé, Malhi, & Checkley, 2001; Stone, Baron-Cohen, & Knight 1998). Although Stone et al.'s (1998) study did include several patients with TBI, we are not aware of other studies that tried to relate understanding of social situations and intentions to behavioural changes following TBI.

The tests of cognitive abilities that have been found to best predict psychosocial outcome following TBI are tests of executive functioning (Tate, 1999; Villki et al., 1994). Executive processes (e.g., planning, rule finding and rule shifting, and response inhibition) are important for the conscious control of behaviour. Impairments in executive abilities, such as inflexibility and disinhibition, are frequently reported following TBI (Levin, 1995; Tate, 1999). Prigatano (1992) suggested that the decreased flexibility in TBI patients could adversely affect their ability to adapt and cope with environmental demands. Consistent with this suggestion, Villki et al. (1994) found that TBI patients' performance on tests of cognitive flexibility predicted their ability to return to work and their level of social activity several months later. By contrast, performance in memory and intelligence tests had no relation to psychosocial outcome. Grattan and Eslinger (1989) reported that patients who scored poorly on tests of cognitive flexibility were also rated as less empathic towards others. Tate (1999) used rule breaking errors on fluency tests as an indication of impulsive behaviour. TBI patients with high numbers of rule breaking scores also showed significant increases in impulsive and restless behaviour as rated by a relative.

In sum, there are various indications for impairments in TBI patients in those abilities that may be relevant to changes in emotional and social behaviour, namely recognition of emotional expressions, understanding of social situations and other people's intentions, and cognitive flexibility. However, with the exception of cognitive flexibility, there have been very few attempts to relate impairments in these abilities to changes in behaviour in TBI patients. Work in patients with behavioural changes following focal frontal lesions has shown that impairments in recognising emotions and understanding social situations can be related to changes in emotional and social behaviour. The first aim of this study was to identify impairments in expression recognition, understanding of situations and intentions and flexibility in patients with moderate to severe TBI. To date, studies in TBI patients assessed some, but not all, of these abilities in the same sample of patients. The second aim of this study was to investigate the relationships between these impairments with ratings concerning the patients' behaviour, in order to identify impairments that might underlie changes in social and emotional behaviour.

METHOD

Participants

Seventeen patients (7 female/10 male) between the ages of 19 and 42 years ($M = 30.5$, $SD = 13.3$) participated in this study. Patients were recruited through two rehabilitation centres in Aberdeen and the Department of Neurosurgery of Aberdeen Royal Infirmary. Estimates of length of the posttraumatic amnesia (PTA) were not available for 2 patients. Mean length of PTA in the remaining 15 patients was 33.6 days ($SD = 27$), indicating severe head injury (Russell, 1971). Glasgow Coma Scale scores also indicated severe head injury ($GCS \leq 8$) in 12 patients and moderate head injuries (GCS between 9 and 12) in 5 patients. Fifteen patients had sustained their injury in a road traffic accident, 1 after a domestic accident and 1 in an assault. Mean time since injury was 4.4 years ($SD = 4.9$). At the time of the study, all patients were living at home. Thirteen patients lived independently without partners, although 4 of

Table 1. Demographic Data from the Patients and Healthy Controls.

	Patients		Controls	
	M	*SD*	*M*	*SD*
Age (years)	30.5	13.3	29.1	12.1
Education (years)	11.6	1.7	11.6	1.3
PTA (days)	33.9	27		
Postinjury (years)	4.4	4.9		
GCS	6.2	2.6		

Note. PTA = Posttraumatic amnesia, GCS = Glasgow Coma Scale.

them had been living with a partner before the injury. Four patients were living with their parents, while 3 of them had been living independently before the injury. None of the patients reported a history of psychiatric disease or a premorbid history of alcohol or drug addiction. Seventeen healthy participants (7 female/10 male) served as controls. Controls were members of the general public who were recruited from the subject panel of the Department of Psychology and through an advertisement in a local newspaper. The control subjects were closely matched to the patients in terms of gender, age and years of education (see Table 1). None of the controls reported ever to have suffered a head injury or any neurological or psychiatric disease.

A relative of each patient was asked to rate aspects of the patient's emotional and social behaviour before and after the injury.

Measures

Questionnaires

Behavioural characteristics of the patients, pre- and postinjury, were measured with the Neuropsychology Behaviour and Affect Profile (NBAP; Nelson, Drebing, Satz, & Uchiyama, 1998). The NBAP is a 106-item questionnaire specifically designed to assess the emotional and behavioural consequences of acquired brain damage, and consists of five subscales: Indifference, Inappropriateness, Pragnosia, Depression, and Mania. Indifference refers to anosognosia and denial of illness, Inappropriateness to unusual or bizarre behaviour, Pragnosia to a deficit in the pragmatics of communication, Depression to apathy, withdrawal and sadness, and Mania to impulsivity, irritability and euphoria. Each item is rated either "agree," meaning typically or often, or "disagree," meaning seldom or hardly at all. "Agree" is scored as 1 and "disagree" as 0. The item scores from each subscale are summed and converted into percentages, taking into account the number of items in each subscale. Higher scores reflect more emotional problems. There are separate scores for premorbid functioning ("Before") and postinjury functioning ("Now"). Total "Before" and "Now" scores, indicating overall emotional functioning, are obtained by summing the scores of the five subscales and converting these into percentages. Patients completed the Self version of the NBAP, while relatives completed the Observer version. The controls rated only their current behaviour on the Self version. Mathias and Coates (1999) examined the validity of the NBAP in patients with traumatic brain injury and found high correlations between ratings on the NBAP and ratings on two other behavioural scales, the Neurobehavioral Rating Scale (Levin et al., 1987) and the Headley Court Psychosocial Rating Scale (Malia et al., 1995).

A Social Integration Questionnaire (SIQ) was adapted from Willer, Ottenbacher, and Coad's (1994) Community Integration Questionnaire (CIQ). This questionnaire assessed three aspects of social outcome: home integration (involvement in household work), social integration (involvement in social activities) and work integration. Each item is rated as "Yes" or "No." "Yes" is scored as 1, "No" as 0. The work integration score refers to employment status. The scores on the home integration and social integration subscales are summed and converted into percentages. The higher the score, the better the social outcome. There are separate scores for before and after injury. This questionnaire was completed by the patient and a relative.

Neuropsychological Tests

Recognising Facial Expressions

Four different tests assessed the recognition of facial expressions in the patients and controls.

- Naming facial expressions. This test consists of 60 photographs from a standard set of facial expressions (Ekman & Friesen, 1976). The expressions depicted are fear, disgust, anger, happiness, sadness or surprise, which are displayed by 10 different individuals. The photographs are presented one by one and the names of the six emotions are printed below each photograph. The task is to choose the emotion name that best describes the facial expression shown.
- Matching facial expression across identity. In this test five photographs of facial expressions displayed by different individuals are fixed on a card. The faces come from the same set as those in the previous test. There are 18 cards, 3 for each of the 6 expressions: fear, disgust, anger, happiness, sadness, and surprise. The task is to match the face at the top of the card with the face that has the same expression.
- Matching expressions to situations. This test comprises of 24 drawings of emotional situations (4 for

each of the 6 target emotions). The faces in these drawings are blank. There are two versions of the test. In the verbal version, the situations have to be matched to one of six emotion names (fear, disgust, anger, happiness, sadness, and surprise) that is most appropriate for each situation. In the picture version, participants have to choose from six photographs of facial expressions, displayed by the same individual, the expression that is most appropriate for each situation. The responses of the control group determine the scoring of the participants' responses. The more controls agreed on a specific item, the more points participants obtained on that item. If all 17 controls choose the same emotion to a situation, a correct response on that item was awarded with 1.7 points. If 10 controls choose one emotion, e.g., surprise, and 7 choose another emotion, e.g., happiness, for the same item, participants responding with "surprise" to that item would receive 1 point, and participants responding with "happiness" would receive 0.7 point. Patients responding with another emotion would receive no point on that item.

Facial Recognition Test

The short version of this test was used to control for possible impairments in face perception which could interfere with expression recognition (Benton, Hamsher, Varney, & Spreen, 1983).

Recognising Emotions in the Voice

Recognition of emotional prosody was tested with four subtests from the Florida Affect Battery (FAB: Bowers, Blonder, & Heilman, 1991).

- Emotional prosody discrimination: 20 pairs of emotionally neutral sentences (e.g., "The lamp is on the table") are spoken in the same or a different emotional tone of voice. Participants have to indicate whether the affective prosody of each sentence pair is the same or different.
- Naming emotional prosody: 20 emotionally neutral sentences are spoken in one of five possible tones of voice: happy, sad, angry, fearful, and neutral. The five possible emotion labels are presented to the participants, who choose for each sentence the emotion which best describes the affective prosody.
- Conflicting emotional prosody: 36 sentences with emotional content are spoken in a tone of voice that is either congruent or incongruent with the content of the sentence (e.g., "The puppies are dead" spoken in a sad or a happy tone of voice). There are four possible emotions (happy, sad, angry, and neutral) and participants have to name the emotion in the tone of voice, while disregarding the sentence content.
- Nonemotional prosody discrimination. This test served as a control task for possible perceptual deficits which could affect performance in the affective prosody tests. The test consists of 16 pairs of sentences spoken either in an interrogative or a declarative tone of voice. For half the sentence pairs the tone of voice is the same, for half it is different, and participants indicate whether the prosody in the two sentences is the same or different.

Understanding Intentions and Social Situations

- Emotional Empathy Questionnaire (EEQ: Mehrabian and Epstein, 1972). This 33-item questionnaire assesses various aspects of emotional empathy. Emotional empathy is defined as the ability to understand the emotional states of others and one's own role in the mental states of others (Eslinger, 1998).
- Faux Pas Test (Stone et al., 1998). This test consists of 20 very short stories, 10 describing a social faux pas, 10 without faux pas. After participants have read each story, they answer a number of questions while keeping the story in front of them. Following stories containing a faux pas, five questions are asked that assess participants' detection of the social faux pas, understanding of the mental states of the characters in the story and comprehension of the story (control question). A sixth question queries empathic understanding for the main character in the story. Following stories without faux pas, two questions are asked that assess detection of the (absence) of the faux pas and comprehension of the story (control question). Participants receive 1 point for each correct response. There are separate scores for the 10 faux pas stories and the 10 stories without faux pas. Control questions and empathic understanding questions are also scored separately.
- Eye Test (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997). This test was designed to assess understanding of other people's mental states from their eyes. The test comprises of 25 pictures of the eye region of different male and female faces. Printed below each pictures are two, opposite, mental state terms (e.g., concerned – unconcerned) and participants have to choose the term that best describes the mental state signalled by the eyes. Baron-Cohen et al. (1997) employed this test in high performing adults with autism or Asperger's syndrome, and found impaired performance in this group, even though the same persons were not impaired at recognising emotional expressions from the (whole) face.

Cognitive Flexibility

Cognitive flexibility was assessed with two fluency tests.

- Ruff Figural Fluency Test (RFFT: Ruff, 1996). This is a test of nonverbal fluency, which requires the generation of as many different unique designs as possible within 1 min. There are five trials of increasing difficulty. In addition to the number of correct, unique designs, there were two error scores: (1) perseveration errors, and (2) rule- breaking errors, for responses that violate the test instructions (e.g., crossing borders). The Five Point Test (Regard, Strauss, & Knapp, 1982) was used as a control test of motor speed. Reduced motor speed in the patients could affect performance on the RFFT. For this motor speed test participants had to draw as many rectangles as possible within 1 min by combining four dots.

– Uses for Objects (UFO: Crawford, Wright, & Bate, 1995). This is a measure of ideational fluency based on Getzels and Jackson's (1961) creativity task, and requires the generation of as many possible uses of a common object within 90 s. There are three trials, one for each common object; bottle, paper clip, and felt hat. In addition to the number of correctly generated uses, there are two types of error scores: perseverative errors and rule breaking errors. Perseverations occur if a possible use is repeated. A rule breaking error occurs if the response does not qualify as an articulated use for the object (e.g., "smash it" or "break it" for the bottle).

Procedure

Both patients and controls performed all the neuropsychological tests. The patients and a relative of each patient, completed the "before injury" and "current behaviour" ratings of the NBAP and the SIQ. The controls only completed the "current behaviour" ratings of the NBAP. In total, testing took 3–4 h for the patients and was carried out in several sessions. The controls required 2–3 h to complete all the tasks, which were carried out in a single session. The order in which the tests were administered was randomised for both patients and controls. Relatives of the patients completed the questionnaires at home. Twelve patients were tested in the rehabilitation centre that they visited as out-patients. Two patients were tested at home and 3 patients as well as all the control subjects were tested in the Department of Psychology.

RESULTS

First, we will describe results on the individual tests and questionnaires in order to reveal impairments in the abilities tested and changes in behaviour following injury in the patient group. Next, we will examine how impairments identified with the neuropsychological tests relate to ratings of emotional and social behaviour.

Behavioural and Social Outcome

Neuropsychology Behaviour and Affect Profile (NBAP)

The mean ratings from the patients, relatives and the controls are displayed in Table 2. The ratings

Table 2. Mean Ratings from Patients, Their Relatives and Matched Controls on the Neuropsychology Behavior and Affect Profile (NBAP) and the Social Integration Questionnaire (SIQ) Concerning the Time Before Injury (Before) and the Current Situation (Now).

	Patients				Relatives				Controls	
	Before		Now		Before		Now		Now	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
NBAP										
Indifference	28.9	18.7	33.3	25.5	15.1	10.2	39.6	30.0	20.6	21.5
Inappropriate	25.2	21.7	47.9	27.6	9.8	19.3	46.4	33.6	31.9	27.4
Pragnosia	14.7	11.9	37.5	25.7	5.2	8.0	32.8	23.7	8.8	11.9
Depression	11.8	14.6	52.4	36.3	8.5	13.5	51.7	34.9	18.7	18.3
Mania	39.0	21.5	43.6	22.4	17.2	15.4	27.9	22.6	38	23.8
Total	26.7	13.6	42.6	20.9	11.9	8.1	36.9	23.9	25.7	16.0
SIQ										
Home integration	64.7	31.9	60.3	31.9	67.2	37.3	54.7	33.2		
Social integration	71.6	12.4	44.9	17.4	69.9	16.2	38.6	18.6		

from one relative were not available. Comparisons were carried out on the Total scores, which consists of the Indifference, Inappropriateness, Pragnosia, Mania, and Depression subscales, and on the individual subscales. To control for the effect of multiple comparisons, the significance level was adjusted by the number of tests in each comparison. In most cases, the number of tests was six, five NBAP subscales plus the Total score, and the resulting alpha level was $0.05/6 = 0.008$.

To determine whether there were significant differences between the patients' behaviour and that of the controls, ratings from the patients on the NBAP subscales and the Total score for current behaviour ("Now") were compared with ratings from the controls. Between-group *t* tests revealed significantly higher ratings in the patient group on the Pragnosia and Depression subscales, $t(32) \geq 3.42$, $p < .005$. The differences on the other subscales and the Total score failed to reach the adjusted alpha level of .008. Comparisons of the controls' ratings and the ratings of the relatives concerning the patients' current behaviour also revealed significant differences on the Pragnosia and Depression scales, $t(31) \geq 3.43$, $p < .005$.

These differences between the patients and controls may reflect differences in premorbid behaviour rather than a consequence of the TBI. In order to investigate this possibility, we compared ratings from the patients concerning their preinjury behaviour ("Before") with ratings from the controls concerning their current behaviour. These comparisons revealed no significant difference on any of the NBAP subscales or the Total score, $t(32) \leq 1.43$, $p > .1$). Comparisons of the relative's ratings concerning the preinjury behaviour of the patients and the controls current behaviour ratings showed significantly lower ratings for the patients on the Mania scale and the Total score, $t(31) \geq 2.95$, $p < .007$). This may reflect a tendency of the relatives to idealise the premorbid functioning of the patients.

The preceding comparisons failed to provide evidence for more premorbid behavioural problems in the patient group. However, the patients' behavioural problems had increased following the TBI. Comparison of the patients' ratings concerning the time before and after injury with pair-wise *t* tests, revealed significant increases in the number of reported problems on the Pragnosia and Depression subscales and on the Total score, $t(16) \geq 3.62$, $p < .005$. Comparison of the relatives' ratings for the patients' behaviour before and after the injury showed significant increases on the Pragnosia, Depression, Inappropriateness, and Indifference subscales and on the Total score, $t(15) \geq 3.29$, $p < .006$.

Social Integration Questionnaire

The mean ratings from patients and relatives relating to Home integration and Social integration before and after ("Now") the injury are displayed in Table 2. The ratings from one relative were not available. There were no significant differences between the Now scores of patients and relatives for Home integration and Social integration, $t(31) \leq 1$. Comparisons of the ratings related to Social integration before and after the injury revealed significant changes reported by both the patients, $t(16) = 4.1$, $p < .01$ and their relatives, $t(15) = 4.7$, $p < .001$; social integration was poorer after the injury. Home integration had not changed after injury according to the ratings of patients and relatives. Work integration had substantially decreased after injury. Before injury 13 of the 17 patients were in full- or part-time employment, while at the time of this study only 5 of the patients were employed, and all 5 worked at a lower level than at the time they sustained their head injury.

Neuropsychological Tests

Recognising Facial Expressions

The mean number of correct responses from patients and controls in the four facial expression tests are shown in Table 3. These scores were averaged across the different expressions. Performance of the patients and controls on the different facial expression tests was compared in separate *t* tests. To control for the effect of multiple comparisons, the significance level was adjusted by the number of comparisons, four in this case, and the resulting alpha level was $0.05/4 = 0.0125$. The patients performed significantly poorer than the controls in Naming facial expressions and Matching

Table 3. Performance of the Patients and Matched Controls on the Neuropsychological Tests from the Four Domains of Interest.

	Patients *M* (*SD*)	Controls *M* (*SD*)	*t*	*p*[1]
Facial expressions				
Naming expressions	46.3 (6.3)	52.5 (4.4)	3.32	.002[2]
Matching across identity	15.8 (2.0)	17.2 (0.8)	2.54	.016
Situations: verbal	25.7 (2.8)	27.9 (1.1)	2.95	.006[2]
Situations: picture	23.0 (4.0)	27.9 (1.3)	4.71	< .0005[2]
Expressions in the voice				
Prosody discrimination	19.6 (0.6)	19.4 (0.5)	0.91	.37
Naming prosody	17.4 (1.8)	19.1 (1.2)	3.13	.004[2]
Conflicting prosody (incon)	15.9 (2.5)	17.9 (1.0)	2.99	.005[2]
Conflicting prosody (con)	15.6 (1.6)	16.5 (0.9)	1.85	.074
Understanding intentions and social situations				
EEQ	27.8 (28.7)	31.0 (23.4)	0.36	.72
Faux Pas: detection	28.0 (7.5)	34.1 (3.3)	3.08	.004[2]
Faux Pas: understanding	9.5 (0.9)	9.8 (0.4)	1.19	.24
Faux Pas: emotional state	8.1 (2.2)	9.2 (0.8)	1.78	.084
No Faux Pas: detection	8.8 (2.51)	9.6 (0.79)	1.38	.18
No Faux Pas: understanding	9.18 (1.13)	10.0 (0)	–	–
Eye Test	18.18 (2.77)	19.71 (1.72)	1.93	.62
Flexibility				
RFFT: no. correct	50.3 (22.4)	96.3 (30.7)	4.99	< .0005[2]
RFFT: persever (%)	2.3 (2.1)	5.6 (6.2)	2.07	.046
RFFT: rule breaking (%)	0.2 (0.7)	0.2 (0.6)	0.10	.92
UFO: no. correct	13.9 (6.4)	20.9 (8.8)	2.66	.012
UFO: persever (%)	0.3 (0.4)	0.4 (0.7)	0.79	.43
UFO: errors (%)	0.4 (0.5)	0.4 (0.7)	0.04	.97
Control tests				
Facial Recognition Test	43.4 (5.1)	47.5 (3.7)	2.67	.012
Nonemotional prosody	14.0 (1.7)	15.3 (1.1)	2.59	.014
Five Point Test	22.1 (8.2)	36.7 (11.1)	4.27	< .0005

[1]two-tailed; [2]significant after appropriate adjustment of alpha level.

expressions to situations, both the verbal and the picture version, $t(32) \geq 2.95$, $p < .01$; see Table 3. However, the patients performed better on the verbal version than on the picture version, $t(16) = 2.8$, $p < .05$. No such discrepancy between the two test versions was found in the control group, $t(16) = 0.01$. The difference in performance between patients and controls on the Matching Expressions Across Identity-test failed to reach significance under the adjusted alpha level.

Benton Facial Recognition Test

To control for the possibility that poor recognition of facial expressions in the patients was caused by perceptual problems affecting recognition of faces in general, we administered the Benton Facial Recognition test. The patient group scored lower on this test than the controls, $t(32) = 2.7$, $p < .05$. To examine whether this impairment was related to the poor performance in the tests of facial expression recognition, we performed a hierarchical regression analysis, with as independent variables the score on the Benton test, followed by group membership (patients or controls) and as dependent variable a composite score comprised of the scores from three of the four facial expression tests. This composite score was obtained by transforming the patients' scores from those facial expression tests on which patients proved impaired (Naming expressions, Matching expressions to situations: verbal and picture version) into *z* scores, using the means and standard deviations of the control group. These *z* scores were subsequently summed to form the composite score. Summation was justified because correlations between the expression tests were all significant ($r \geq .39$, $p < .05$). Results of the regression analysis showed that performance on the Benton test did not predict performance on the facial expression tests ($R^2 = .08$, $p > .1$), while subsequent entry of group membership (patient or control) did ($R^2 = .39$, $p < .01$). This indicated that the relatively poor performance of the patients on the Benton test was not related to their impairment at recognising facial expressions.

Recognising Emotions in the Voice

The mean number of correct responses in the vocal expression tests is shown in Table 3. All these scores were averaged across the different expressions. Again, performance of the two groups was compared with separate *t* tests, while adjusting the significance level of the number of comparisons, in this case four. The patients scored significantly lower on Naming emotional prosody and Conflicting emotional prosody, $t(32) \geq 2.99$, $p < .01$). In the latter test, the patients tended to choose the emotion conveyed by the sentence content. There were no significant differences on the two remaining vocal expression tests (see Table 3).

Nonemotional Prosody Discrimination

This test served as a control task for possible perceptual deficits. The patients scored significantly poorer on this test than controls, $t(32) = 2.6$, $p < .05$. In order to examine whether this poor recognition of nonemotional prosody could explain the patients' poor recognition of emotional prosody, we performed a hierarchical regression analysis. Independent variables were the number of correct responses on the nonemotional prosody test and group membership. The dependent variable was a composite score comprised of the scores of the two emotional prosody tests on which the patients were impaired: Naming emotional prosody and Conflicting prosody. This composite score was created by transforming the patients' scores in these two tests into *z* scores, using the means and standard deviations of the control group, and summing these *z* scores to form the composite score. Summation was justified because the correlation between the two prosody tests was substantial ($r = .56$, $p < .01$). Nonemotional prosody explained a modest but significant proportion of the variance in the emotional prosody tests, ($R^2 = .12$, $p < .05$), but addition of group membership significantly increased the proportion of variance explained ($R^2 = .30$, $p < .01$) in the prosody tests. Although recognition of nonemotional prosody was associated with recognition of emotional prosody, its effect was limited compared to the effect of group membership, and could not fully explain the impaired recognition of emotional prosody in the patients.

Understanding Intentions and Social Situations

The mean scores on the empathy questionnaire and mean number of correct responses on the intentions tests are shown in Table 3. Performance of the patients and controls on the various measures in this domain were compared with separate *t* tests. The alpha level was adjusted by the number of comparisons (seven), and the resulting alpha level was $0.05/7 = 0.007$. With this correction, the only significant difference between patients and controls was the Faux Pas Detection score, $t(32) = 3.08$, $p < .005$. The patients detected fewer social faux pas than controls in the 10 stories that contained a faux pas. On none of the other measures did the patients score significantly poorer than controls. The results from the Faux Pas Test suggest that the patients did have difficulties detecting inappropriate social behaviour, which could not be attributed to poor understanding of the stories containing a faux pas, as there was no difference between patients and controls on the control questions for the faux pas stories. The patients' good performance on the stories without faux pas might reflect a response bias. That is, the patients may have been tempted to respond that no faux pas had occurred in the stories, regardless whether the stories did contain a faux pas or not.

Cognitive Flexibility
The mean number of correct responses plus the error scores from patients and controls on the flexibility tests are shown in Table 3. Again, performance on these tests were compared with separate *t* tests and the alpha level were adjusted by the number of comparisons to control for the effects of multiple comparisons: six. The number of correct unique designs in the Ruff Figural Fluency Test (RFFT) was significantly smaller in the patient group than the control group, $t(32) = 4.99$, $p < .0005$, but none of the other measures showed a significant difference between patients and controls (see Table 3). The RFFT requires quick and fairly precise hand movements and poor motor speed is likely to have an adverse effect on the fluency score. We used the Five Point Test as a control test to assess the patients' manual motor speed. The patients produced significantly fewer rectangles on this test than controls, $t(32) = 4.27$, $p < .001$, indicating slower motor speed in the patients. To examine the contribution of this impairment in motor speed to the RFFT score, we performed a hierarchical regression analysis, with motor speed and group membership as independent variables and the number of correct designs on the RFFT as the dependent variable. Motor speed explained a significant proportion of the variance on the RFFT ($R^2 = .29$, $p < .01$), but adding group membership resulted in a significant increase in the proportion of explained variance ($R^2 = .50$, $p < .01$). In sum, although reduced motor speed did contribute to the poorer score on the RFFT, it could not fully account for the patients' impaired performance.

When, as in the present study, performance on neuropsychological tests is expressed on widely different metrics, the relative strengths and weaknesses of a clinical sample are more readily appreciated if the test scores are converted on a common metric. To this end, we expressed the patients' performance on each neuropsychological tests as *T* scores, which were derived from the mean score and standard deviation of the control group. *T* scores have a mean of 50 and a standard deviation of 10. For example, a *T* score of 50 indicated that the mean scores of the patients and controls on that test were identical. A *T* score of 30 means that the mean score of the patients on that test was 2 *SD* below the controls' mean. Figure 1 shows the *T* scores for the patients' performance on the tests of expression recognition, understanding of intentions and flexibility in order to provide an overview of the patients' performance profile. Figure 1 confirms the data

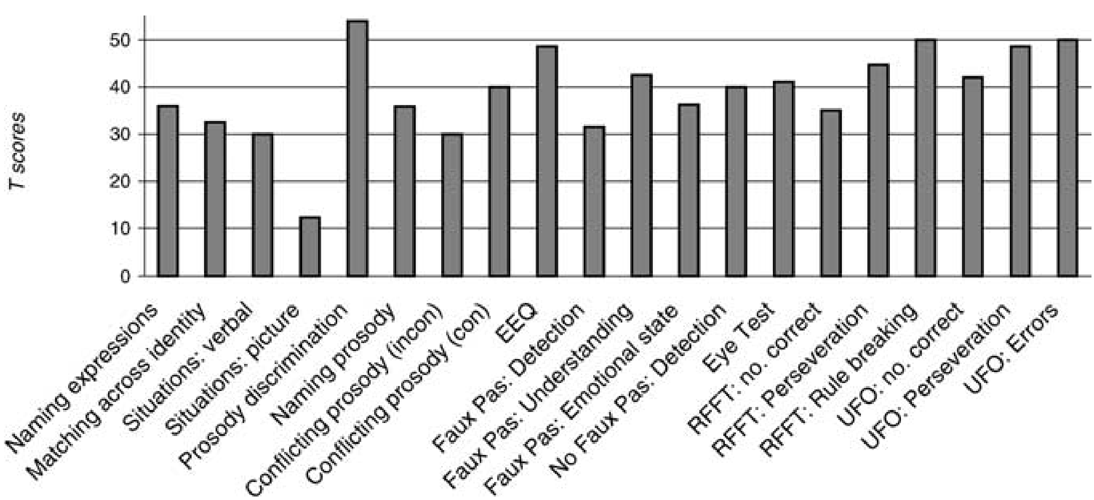

Fig. 1. Mean scores of the patient group on the main neuropsychological tests expressed as *T* scores. *T* scores have a mean of 50 and a standard deviation of 10, and are derived from the mean and standard deviation of the control group on each measure.

Table 4. Correlations Within the Patient Group Between Tests on Which Patients were Impaired and Relatives' Ratings of Changes in the Patients' Behaviour.

	NBAP Pragnosia	NBAP Depression	NBAP Total	SIQ Social integration
Facial expression sumscore	−.084	.125	−.202	−.140
Vocal expression sumscore	.280	.474	.372	−.284
RFFT no. correct	−.158	.247	−.021	.095
Faux Pas no. correct	−.456	−.391	−.612	−.191

presented in Table 3 in that the patients scored poorer than the controls on all measures, except Prosody discrimination, the Emotional Empathy questionnaire, RFFT rule breaking errors, UFO perseverations and UFO errors. In general, recognition of emotional expressions, especially facial expressions, appears more severely impaired in the patients than their performance on the measures of cognitive flexibility or of understanding intentions and social situations.

Relationship Between Cognitive Impairments and Emotional and Social Behaviour

The second aim of this study was to investigate whether impairments identified on the neuropsychological tests were related to changes in the patients' emotional and social behaviour following the head injury, as inferred from the questionnaires. To examine this question, we correlated ratings on the questionnaires with the patients' performance on the different tests. In order to reduce the number of analyses we first formed four deficit scores, one for each of the abilities tested: (1) recognition of facial expressions; (2) recognition of expressions in the voice; (3) understanding intentions and social situations; and (4) cognitive flexibility. These deficit scores contained scores from only those tests in which patients proved impaired and were obtained by transforming the test scores into z scores, using the means and standard deviations of the control group and summing these z scores into a deficit score. Only one test for understanding intentions, the Faux Pas Test, and one flexibility test, the RFFT, showed significantly poorer performance in the patients. Hence, the deficit scores for these abilities consisted of the number of correctly detected faux pas from the Faux Pas Test and the number of correct designs from the RFFT, respectively. The composite scores for recognition of facial expressions and tone of voice have already been described above and contained three and two test scores, respectively. We calculated Pearson's correlations between each of the four deficit scores and those subscores of the NBAP that showed a significant increase in reported problems from before injury to the current behaviour ('Now'), namely Pragnosia, Depression and the Total score (see Table 4). In line with most studies in this field, we used only the ratings obtained from the relatives. The alpha level was adjusted by the number of correlations and was $0.05/12 = .004$. As Table 4 shows, none of the correlations was significant under this adjusted alpha level. The only correlation that was relatively high ($r = -.61$) was between the Faux pas score and the NBAP Total score, suggesting that poorer performance on the Faux Pas Test was related with more behavioural problems. A similar analysis of the association between the four deficits scores and the Social integration score, the relatives' ratings on the SIQ that indicated an increase in problems from before to after the injury (''Now''), revealed no significant correlations (see Table 4).

DISCUSSION

The patients with TBI tested for this study had more problems in emotional and social behaviour following injury than matched controls. Comparison of the ratings concerning the patients' premorbid behaviour suggested that these differences between the patients and the controls stemmed from the period after the injury. Performance on the neuropsychological tests showed that the TBI patients were impaired at recognising expressions in the face and the voice, detecting social faux pas and one measure of cognitive flexibility, the correct score on the RFFT. Attempts to relate these cognitive impairments to the behavioural problems failed to reveal significant correlations, although there was a relatively high correlation between detection of social faux pas and current problems in the patients' emotional and social behaviour, as rated by the patients' relatives. Poorer detection of social faux pas was associated with more behavioural problems.

Our finding of changes in emotional and social behaviour following severe TBI is in line with the findings of numerous other studies. According to the ratings on the NBAP of both patients and their relatives, the head injured patients showed an increase in unusual and inappropriate behaviour, an increase in depression, apathy, and withdrawal and a decrease in communicative ability. Similar behavioural changes have been reported before in TBI patients (Levin, 1995; Morton & Wehman, 1995; Prigatano, 1992). Although most of the patients in our study had sustained their injury several years ago, they still reported important changes in behaviour compared to the time before injury, as did their relatives. This confirms the conclusions of other studies that behavioural changes following severe TBI can last for a very long time and are probably permanent (Koskinen, 1998). The fact that the patients' ratings concerning their premorbid behaviour did not differ from the current behaviour ratings of the healthy controls, may suggest that the patients did not have abnormal levels of behavioural problems before their injury. It has been argued that premorbid behavioural problems predispose people to develop emotional and behavioural disturbances following brain injury (Lishman, 1973, Prigatano, 1992). Our results do not confirm that position, but this conclusion should be regarded with caution given the difficulties of measuring premorbid behaviour, especially when that measurement takes place several years after injury. Furthermore, the ratings of the patients' premorbid behaviour and the controls' current behaviour may not be entirely comparable because, unlike the patients and their relatives, the control group did not provide retrospective ratings of their behaviour several years previously.

Recognition of emotional expressions in the face and the voice were both impaired in the patient group. Impaired recognition of facial expressions in TBI patients has been reported before (Braun et al., 1989; Jackson & Moffat, 1987; Pettersen, 1991). We are not aware of studies in TBI patients that tested recognition of emotional prosody, but Hornak et al. (1996) did find impaired recognition of emotional prosody in patients with ventromedial frontal lesions, half of whom had suffered TBI. Although the patients in our study were impaired at recognising emotional expressions, these impairments were not associated with more emotional and social behavioural problems. Likewise, Hornak et al. failed to report a correlation between recognition of expressions and behavioural ratings in their patients with ventromedial frontal lesions. These authors only reported significant correlations between expression recognition and ratings concerning changes in the subjective experience of emotions in the patients. This raises the possibility that impaired recognition of emotional expressions is not necessarily related to changes in emotional and social behaviour.

The patients with TBI in our study did not show impaired empathy ratings. This is in contrast to findings by Grattan and Eslinger (1989), who did report reduced empathy ratings in brain damaged patients compared to normal controls. However, Grattan and Eslinger's study contained only 10 head injured patients in a sample of 50 patients, and the results of those TBI patients were not reported separately. In addition, the empathy ratings by Grattan and Eslinger were collected within the first year after injury, while the patients in our study were on average more than 4 years postinjury. Perhaps empathy ratings improve with increasing chronicity. The Faux Pas Test revealed an impairment at judging social situations in the patient group, which was unlikely to result from a comprehension deficit. The patients were impaired at detecting social faux pas while performing normally on the control questions and being able to correctly describe the emotional state of the protagonists in the stories. Stone et al. (1998) reported very similar findings in patients with localised lesions in the orbital frontal cortex. The Faux Pas Test was the test in our study with the highest correlation with problems in emotional and social behaviour following head injury. Although this correlation was not significant, which was not very surprising given the small sample size, it may suggest that the ability assessed by the Faux Pas Test is relevant for adequate emotional and social behaviour. According to Stone et al. detection of a faux pas requires (1) the understanding that one person has knowledge that the other person is not aware of, and (2) the empathetic knowledge about what other people find upsetting or insulting. Stone et al. argued that the empathetic knowledge was intact in their patients and that the impairment in the Faux Pas Test arose because of an inability to connect understanding of other people's beliefs and thoughts with other people's emotions. Therefore, Stone et al. (1998) presented the Faux Pas Test as a test of theory of mind, which refers to the ability to recognise and make inferences about other people's intentions and mental states. Our results also suggest an impairment in patients with TBI in their ability to understand and make inferences about other people's intentions.

As expected, the patients with TBI were impaired on the RFFT and their performance on the UFO ideational fluency test was also considerably poorer than that of the controls. Numerous studies have already shown impaired fluency scores in patients with TBI. In our study performance on the RFFT was not associated with behavioural ratings on the NBAP or SIQ. By contrast, Tate (1999) and Villki et al. (1994) did find that performance on flexibility tests could predict psychosocial outcome that is, emotional behaviour, return to work, and social activity. However, these authors used slightly different flexibility measures than we did. Villki et al.'s flexibility tests included the Stroop colour-word naming task, a modified version of the Wisconsin Card Sorting Test (WCST) and a version of the Corsi block task in which participants set their own learning goals. Villki et al. found that a fourth flexibility test, a verbal fluency task, was not associated with social outcome. Tate did employ fluency tests, but used only error scores and also administered the WCST and the Austin Maze test as tests of flexibility. Perhaps fluency scores are not very sensitive measures of the abilities that are important for adequate social behaviour and psychosocial outcome. This might explain why we found no association between patients' performance on the fluency tests and the ratings concerning behaviour and social integration in our study.

Fluency tests are examples of spontaneous flexibility tests. Spontaneous flexibility refers to the ability to generate a diversity of responses within a particular time (Grattan & Eslinger, 1989). The flexibility tests that Villki et al. (1994) found to predict social outcome are all examples of tests of reactive flexibility. Reactive flexibility refers to the ability to change responses according to demands of the (test) situation. This type of flexibility is measured in rule finding and shifting tests. It seems plausible that the ability to adjust one's response in line with the demands of the (test) situation, as assessed with reactive flexibility tasks, is important for adequate social behaviour. However, the choice of the behavioural rating scale might also affect the association between flexibility scores and behaviour. Tate (1999) and Villki et al. (1994) used other measures than the NBAP to assess behaviour, while Mathias and Coates (1999), who did use the NBAP, found no correlations between behavioural ratings on the NBAP and performance on either a modified version of the WCST (reactive flexibility task) or a verbal fluency test (spontaneous flexibility task) in patients with TBI.

Finally, theories of social behaviour in schizophrenia have proposed three main stages involved in adequate social functioning: perception of social cues, retrieval of social knowledge and response selection (Corrigan, 1997). Impairments at each of these stages could result in problems with social behaviour. A similar framework can be applied to patients with TBI. Following this framework, inadequate social behaviour could result from: (1) insensitivity to important social cues, such as emotional expressions; (2) impaired understanding of social situations and other people's intentions; (3) failures to adjust one's behaviour in accordance with social rules and demands. Our findings suggest that in this sample of patients an impairment in understanding social situations and other people's intentions, as assessed with the Faux Pas Test, is more strongly associated with changes in behaviour following TBI than impairments in the other two abilities. However, this conclusion is very much preliminary given that the correlation was not actually significant and because of various limitations of our study.

Among the limitations were the relatively small sample size and the way the patients had been recruited. Our sample of patients was selective in that most of them were recruited from a rehabilitation centre where patients are prepared for return to work or for protected employment. Patients who suffer severe behavioural problems following TBI that would prevent their return to work, were unlikely to attend this centre and to enter this study. As a result, our study may have underestimated the extent and severity of changes in emotional and social behaviour in patients with severe TBI. Other limitations of our study include the fact that most of the tests used were not standardised, that there was a long interval between the time of testing and the onset of injury in most patients, and the fact that the patients were assessed only once. Repeat testing could have provided more reliable baseline data and would have allowed us to follow changes over time. To date, very few neuropsychological measures that attempt to assess abilities such as recognition of emotional expressions or social understanding are fully standardised. We have tried to overcome the lack of standardisation by using control subjects, but this could not fully compensate for the absence of data on test properties such as test-retest reliability. It is likely that with the increasing interest in emotional and social behaviour following brain injury, more standardised tests will be developed in the coming years. Also unclear is the influence of premorbid abilities on performance on the tests used in our study. By matching patients and controls for years of education we attempted to control for differences in intellectual ability, although this is by no means an ideal method. On the other hand, whether premorbid intelligence in TBI patients can be accurately estimated with tests such as the National Adult Reading Test (NART; Nelson & Willison, 1991) is still a matter of debate. Although some studies suggested that the NART score is an accurate estimate of TBI patients' premorbid intelligence (Moss & Dowd, 1991; Watt & O'Carroll, 1999), other studies found that in a large proportion of the TBI patients NART performance was impaired relative to the expected performance based on the patients' education, social economic status, age and gender, thus underestimating premorbid intellectual ability (Freeman, Godfrey, Harris, & Partridge, 2001).

Because of the limitations of our present study it would be important to investigate whether these findings can be replicated in a larger sample of consecutively recruited patients. Our present results suggested that the ability to understand other people's thoughts and intentions or theory of mind may be related to changes in emotional and social behaviour after TBI. Therefore, future work may put more emphasis on assessing this ability in TBI patients by employing additional tests of theory of mind and to examine their association with behavioural ratings. Another potentially important improvement in future studies would be to assess patients much earlier after their injury. It may be that soon after injury impairments on tasks such as those used in our study are more severe, and more importantly, it may be that impairments observed soon after injury can help to predict the occurrence of changes in emotional and social behaviour.

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