Hyposmia, not emotion perception, is associated with psychosocial outcome after severe traumatic brain injury

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Word Count: 6277 (excl. title page, abstract, references, tables and figures)

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Osborne-Crowley, K. & McDonald, S. (2016) Hyposmia, not emotion perception, is associated with psychosocial outcome after severe traumatic brain injury. Neuropsychology, 30(7), 820-829, DOI: 10.1037/neu0000293

Abstract

Objective: The current study aimed to determine whether two variables associated with orbitofrontal damage, hyposmia and emotion perception deficits, are associated with socially disinhibited behaviour and psychosocial outcome after traumatic brain injury (TBI).

Methods: The *Brief Smell Identification Test* (BSIT), an emotion labelling task and an emotion intensity rating task, and an observational measure of social disinhibition were completed by 23 individuals with severe TBI. The disinhibition domain of the *Neuropsychiatric Inventory* (NPI-D) and the interpersonal relationships subscale of the *Sydney Psychosocial Reintegration Scale* (SPRS-IR) were completed by a close other. Fifteen control participants provided norms against which to assess performance on the emotion intensity rating task.

Results: BSIT scores predicted informant-reported change in interpersonal relationships on the SPRS-IR. Hyposmia, though, was not associated with informant-reported or observed social disinhibition. An impairment in accuracy scores on both emotion perceptions tasks was found for participants with TBI, yet intensity ratings did not differ between groups suggesting that people with TBI are not actually impaired at detecting intensity of emotion but are less likely to perceive the target emotion as the dominant one. Emotion perception was not related to disinhibition or change in interpersonal relationships.

Conclusions: These results support previous claims that hyposmia has prognostic significance following TBI. On the other hand, emotion perception impairment measured by standardised tasks does not appear to be an important factor in interpersonal outcomes. Finally, these results suggest that standardised emotion perception tasks may underestimate the emotion perception capabilities of people with TBI.

Keywords: Traumatic brain injury (TBI), head injury, social disinhibition, socially inappropriate behaviour, hyposmia, smell deficit, emotion perception, emotion recognition

Social disinhibition, the inability to inhibit socially inappropriate behaviours, is a commonly experienced outcome of traumatic brain injury (TBI) and likely contributes to commonly reported problems with social relationships, community reintegration and employment after TBI (Brooks, Campsie, Symington, Beattie, & McKinlay, 1986; McKinlay, Brooks, Bond, Martinage, & Marshall, 1981; Winkler, Unsworth, & Sloan, 2006). Social disinhibition after TBI is thought to result from damage to the orbitofrontal cortex (Namiki et al., 2008), an area of the brain known to be particularly susceptible to damage in TBI (Levin & Kraus, 1994). Despite this, there is little research that has examined the neuropsychological correlates of social disinhibition in TBI. While numerous studies have focused on impairments associated with general social outcomes after TBI, none have investigated those associated with social disinhibition specifically. The current study aimed to determine whether two variables also associated with orbitofrontal damage, hyposmia and emotion perception deficits are associated with socially disinhibited behaviour after TBI. The first might be anticipated to correlate simply on the basis of proximity of neural substrate while the latter may also play a causative role. Examining these relationships potentially serves two roles; identification of simple tests that could be used to indicate when an individual is at risk of developing this debilitating syndrome and shedding light on mechanisms that underlie social disinhibition and thus aid in targeting rehabilitation.

Hyposmia

TBI can result in the shearing of, or abrasive injury to, the olfactory nerves causing partial or total loss of smell, known as hyposmia and anosmia respectively. This damage to the olfactory nerve is typically associated with contusions and lacerations of the surrounding orbital frontal cortical areas (Jennett & Teasdale, 1981) leading researchers to suggest that anosmia can be used as an indicator of orbitofrontal damage following brain injury (Varney, 1988). Recent research has repeatedly demonstrated this association (for a review see

Roberts, Sheehan, Thurber, & Roberts, 2010). As an indicator of orbitofrontal damage, then, it might be expected that hyposmia would be associated with socially disinhibited behaviour following TBI, which likely results from damage to the same brain region. Although research has not investigated this link directly, a number of studies have focused on the ability of hyposmia to predict related psychosocial outcome, such as employment difficulties. Varney (1988) found that of a group of brain injured participants with total anosmia, 92% showed chronic unemployment problems despite having normal physical health and adequate intellectual and mnemonic resources. The patients often reported that these employment problems stemmed from an inability to get along socially with co-workers and supervisors, among other problems. On the basis of this finding, Varney (1988) suggested posttraumatic anosmia, as a sign of orbitofrontal damage, has prognostic significance in closed head injury. In a partial replication of this study, Martzke, Swan, and Varney (1991) reported a rate of 80% vocational dysfunction among people with head injuries and anosmia.

More recent studies, however, have failed to replicate this result, generally finding that those with post-traumatic anosmia do not have different occupational outcomes to those without anosmia (Correia, Faust, & Doty, 2001; Crowe & Crowe, 2013). Correia et al. (2001) found that only one of a group of fifteen patients with mild TBI and anosmia reported chronic unemployment problems, using the same criteria as Varney. Another study found no difference between an anosmic and a nonanosmic group of TBI patients of varying severity in employment status after injury (Crowe & Crowe, 2013). Further the review by Roberts et al. (2010) concluded that there was not enough data on real world outcomes, such as vocational dysfunction, to draw conclusions about whether post-traumatic anosmia has ecological validity as an indicator of poor psychosocial prognosis.

Other studies have focused on investigating associations between smell identification and neuropsychological tests of disinhibition, with mixed results. In one study, patients with

TBI and anosmia made more errors on the Controlled Oral Word Association Test (COWAT) than did matched patients (Crowe, 1996). However, these errors mainly constituted repeats of previously presented words, rather than neologism or other rule breaks. Another study found olfactory dysfunction was related to inhibition of prepotent verbal responses on the Color-Word Interference Test (CWIT), and to response inhibition and flexibility as assessed by verbal fluency tasks (Sigurdardottir, Jerstad, Andelic, Roe, & Schanke, 2010). Crowe and Crowe (2013), on the other hand, did not find any differences between patients with TBI with and without anosmia on errors or disinhibited responding on a number of neuropsychological measures. Overall, while some studies have found associations between hyposmia and disinhibition assessed by formal tests, and others have found associations between hyposmia and psychosocial outcomes such as employment difficulties, no studies have specifically investigated whether post-traumatic hyposmia is associated with socially disinhibited behaviours after TBI. This was the first aim of the current study.

Emotion Perception Deficits

Emotion perception refers to the ability to perceive and understand affective information from facial expressions, emotional prosody and body posture (Bornhofen & Mcdonald, 2008) all of which are critical to social competence. Emotion perception deficits are common after TBI (for a review see Bornhofen & Mcdonald, 2008) and have been linked specifically to orbitofrontal damage (Barrash, Tranel, & Anderson, 2000; Blair, Morris, Frith, Perrett, & Dolan, 1999; Heberlein, Padon, Gillihan, Farah, & Fellows, 2008). Studies have demonstrated this impairment after TBI both acutely and several years post-injury (Borgaro, Prigatano, Kwasnica, Alcott, & Cutter, 2004; Green, Turner, & Thompson, 2004). Further, Ietswaart, Milders, Crawford, Currie, and Scott (2008) examined longitudinal changes in emotion perception deficits after TBI and found that impairments persisted at one-year

follow-up, suggesting that deficits are stable overtime and likely the result of brain damage rather than secondary factors such as depression developing after brain injury.

Not only do emotion perception deficits and social disinhibition share the same underlying neuropathology, there is good reason to suggest a functional relationship between the two. Since facial and vocal expressions of emotion can act as social rewards or punishments, impairment in the ability to recognise these emotions has clear implications for social behaviour and learning. Outside the domain of TBI research, emotion perception impairments have been linked with impairment in social functioning. For example, normal adults who are poor at reading social cues also demonstrate poor social skills (Morrison & Bellack, 1981; Trower, 1980). Further, poor emotion perception in children has been related to poor social adjustment (Leppanen & Hietanen, 2001). Evidence from clinical groups, including schizophrenia (Hooker & Park, 2002; Sergi, Rassovsky, Nuechterlein, & Green, 2006), autism (Boraston, Blakemore, Chilvers, & Skuse, 2007), and children with ADHD characteristics (Kats-Gold, Besser, & Priel, 2007), has also demonstrated an association between emotion perception deficits and social functioning.

Despite these clear associations in other clinical groups, research investigating the link between emotion perception and social functioning following TBI has had mixed results. Spikman et al. (2013) found that impaired emotion recognition, particularly of sad and angry expressions, was related to informant-reported behavioural problems on the Dysexectuvie Questionnaire. Similarly, Watts and Douglas (2006) found a correlation between impairment in interpretation of facial emotion after TBI and informant-rated communication competence. Another study found a relationship between facial emotion recognition and social integration after controlling for cognitive factors (Knox & Douglas, 2009). Further, McDonald, Flanagan, Martin, and Saunders (2004) found that emotion recognition was related to the ability to use humour appropriately in a social context, as rated from a videotaped interaction.

These findings suggest that impaired recognition of facial emotion after TBI reduces the capacity to respond appropriately in social interactions. Conversely, though, Milders and colleagues (Milders, Fuchs, & Crawford, 2003; Milders, Ietswaart, Crawford, & Currie, 2008) failed to find any significant relationships between recognition of facial or vocal emotion after TBI and a number of different questionnaires designed to assess emotional and behavioural functioning of neurological patients. Further, Beer, Heerey, Keltner, Scabini, and Knight (2003) found inappropriate social behaviour in participants with orbitofrontal damage, despite evidence of intact recognition of basic facial expressions. Thus, the findings of studies investigating the relationship between emotion perception deficits and social competence have been inconsistent.

One reason for this inconsistency may be the nature of the emotion perceptions tasks used. Previous studies have tended to use forced-choice recognition tasks to assess emotion perception deficits. In such tasks, participants must choose the correct label for the presented emotion among provided alternatives. These types of emotion perception tasks may not represent an ecologically valid measure of the emotion perception deficits which impact upon social behaviour, since providing a verbal label for an expressed emotion is not a usual requirement in social interactions. Furthermore, in everyday interactions a given emotion may be expressed fleetingly, subtly, or in combination with others, requiring judgments of its relative intensity and salience. Another source of inconsistency might arise from the wide range of outcome measures used to measure the construct of social competence. The current study sought to address these potential issues by examining detection of emotional intensity as well as conventional emotion labelling and by determining whether emotion perception deficits are associated with socially disinhibited behaviour specifically, rather than social competence more broadly.

Thus, this study investigated whether two variables, impaired sense of smell and impaired emotion perception, both associated with orbitofrontal damage, were related to social disinhibition specifically and psychosocial outcome more broadly following severe TBI. It was hypothesised that impaired smell and impaired emotion perception, as measured by both a labelling task and an intensity rating task would be associated with disinhibited behaviours observed in the laboratory, informant-rated social disinhibition and also informant-rated psychosocial outcome.

Method

Participants

Participants were 23 individuals (18 male) who had sustained severe TBI of mean age 45.43 years (*SD*=15.44, range: 22 - 69) and with an average of 13.61 years of formal education (*SD*=2.74, range: 9 - 22). Participants were recruited from the outpatient records of three metropolitan brain injury units in Sydney. The TBI group had a mean post-traumatic amnesia of 67.43 days (*SD*=44.22, range: 12 – 189 days) and were, on average, 14.59 years post injury when tested (*SD*=11.05, range: 2 – 45 years). TBIs were caused by motor vehicle accidents (n=14), falls (n=6) and assaults (n=2). Demographics of the TBI group are outlined in Table 1. Their performance on standard neuropsychological tests measuring new learning (Logical Memory I from the Wechsler Memory Scale III) processing speed (Digit Symbol subtest from the Wechsler Adult Intelligence Scale III: WAISIII; Trails A) and attention (Digit Span subtest from the WAISIII, Trails B) is outlined in Table 2. As can be seen, the TBI participants were, on average, within the average range on Wechsler subtests.

Tables 1 and 2 about here

Additionally, there were 15 control participants (12 males) with a mean age of 42.67 years (*SD*=15.27, range: 20 - 63) and an average of 14.87 years of formal education (*SD*=1.69, range: 12 - 18) who also undertook the emotion intensity task and the smell test. Controls

were recruited from the community via online and local newspaper advertisements. Participants with a TBI did not differ significantly from controls with respect to age, $t(36)=-.54$, $p=.591$, or number of years of formal education completed, $t(36)=1.58$, $p=.123$.

Materials

Measures of emotion perception

Two tasks were included to measure emotion perception, one designed to measure sensitivity to emotional intensity and the other, a more conventional emotion labelling task using naturalistic audiovisual displays.

Emotion Recognition Intensity Rating Task

Stimuli were 21 static images of one of four actors (two male and two female) portraying one of six emotions (happiness, surprise, sadness, anger, fear and disgust), or a neutral expression. The stimuli were still images taken from the emotion recognition task (ERT; Montagne, Kessels, De Haan, & Perrett, 2007), a computer-generated program which shows a series of 216 video clips of facial expressions across different intensities. The stimuli were developed using algorithms (Benson & Perrett, 1991) which created intermediate morphed images between a neutral face (0% emotion) and a full-intensity expression (100% emotion). Data from a study by Rosenberg, McDonald, Dethier, Kessels, and Westbrook (2014) which used the ERT video stimuli suggest that fear, sadness and surprise are the most difficult emotions to recognise for controls, while happiness is exceptionally easy to recognise. Thus, in order to avoid floor and ceiling effects in recognition of emotion in the current study, 100% intensity of expression was used for fear, sadness and surprise stimuli, 80% intensity of expression was used for anger and disgust stimuli, while 30% intensity was used for happy stimuli.

Following the protocol of Heberlein et al. (2008), participants were asked to rate each facial expression for how intensely each of the six basic emotions were expressed on six

corresponding scales from 0 (none of the specified emotion detected) to 10 (an intense amount of the specified emotion detected). Thus, for each stimulus, participants provided six ratings of intensity (corresponding to six emotions) before proceeding to the next stimulus. For each participant, three scores were derived for each emotional category.

The emotion intensity score measured *general sensitivity to the intensity of the target emotion* and was corrected for baseline biases in participant rating tendencies. To calculate the emotion intensity score, following Adolphs and Tranel (2004) and Heberlein et al. (2008), the mean intensity rating provided for target emotion on the corresponding scale was first calculated for each participant. The mean intensity rating provided for 3 neutral stimuli was then subtracted. For example, the emotion intensity score for happiness would be calculated by deriving the mean happiness rating provided for the 3 happy stimuli and subtracting the mean happiness rating provided for the 3 neutral stimuli. This created a simple measure of the detected intensity for each emotion, adjusted for any baseline biases in participants' rating tendencies.

The difference score measured *differential sensitivity to the target emotion.* The difference score was the mean difference between the intensity rating provided for the target emotion and the next highest intensity rating provided for that stimulus. For example, the difference score for happiness would be calculated by averaging the difference between the happiness rating provided and the next highest rating provided for each of the 3 happy stimuli. Thus, this difference score was a measure of the participants' ability to differentiate the target emotion from other emotions in each stimulus. More positive scores indicated greater ability to differentiate the target emotion and more negative scores indicated that the participant had confused the target emotion for another emotion.

Finally, an overall score measured the *overall accuracy in detecting the target emotion.* This score was derived for each participant by counting the number of trials on

which the target emotion (the emotion actually expressed by the actor in the photograph) was given the highest intensity rating. This was a score out of 18, as there were 18 non-neutral stimuli.

The Awareness of Social Inference Test (TASIT) – Emotion Evaluation Test (EET)

TASIT (McDonald, Flanagan, Rollins, & Kinch, 2003) is an audiovisual clinical assessment tool designed to measure social perception in a TBI population. Part one, the EET, measures recognition of basic emotions and comprises 28 short video vignettes in which a professional actor engages in an everyday interaction. The target actor in each vignette enacts a neutral script according to one of six basic emotions – happiness, surprise, fear, anger, sadness or disgust – or no particular emotion. Participants were asked to decide from a list of alternatives which of these emotions was expressed. Participants' EET scores represented the total number correct. The test-retest reliability of the EET has been reported as .74 (McDonald et al., 2006).

Brief Smell Identification Test (BSIT)

The BSIT (Doty, Marcus, & Lee, 1996) is a 12 item test of olfactory function. The 12 different odourants are embedded in ureaformaldehyde polymer microcapsules and are released by scratching the odour strips with a pencil. For each odourant, participants are asked to identify which of the four provided response options the odour smells most like. Norms provided for this test allow the administrator to determine whether a smell deficit is present relative to individuals of the same sex and age. This deficit is defined by scoring below the 5^{th} percentile of those of the same sex and in the same 5 year age bracket. The test-retest reliability coefficient of the BSIT has been reported as .71 (Doty, McKeown, Lee, & Shaman, 1995). Prior to administration of the BSIT, participants were asked if they were aware of having any problems with their sense of smell and a yes or no response was recorded for this question.

249 **Measures of social disinhibition**

250 Two measures of social disinhibition were included, one involved observing
251 behaviour directly while the other was an informant-based questionnaire.

252 ***Observational Measure of Social Disinhibition***

253 The current study used an adaptation of the self-disclosure task developed by Beer,
254 John, Scabini, and Knight (2006). Participants were initially told that they would be asked a
255 number of questions about themselves and their experiences, it was their choice how much
256 information they wished to disclose and they could skip any question at any time. These
257 instructions were designed to minimise an expectation of excessive self-disclosure.
258 Participants were then asked a series of nine questions, which included: "Tell me about an
259 embarrassing moment you've had" and "Tell me about something someone has done to make
260 you angry". The interviews were videotaped and rated by two independent judges, blind to
261 whether the participant had sustained a TBI or was a control. Judges rated the frequency of
262 each participant's socially inappropriate behaviour on a scale of 1 to 5 (1 ='never' and 5
263 ='always') on items such as: 'While talking with the interviewer, the participant spoke too
264 candidly', 'The participant made inappropriate jokes or remarks', 'The participant did not
265 know when to stop talking'. Thus, the disinhibition ratings can range from 8 to 40. The
266 judges were trained in the use of the rating scales on five practice recordings, which were not
267 used in the final data analyses. The length of the interview varied depending on the
268 participant but no interview ran longer than 15 minutes. The judges were asked to watch each
269 recording in full before providing a rating for each of the 8 statements before moving onto the
270 next recording. The inter-rater absolute agreement was acceptable (Barker, Pistrang, & Elliot,
271 1994), α=.69, and so an average of the two ratings for each participant was calculated and
272 was used in all analyses that follow.

273 ***Neuropsychiatric Inventory Disinhibition Domain (NPI-D)***

The NPI (Cummings et al., 1994) uses informant ratings to evaluate neurobehavioural disturbances across 12 domains. For each domain, a screening question determines whether problems in that domain are present and is followed by seven to nine questions which address specific symptoms. The informant then rates the severity and frequency of behaviours as well as the level of distress caused by these symptoms. Only the disinhibition domain was of interest in this study. The NPI has well-established psychometric properties including an overall Cronbach's alpha of .88, inter-rater agreement ranging from 93.6% to 100% for different behaviours, and a 3-week test-retest reliability estimate of .79 for frequency scores and .86 for severity scores (Cummings, 1997; Cummings et al., 1994). Since its initial validation in dementia patients, the NPI has been used to successfully describe neuropsychiatric symptoms after TBI (Cantagallo & Dimarco, 2002; Ciurli, Formisano, Bivona, Cantagallo, & Angelelli, 2011; Monsalve, Guitart, Lopez, Vilasar, & Quemada, 2012). For use in a TBI population, it has the advantage of being developed and normed especially for individuals with neurological impairment. The current study did not use the screening questions but rather had all caregivers complete the full form. This approach was recommended by Kilmer et al. (2006) who found a high false negative rate for the disinhibition subscale, such that caregivers who did not endorse the screening item went on to endorse a number of metric items. The severity scale was adjusted to include a 'not applicable – disinhibition not present' response item to reflect this. A NPI-D total score was derived by adding the frequency, severity and distress scores for each participant. Informants were a family member or close friend who knew the participant well both before the injury and after the injury. Of the 23 participants with a TBI in the current study, data for the NPI-D was only available for 21 participants.

Sydney Psychosocial Reintegration Scale - Interpersonal Relationship Scale (SPRS-IR)

Finally, the Sydney Psychosocial Reintegration Scale 2 Form A (Tate, Hodgkinson, Veerabangsa, & Maggiotto, 1999) was completed by a relative or close friend of each TBI participant to provide a measure of broad psychosocial outcome. The SPRS-2 was designed to measure reintegration of people after a TBI in three domains; occupation, interpersonal relationships and independent living skills. In each domain there are four items which measure level of change in a particular behaviour or activity since the injury. Response items range from 0 (an extreme amount of change) to 4 (no change at all). Total scores for each domain range from zero to 16, with higher scores representing better levels of psychosocial reintegration. The current study was only concerned with the interpersonal relationships scale of the SPRS. Form A of the SPRS-2 has good psychometric properties, with high inter-rater reliability, intraclass correlation (ICC)=.95, and one-week test-retest reliability (ICC=.90), as well as good concurrent validity with the London Handicap Scale (r_s=-.85) (Tate et al., 1999). The SPRS-2 was completed by the same informant who completed the NPI-D. Of the 23 participants with a TBI in the current study, SPRS-IR data was only available for 22 participants.

Procedures

All participants were informed of the study procedures and gave informed written consent to participant in the study. The procedures were approved by the Human Research Ethics Committee of the Sydney South West Area Health Service (Royal Prince Alfred Hospital Zone) and were conducted at the neuropsychology laboratory at the University of New South Wales. In a single visit, participants with TBI were administered the observation measures, the emotion intensity rating task, the BSIT and the DASS. On this visit they were given a package of questionnaires, which included the NPI and SPRS as well as other measures not used for this study, to be filled out by a family member or close friend who had known the participant since before their injury. Thus, the same caregiver provided both the

NPI and the SPRS ratings. The TASIT had been administered to all participants on a previous visit no longer than two years prior. Controls were administered the BSIT and the emotion intensity rating task on a single visit.

Results

Hyposmia

Of the 23 individuals with TBI tested, eight (35%) were identified by the BSIT as having a smell deficit relative to others of the same gender and age. This compared to two of the 15 (13%) control participants who were identified as having a smell deficit. Of the eight TBI participants with hyposmia, only three were aware of having any trouble with their sense of smell.

A hierarchical multiple regression was run using participants with TBI to determine if the addition of BSIT score improved the prediction of change in interpersonal relationships on the SPRS above age, post traumatic amnesia and time since injury. Results can be observed in Table 3.

Table 3 about here

The full model of BSIT score, PTA, TSI and age to predict SPRS-IR was significant, R^2=.44, $F(3, 20)=3.19$, p=.032, adjusted R^2=.31. The addition of BSIT score led to a significant increase in R^2 of .27, $F(1,16)=7.75$, p=.013. Similar models conducted to determine whether BSIT scores could predict observed disinhibition or informant reported disinhibition above age, PTA and TSI revealed no significant results.

Emotion Recognition

Table 4 provides means and standard deviations for all emotion perception scores for both groups.

Table 4 about here.*General sensitivity to intensity of target emotion*

A repeated measures ANOVA (emotion category by group) was conducted to determine whether participants with TBI rated emotions as being expressed with less intensity than did controls. There was no significant effect of group, $F(1,36)=.18$, $p=.678$, and no significant interaction, $F(5,180)=.78$, $p=.562$. There was, however, a significant main effect of emotional category, $F(5,180)=13.34$, $p<.001$. Pairwise comparisons with Bonferroni adjustment for multiple comparisons revealed a general pattern showing that happy and sad were rated as less intense than the other four emotions, which can be observed in Table 4.

Differential sensitivity to intensity of target emotion

Difference scores for each emotional category are detailed in Table 4. A repeated measures ANOVA (emotion category by group) was conducted to determine whether participants with TBI were impaired at differentiating emotions compared with controls. There was no significant effect of group, $F(1,36)=1.86$, $p=.181$, and no significant interaction, $F(5,180)=1.01$, $p=.415$. There was, however, a significant main effect of emotional category, $F(5,180)=19.94$, $p<.001$. Pairwise comparisons with Bonferroni adjustment for multiple comparisons revealed a general pattern showing that happy and disgust were the most well differentiated emotions while fear was the least well differentiated.

Overall accuracy in detecting target emotion

A Levene's test for equality of variance revealed that the group of participants with TBI had a larger variance in overall accuracy scores ($SD=3.12$) than did the control group ($SD=1.54$), $F(1,37)=7.61$, $p=.009$. An independent samples t-test with equal variances not assumed revealed that TBI participants scored significantly lower overall ($M=11.09$) than did control participants ($M=12.80$), $t(36)=2.063$, $p=.046$, as shown in Table 4.

Accuracy on TASIT

The performance of the group with TBI on TASIT was compared to the normative data provided by McDonald et al. (2003). A one sample t-test revealed that the mean TASIT EET score for the TBI group (M=22.05, SD=5.03) was significantly poorer than the mean (M=24.86, SD=2.11) for a group of 169 normal adults, $t(20)$=-2.57, p=.018, as shown in Table 4.

Relationships between emotion perception and disinhibition/psychosocial outcome

In the TBI group, Pearson correlations were performed to determine whether impaired emotion perception was related to observed or reported disinhibition or change in interpersonal relationships since injury. For emotion intensity ratings, a mean z-score representing overall accuracy was created. This was derived by converting the average emotion intensity score across all emotional categories to a z-score, using the control mean and standard deviation. This was taken as an index of the level of deficit in the ability to detect emotion intensity relative to control participants. Neither observed disinhibition, informant-reported disinhibition nor informant-reported change in interpersonal relationships were significantly correlated with any of the intensity z-scores. In addition, the overall accuracy score was not significantly related to observed disinhibition (r=.11, p=.619), informant-reported disinhibition (r=.036, p=.876) or informant-reported change in interpersonal relationships (r=.04, p=.845). Similar correlations were conducted to examine the relationship between overall emotion recognition as measured by TASIT. TASIT EET scores were not significantly related to observed disinhibition (r=.35, p=.117), informant-reported disinhibition on the NPI-D (r=.38, p=.114), or informant-reported change in interpersonal relationships on the SPRS (r=-.34, p=.143).

Discussion

The current study sought to determine whether two variables associated with orbitofrontal damage, hyposmia and emotion perception deficits, are associated with socially

disinhibited behaviour and resulting problems with interpersonal relationships following traumatic brain injury. It was found that while hyposmia was associated with interpersonal problems, but not disinhibited behaviour, emotion perception deficits were not related to either socially disinhibited behaviour or interpersonal problems,.

Hyposmia

The current study found that eight of the 23 individuals with TBI (35%) had hyposmia with only three of those participants aware of having any difficulties with their smell. Due to sampling bias and methodological variations in published studies, the true incidence of post-traumatic hyposmia has been difficult to ascertain. Reported incidence rates among studies utilising modern standardised olfactory function tests vary greatly, ranging from 13% to 69% across all severity levels of TBI (for a recent review see Schofield, Moore, & Gardner, 2014). This variability may arise from differences in methods of olfactory testing, sampling biases and differences in spectrums of TBI severity within study samples (Haxel, Grant, & Mackay-Sim, 2008). Of the two studies investigating anosmia among patients with a severe TBI, one reported an incidence rate of 61% (Callahan & Hinkebein, 2002), while the other reported 33% (Sigurdardottir et al., 2010), the latter being consistent with the rate observed in the current study. Additionally the current data supports previous findings that many post-traumatic hyposmics are unaware of their olfactory deficits (Callahan & Hinkebein, 1999, 2002; Fortin, Lefebvre, & Ptito, 2010), illuminating the importance of using standardised tests of smell perception rather than self-report.

The current study further found BSIT scores significantly predicted informant-reported change in interpersonal relationship since injury, even when controlling for age, injury severity (measured by post-traumatic amnesia) and time since injury. This finding supports previous claims that post-traumatic hyposmia has prognostic significance in TBI and can predict psychosocial outcome. Further, while past studies have demonstrated a

relationship between total anosmia (complete loss of smell) and social outcome (Martzke et al., 1991; Varney, 1988), the current study is the first to show that a partial loss of smell has similar predictive power. This finding has clinical significance since, unlike psychosocial outcome, smell impairment can be measured objectively soon after injury and may indicate a patient's susceptibility to developing problems with maintaining social relationships causing significant distress to themselves and those close to them. Thus, the current and past findings suggest that routine use of an odour identification test such as the BSIT could act as a simple and fast way to identify individuals at risk of social isolation after TBI.

Although it has been suggested that past findings of an association between hyposmia and psychosocial outcome reflect problems with inappropriate social behaviour (Varney, 1988), no previous studies have directly investigated this claim. It was predicted that hyposmia would be related to social behaviour as research attests to hyposmia as a good indicator of damage to the orbitofrontal cortex (Bitter et al., 2010), a region associated with social disinhibition in a range of neurological patient groups (Blair & Cipolotti, 2000; Namiki et al., 2008; Rosen et al., 2005). The current study, however, found no relationship between hyposmia and social disinhibition observed in the laboratory or reported by an informant. This suggests that the ability of hyposmia to predict psychosocial outcome is not due to its ability to predict disinhibited social behaviour. Smell impairment after TBI has been shown to be related to a number of cognitive and other neuropsychological and functional outcomes which may help explain why olfactory impairment is predictive of interpersonal outcome. For instance, olfactory deficits have been found to be associated with emotion recognition and empathy (Neumann et al., 2012), verbal fluency (Sigurdardottir et al., 2010), tasks of executive functioning such as Trailing Making Test B and the Wisconsin Card Sorting Task (Callahan & Hinkebein, 1999; Crowe & Crowe, 2013) and disinhibition measured by rule breaks on the Controlled Oral Word Association Test (Crowe, 1996). Thus, that smell

impairment is associated with interpersonal outcomes or return to work may be due to it being predictive of a general frontal lobe dysexecutive syndrome, rather than an orbitofrontal disinhibition syndrome more specifically. Further, olfactory impairment, particularly complete anosmia, may also indicate greater injury severity (Green, Rohling, Iverson, & Gervais, 2003; Sigurdardottir et al., 2010), although this is not a consistent finding (Fortin et al., 2010). Further research should seek to determine the nature of the relationship between hyposmia and psychosocial outcome. With a better understanding of the variables that mediate this relationship, hypsomia may be a useful tool in indicating rehabilitation targets with the aim of alleviating social dysfunction before long-term changes in relationships occur.

Emotion Perception

Consistent with past research, participants with TBI in the current study demonstrated impairment in their capacity to *discriminate* between specific emotions evidence by their TASIT scores and overall accuracy scores on the intensity rating task. Despite this impairment, the participants with TBI did not actually differ from the control group in their ability to *detect the intensity* of emotions. Furthermore, participants with TBI did not differ from controls in the degree to which they perceived the target emotion as being expressed at greater intensity than other emotions (their difference scores). Thus while participants with TBI were more likely to rank the wrong emotion as the most intense some of the time (as captured in the accuracy data) their relative rankings of differential intensity were actually close to that of the control group. This suggests that participants with TBI are not insensitive to emotional intensity per se, but demonstrated difficulty identifying which was the preponderant emotion. Importantly, these findings suggest that forced-choice labelling tasks do not provide a full picture of emotion perception capabilities and impairments after TBI. The results highlight that failure to select the correct label does not imply an inability to

recognise that the target emotion is present or even to appreciate at what intensity the target emotion is being expressed. Research should aim to further tease apart processes underpinning the recognition of emotionality versus the differentiation of different emotions following TBI.

Differences in the intensity ratings and difference scores across the emotions were also examined. Participants rated happiness as being expressed at lower intensity than other emotions, which is consistent with the actual intensity of happy stimuli (30%). Interestingly, sadness was also rated as less intense than other emotions, despite it actually being expressed at 100% intensity. This may indicate that sadness is a more subtle facial emotion than others. Comparisons of differences scores across emotion categories revealed that fear was the least well differentiated emotion, while happiness and disgust were the best differentiated emotions. The negative difference score for fear seen in Table 4 indicates that both participants with TBI and controls, on average, confused fear with other emotions, despite the fact that fear stimuli were presented at 100% intensity in an attempt to eliminate floor effects identified in previous research. This suggests that fear is extremely difficult to differentiate, even for healthy controls, and is consistent with past findings (Rosenberg et al., 2014). In contrast, happiness was very well differentiated by both control participants and participants with TBI in the current study, despite happiness stimuli being presented at only 30% intensity, also consistent with Rosenberg et al. (2014). Happiness is so easily discernable from other emotions probably because it can be recognised on the basis of the presence of a single feature; a smile. In contrast, distinguishing between emotions such as fear and surprise may be more difficult, since it requires attention to multiple aspects of face configuration (Adolphs, 2002). Interestingly, disgust was also well differentiated from other emotions, which may be because it is easily identified by the distinctive scrunching of the nose.

Finally, the current study attempted to improve the quality of emotion perception measurement used in prior research with people with TBI in order to detect its relationship to social disinhibition, in particular, or psychosocial outcome more broadly. In contrast to predictions, no relationship was found, regardless of the kind of task used. This is consistent with a number of prior studies (Beer et al., 2003; Milders et al., 2003; Milders et al., 2008) but contradicts others (Spikman et al., 2013; Watts & Douglas, 2006). These findings suggest that the behaviours which have the largest impact on psychosocial wellbeing may be driven by problems other than impairments in recognition of another's emotional state. For instance, a person with TBI may act in a socially inappropriate manner due to an inability to inhibit an urge, regardless of whether emotional feedback from others is positive or negative. Further research should seek to clarify the role of emotion perception impairments in a broader model of social behaviour which accounts for other neuropsychological deficits such as inhibition.

There are some limitations of the current study that should be noted. Although assumptions were made about OFC damage underlying hyposmia and emotion perception deficits after TBI, the current study cannot confirm the origins of these observed impairments. That neither hyposmia nor emotion perception deficits were associated with observed or informant-reported disinhibition suggests that the neuropathology underlying these deficits is complex and not isolated to the OFC region. The use of high resolution imaging technology in combination with the measures used here could clarify these findings. Another limitation of the current study was that the TBI sample varied greatly with respect to time since injury. Thus, it cannot be determined whether disinhibited behaviour observed in participants developed as a direct result of their injury or if the behaviours developed later perhaps as the result of advanced age interacting with injury-related changes. Finally, this study was limited by the small sample size of the comparison group, and thus results may be influenced by low power. However, the current study was able to replicate established

differences between people with TBI and controls on both smell identification and emotion labelling.

Conclusions

The current study found an association between hyposmia and informant-reported change in interpersonal relationships, supporting past claims that hyposmia has prognostic significance following TBI. Contrary to suggestions that the association between hyposmia and psychosocial outcome results from the presence of inappropriate social behaviour, however, the current study found no relationship between hyposmia and social disinhibition after TBI. That hyposmia was associated with psychosocial outcome more broadly may be due it being an indicator of impact at the front of the head and thus damage to the frontal brain areas generally.

The current study further found evidence of impairment in differentiating emotion but not in recognising emotional intensity among participants with TBI, suggesting that forced-choice labelling tasks may distort characterisation of impairments in the perception and understanding of emotion following TBI. Sensitivity to emotional intensity was surprisingly intact, and may represent a useful target for remediation or compensatory approaches in this group. Finally, emotion perception after TBI was not found to be related to either social disinhibition or change in interpersonal relationships since injury, indicating that there may be more important predictive factors to consider when investigating social disinhibition and psychosocial outcome.

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742

743 *Figure 1.* Intensity ratings provided by the TBI and control group for each emotion compared
744 to the actual intensity of emotion used in stimuli for that emotion category

745 *Figure 2.* Intensity rating difference scores for the TBI and control group for each emotion
746 category

Table 1

Means, standard deviations, ranges and results of group comparisons for demographic variables

	Mean (SD), Range			
	TBI (*N*=23)	Control (*N*=15)	Diff (*p*)	Cohen's d
Demographics				
PTA (days)	67.43 (44.22), 12-189			
Time Since Injury (years)	14.59 (11.05), 2-45			
Age	45.43 (15.44), 22-69	42.67 (15.27), 20-63	.591	.18
Years of education	13.61 (2.74), 9-22	14.87 (1.69), 12-18	.123	.55

Table 2

Performance of the TBI group on standard neuropsychological tests

Cognitive Variables	Mean	SD	Range
WMS-III Logical Memory I	9.77	3.32	2-17
WAIS-III Digit Span	10.14	2.25	7-13
WAIS-III Digit Symbol Coding	7.24	3.02	4-15
Trails A (secs)	41.43	14.54	24-69
Trails B (secs)	91.10	38.85	44-194

Table 3

Multiple regression predicting SPRS-2 ratings from age, PTA, TSI and BSIT scores

Variable	B	β	*p*
Constant	.85		
Age	.07	.26	.261
PTA	.03	.27	.194
TSI	-.13	-.33	.156
BSIT	.82	.54	.013*
Adjusted R^2		.31	
F		3.19	.042*

PTA= Post-Traumatic Amnesia, TSI=Time since injury, BSIT= Brief Smell Identification Test. Note. N=23 *p<.05

Table 4

Means, standard deviations and results of group comparisons for all emotion perception scores for both groups

Emotion Perception Scores	Mean (SD)			
	TBI (*N*=23)	Control (N=15)	Diff (*p*)	Cohen's d
Emotion Intensity Score				
Happy (30%)	2.81 (1.35)	2.82 (1.27)	.986	<.01
Fear (100%)	3.66 (2.27)	4.73 (2.65)	.195	.43
Surprise (100%)	4.73 (2.26)	5.02 (1.94)	.687	.14
Sad (100%)	3.39 (3.04)	3.20 (1.85)	.826	.08
Anger (80%)	4.88 (2.30)	4.64 (1.83)	.737	.12
Disgust (80%)	5.22 (2.17)	5.60 (2.06)	.591	.18
Difference Score				
Happy	2.68 (2.65)	3.20 (2.96)	.576	.19
Fear	-1.55 (1.08)	-1.08 (1.92)	.398	.30
Surprise	-0.07 (1.71)	0.46 (1.24)	.415	.26
Sad	0.69 (3.06)	0.40 (2.73)	.769	.10
Anger	0.14 (2.00)	0.93 (1.77)	.219	.42
Disgust	1.16 (2.61)	2.93 (2.37)	.041*	.71
Overall Score	10.91 (3.12)	12.67 (1.54)	.028*	.72
TASIT Accuracy	22.05 (5.03)		.018*	.73