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Ostracism and Physiological Arousal Following Traumatic Brain Injury

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Keywords: skin conductance, social exclusion, TBI, brain injury, Cyberball, social reintegration

Abstract

Primary objective: This study aimed to examine the psychological and physiological effects of ostracism in adults with traumatic brain injury (TBI). *Research design:* A within-subject, counterbalanced design was used. The two conditions, inclusion and ostracism, were examined across two groups (between subjects). *Methods and procedures:* A group of 21 adults with TBI and 17 matched controls participated in the Cyberball paradigm. This task is a computerised task which exposes participants to a game of catch and throw. In the inclusion condition they are included fairly in the game, while in the ostracism condition they are excluded from the game following the first few throws. Skin conductance levels (SCLs) were measured throughout the game as a proxy for social stress. *Main outcomes:* Results showed that people with TBI were cognitively aware of when they are being ostracized, however, that their self-reported emotional experience to social exclusion was different to that of the control group. Differences in SCLs between groups and between conditions did not reach significance, nor did they correlate with behavioral responses. *Conclusions:* These findings are discussed in terms of the consequences of dissociation between psychological and physiological responses and the implications for motivating behaviors associated with re-inclusion.

Keywords: traumatic brain injury, social exclusion, ostracism, physiological, Cyberball

Introduction

Severe traumatic brain injury (TBI) commonly occurs following motor vehicle and sporting accidents, falls and assaults [1]. Brain injury of this nature leads to heterogeneous pathology throughout the brain, although there is a preponderance of lesions in the orbito-medial frontal and temporal regions and diffuse white matter injury [2]. Following TBI there are noted changes in cognition, emotional experience, behavior and physical capabilities [3,4]. These changes can give rise to problematic behaviors such as saying inappropriate things to family members and not being able to control one's emotional responses [3-5]. Over time, these impairments lead to carer stress and burn-out and break-down in relationships, and contribute to the social isolation reported by many with TBI [6,7].

While the neuropsychological impairments associated with TBI, such as poor new learning and executive function, have been well studied, these do not clearly explain the disruption in social function [e.g., see 8,9]. Instead, it is becoming increasingly recognised that people with TBI suffer additional impairments in social cognition. For example, they have been found to have problems in recognising emotions in others [10] and are also poor at judging what is on another's mind [an ability known as theory of mind; 11]. Of particular relevance to the current study is the finding that people with severe TBI reported less emotional pain than a healthy control group after having been ostracized during Cyberball [12], an internet based social exclusion paradigm [13]. This attenuated subjective response to socially salient stimuli is interesting because it is consistent with other experimental work in which people with TBI have reported muted emotional experiences in general [14] and in response to postural manipulations [15]. They have also reported being less aroused by distressing images than demographically matched control participants [16,17]. These reductions in self-reported emotional experience are also reflected in objective physiological measures. For example, using facial mimicry and skin conductance as a measure of

physiological engagement, people with severe TBI have been found to have muted responses to photos of affective faces [18], unpleasant stimuli [16,19], and emotionally laden videos [20]. Indeed some have proposed that this loss of physiological responsivity to emotional stimuli is directly linked to diminished accuracy in emotional and social judgments [21,22].

Such objective measures have also been used to assess the physiological response to exclusion in the Cyberball ostracism task. Healthy adults have higher skin conductance levels (SCL) and show less habituation when they are being ostracized, compared to when they are being included [23]. This is a similar response as to that which occurs in response to mental stress [24], or physical pain [25], and is closely linked with the ‘fight or flight’ response system [see 26 for review]. Increments in skin conductance associated with the ‘fight or flight’ response are proposed as a marker for propelling us into action when danger is perceived [27,28]. Similarly, autonomic markers in response to ostracism may drive the impetus to engage in strategies that will promote re-inclusion in a social situation. Physiological responses to ostracism have not been examined in people with TBI although, given the finding of muted responses to other emotional stimuli, such a reduction may be anticipated. The current study aimed to examine the physiological effects of ostracism in individuals with a traumatic brain injury (TBI) relative to matched controls. It was predicted that:

- 1) Both healthy controls and participants with a TBI would report lower levels of belonging, self-esteem, meaningful-existence and control following ostracism when compared to inclusion, as well as report their current mood being more negative following ostracism compared with inclusion.
- 2) The magnitude of the effect of ostracism would be less for the TBI group when compared to the control group. That is, that the TBI group would report a smaller

difference on the fundamental needs between the two conditions, than would control participants.

- 3) Both the TBI group and the control group would display higher levels of arousal (indexed by SCL) during ostracism when compared with inclusion.
- 4) Consistent with earlier research [23], the control group would show greater habituation in arousal to the inclusion condition than to ostracism.
- 5) Consistent with the subjective data, the difference between arousal (SCL) in the two conditions would be less evident in the TBI group, that is, their average physiological response would be attenuated in comparison with the control group and they would show greater habituation than controls to the ostracism condition.

Method

Participants

Twenty one¹ adults (4 women and 17 men) between the ages of 25 and 69 years ($M = 49.81$, $SD = 11.81$) with a moderate-severe traumatic brain injury (TBI) were recruited from local brain injury rehabilitation units and support services (Sydney, Australia). Participants were included if they had sustained a moderate-severe TBI defined as having altered consciousness for greater than 24 hours [29], were living in the community and were fluent English speakers, and did not have aphasia or any hearing or sight impairments that would prevent them from participating in the experiments fully. Clinical information was obtained from hospital records and self-report. In five cases, information regarding the nature and severity of the initial injury was only available by self-report, but additional information supported the 'severe' TBI classification. PTA data were not available for four participants,

¹ There were originally 22 participants in the TBI group, 1 was removed due to suspicions of task reality (explained in methods).

however, they were considered to have had a severe injury as they required extensive inpatient rehabilitation, had changes to vocational status post injury and two remained dependent thereafter, living with family members. Post-traumatic amnesia (PTA) ranged between 2 and 189 days ($M = 66.85$, $SD = 53.13$). Participants in this study were of at least 24 months post-injury. The causes of brain injury with the current sample were motor vehicle accidents (10), motor cycle accidents (2), falls (2), pedestrian vs. motor vehicle (4), assaults (2), and a sporting accident (1). Pathology on admission included skull fractures (5), subdural hematoma (3), extradural hematoma (2), subarachnoid hemorrhage (1), intracerebral hematoma (4), intracerebral hemorrhage (2), as well as petechial hemorrhage (1), cortical contusions (6) and diffuse axonal injury (1). Thirteen of the participants had injuries to the frontal lobes, ten had temporal lobe injuries, three parietal lobe injuries and four occipital lobe injuries. The TBI group had achieved between 10 and 17 years of education ($M = 13.67$, $SD = 2.35$).

A group of 17 adults² without a brain injury was recruited through advertisements in local newspapers, as well as social and sporting clubs. This group comprised 12 men and 5 woman aged between 22 and 68 years ($M = 46.29$, $SD = 16.22$). Formal education ranged between 12 and 19 years ($M = 15.24$, $SD = 1.86$). The control group did not significantly differ to the group with brain injury on the basis of age [$t(28.49) = .75$, $p = 0.45$] and gender distribution (Pearson's $\chi^2 = 0.56$, $p = 0.45$). Those in the control group had significantly greater years of education than those in the TBI group [$t(36) = 2.25$, $p = 0.03$], and had a significantly higher level of premorbid intelligence [$t(36) = 3.32$, $p = 0.002$]. No association

² There were originally 26 participants in the control group, 9 were removed due to suspicions of task reality (explained in methods).

was found between the main behavioral measure (experience of exclusion) and education ($r = 0.09, p < 0.05$) or estimated premorbid intelligence ($r = -0.04, p < 0.05$).

Participants in both groups were excluded if they had a history of significant mental illness, substance abuse, learning disability, or any other neurological disorder (prior to the TBI for the clinical group). All participants were naïve to the Cyberball paradigm and had not previously participated in our groups studies on ostracism. Participation was voluntary and informed consent was obtained in line with a protocol approved by the New South Wales Health Human Research Ethics Committee.

Materials

Cyberball

The computer based Cyberball [13] game was used for the current study. The Cyberball paradigm has been used extensively in previous work with both healthy controls and clinical populations including TBI [12,13,30-34]. The effects of the paradigm are moderate to strong and have been demonstrated both with self-report measures and physiological and imaging measures [23,35]. As per the original protocol, participants were told they would be playing a game of toss with three other volunteers over the internet (see Figure 1). In reality, the other three players were programmed to either include or exclude the real participant from the game. All participants played in both the inclusion condition and the exclusion condition of game. In the inclusion condition throws were fairly shared between all players. In the exclusion condition, the real participant received four balls at the beginning of the game and were then ignored, not receiving any of the 29 ball tosses thereafter. Participants were not provided with any further information about the other ‘participant’s to ensure that they did not have any other reason for disliking other players apart from the fact that they were being ostracized by them.

FIGURE 1 ABOUT HERE

Cyberball questionnaire

The standard Cyberball questionnaire comprised (a) the four fundamental needs (3 questions per need), and (b) current mood. These were rated on a 5-point Likert scale from ‘not at all’ to ‘very much’. The fundamental needs questions were: *sense of belonging* (e.g., “I felt disconnected”), *control* (e.g., “I felt powerful”), *meaningful-existence* (e.g., “I felt non-existent”), and *self-esteem* (e.g., “I felt good about myself”). The mood questions were: “My mood is” good, bad, happy, sad, friendly, unfriendly, tense, relaxed, “I felt angry” and “my feelings were hurt”. The effectiveness of the manipulation was determined using the questions: “I felt included”, “I felt excluded”, and, “Assuming 33% of the time you would receive the ball if everyone received it equally, what percent of the throws did you receive?” The final open-ended question asked the participant to comment on their thoughts about the game, allowing the participant to express whether they questioned the authenticity of the social interaction. Data was removed for participants whom were aware that the game was not real. Whilst this is a different approach to previous studies conducted in our lab [23], the extent to which participants were aware of the deception was much clearer in the current study. Whereas undergraduate students [23] were generally suspicious without specific reference to the manipulation, many of the suspicious participants in the current study specifically referenced that the experiment was examining and controlling exclusion status. The questionnaires were computerized versions presented in Medialab (Empirisoft Corporation, Version 2008.1.33).

Psychophysiological recording

PowerLab 8/30 Data Acquisition System (AD Instruments, Castle Hill, Australia) at a sampling rate of 100 Hz was used to acquire physiological data. The PowerLab was triggered by Inquisit (Version 3.0.4.0; Millisecond Software, 2010). This software was responsible for precisely synchronizing the timing of responses with recording of the data acquisition

system. For half of the participants, skin conductance was recorded continuously from two dry, bright-plated bipolar electrodes placed on the distal volar surface of digits II and IV of the non-dominant hand. For the remaining participants SCL was collected with two silver-silver chloride (Ag/AgCl) electrodes with electrode paste of 0.05 M NaCl. The signal was calibrated before each session³.

Data reduction and analysis

Participants were instructed to relax for two minutes to get a baseline measure of arousal [i.e. skin conductance level (SCL)] prior to commencing the game. In order to examine changes in arousal over the course of the game, the raw skin conductance traces were extracted offline in 10-second epochs. The difference between the mean value obtained for the 2-minute baseline period and the mean value for each 10-second epoch throughout the game provided the SCL ‘change score’ for each participant. These data were then log transformed to improve normality.

The data were analyzed in a three-way repeated-measures ANOVAs, with between subjects factor of group (TBI, Control) and within-subject factors of condition (inclusion vs. exclusion) and time (baselined data for each 16 x 10 second epochs). Within time, simple planned contrasts were examined to obtain linear, quadratic and cubic trends over trials. Greenhouse-Geisser type correction was not necessary because single degree of freedom contrasts are not affected by the violations of sphericity assumptions common in repeated-measures analyses of physiological data [36].

Procedure

After participants consented, electrodes were attached and participants were asked to keep as still as possible (observed via video monitor). Participants were asked to relax for up

³ Data was collected this way due to changes in lab practices. Data from approximately half of each group (controls and TBIs) were collected using each type of electrode.

to 10 minutes while their SCLs stabilized, the final two minutes of this data was recorded to obtain a baseline measure of skin conductance. Following this they played the first Cyberball game. Participants were instructed: *"In the upcoming experiment, we test the effects of practicing mental visualization on task performance. Thus, we need you to practice your mental visualization skills. We have found that the best way to do this is to have you play an on-line ball tossing game with other participants who are logged on at the same time. In a few moments, you will be playing a ball tossing game with other volunteers over our network. The game is very simple. When the ball is tossed to you, simply click on the LABEL of the player you want to throw it to. When the game is over, the experimenter will give you additional instructions. What is important is not your ball tossing performance, but that you MENTALLY visualize the entire experience. Imagine what the others look like. What sort of people are they? Where are you playing? Is it warm and sunny or cold and rainy? Create in your mind a complete mental picture of what might be going on if you were playing this game in real life.*

Okay, ready to begin? Please click 'Start' to begin."

Participants then completed the Cyberball Questionnaire and a questionnaire gathering demographic information. Participants then played a second game of Cyberball, including pre- and post-rest periods and a repeated version of the Cyberball Questionnaire. Participants were then debriefed regarding the deceptive nature of Cyberball. The order (exclusion, inclusion) was counterbalanced across participants. Participants also completed a number of other measures as part of an unrelated study.

Results

Manipulation check

Participants in the control group accurately perceived the percentage of throws they received in the inclusion (actual = 33%; estimated $M = 35.94$, $SD = 9.84$) and ostracism (actual = 8%; estimated $M = 7.81$, $SD = 5.69$) conditions. One-sample t -tests revealed that control participants' reported percentage of balls received in each condition was not significantly different to the actual receipt of the ball [Inclusion, $t(15^4) = 1.2$, $p = 0.25$; Ostracism, $t(15) = -.13$, $p = 0.9$]. Participants in the TBI group also accurately perceived the percentage of balls they received in both conditions (Inclusion: $M = 34.86$, $SD = 14.16$; Exclusion: $M = 10.5$, $SD = 9.71$) which was not significantly different to the actual receipt of the ball [Inclusion, $t(20) = 0.60$, $p = 0.56$; Ostracism, $t(19^5) = 1.15$, $p = 0.26$]. Participants in both groups reported receiving less balls in the ostracism condition than in the inclusion condition [Controls: $t(15) = 11.06$, $p < 0.001$; TBIs: $t(19) = 6.26$, $p < 0.001$].

Self-reported levels of fundamental needs

The three questions assessing each fundamental need were evaluated for internal consistency. Cronbach's alpha coefficients for each need were: belonging = 0.80; self-esteem = 0.82; meaningful-existence = 0.74; and control = 0.85 which are consistent with previous studies [37,38]. Given items within each of the four needs categories demonstrated adequate internal consistency the items were averaged to form an overall score for belonging, self-esteem, meaningful existence and control to be used in the following analyses [methodology consistent with previous studies, e.g., 23,33].

⁴ Behavioral data was missing for one participant in the control group

⁵ Numeric response missing, participant responded "I don't know, I don't care"

A 2 (group) x 2 (condition) x 4 (needs) ANOVA revealed a significant main effect of condition [$F(1, 35) = 30.54, p < 0.001, \eta^2 = 0.47$]. In support of Hypothesis 1, participants across groups reported lower needs following ostracism when compared to inclusion. The condition x needs interaction did not reach significance [$F(3, 105) = 2.18, p = 0.1, \eta^2 = 0.06$] suggesting that there was no discernible difference between the extent to which each of the four needs were affected. Of particular interest to this study and in keeping with Hypothesis 2, there was a marginally significant group by condition interaction, $F(1, 35) = 4.10, p = 0.05, \eta^2 = 0.11$ suggesting that the TBI group responded to the experience differently to the control group. Scores averaged across the four needs for the two groups in the inclusion and ostracism condition are depicted in Figure 2.

FIGURE 2 ABOUT HERE

Follow-up analyses for differences between the two conditions for the two groups separately demonstrated that both did experience a reduction in their self-reported needs fulfilment as a result of the ostracism [Controls: $t(15) = 4.27, p = 0.001$; TBI: $t(20) = 3.15, p = 0.005$], however, as can be seen in Figure 2 the lines reflecting within group changes are not parallel, demonstrating that the TBI reported less of a reduction in fundamental needs as a result of ostracism ($M = 0.61, SD = 0.19$) than the control group ($M = 1.32, SD = 0.26$). Indeed, it seems that this effect arises from the TBI group reporting feeling less included in the inclusion condition than are the control group [$t(35) = 3.47, p = .001$] but similarly excluded in the exclusion condition [$t(35) = 0.13, p = .90$].

In order to determine whether this finding was consistent across all needs, follow-up within-group's analyses were conducted for each need separately. Following Bonferroni adjustment ($\alpha/4 = 0.0125$) participants in the **control** group reported significantly lower levels of belonging [$t(15) = 4.05, p = 0.001$], self-esteem [$t(15) = 3.68, p = 0.002$],

meaningful-existence [$t(15) = 3.62, p = 0.003$], and control [$t(15) = 3.18, p = 0.006$] in the ostracism condition when compared to the inclusion condition (see Figure 3A).

Participants in the **TBI** group reported lower levels in each of the needs belonging [$t(20) = 2.33, p = 0.030$], self-esteem [$t(20) = 3.35, p = 0.003$], meaningful-existence [$t(20) = 1.63, p = 0.118$], and control [$t(20) = 2.95, p = 0.008$] in the ostracism condition when compared to the inclusion condition, however, following Bonferroni adjustment ($\alpha/4 = 0.0125$) only self-esteem and control remain significant (see Figure 3B).

FIGURE 3 ABOUT HERE

Mood

Mood, as assessed by the Cyberball post-measure is presented for each group in Figure 4. Moods that can be characterized as “positive” (i.e. “good”, “happy”, “friendly”, “relaxed”) are shown on the left of the figure and those that can be categorized as “negative” (i.e. “bad”, “sad”, “unfriendly”, “tense”) are depicted on the right. Positive moods would be expected to decrease as a function of ostracism and negative moods to increase. In order to depict this more clearly, Figure 5 shows the mean difference in positive and negative mood states (averaged across the four emotions in each category) in the ostracism and inclusion conditions. This suggests that both groups did show the anticipated change in mood (Hypothesis 1), however, the TBI group did not differ from the Control group. A 2 (group) x 2 (condition) x 2 (valence) x 4 (mood) ANOVA *did not* reveal a significant group x condition interaction [$F(1, 35) = 0.07, p = 0.79, \eta^2 = 0.002$], although consistent with Hypothesis 1, it did reveal a significant condition x valence interaction [$F(1, 35) = 13.31, p = 0.001, \eta^2 = 0.28$] and suggested that negative mood increased following exclusion.

FIGURE 4 ABOUT HERE

FIGURE 5 ABOUT HERE

Finally, participants in both groups were asked how angry they were following each game, as well as how hurt their feelings were (part of the standard post-Cyberball questionnaire). There was no difference between groups in the extent to which their anger increased in the ostracism conditions, nor was there a difference between groups as to the extent their feelings were hurt (all p 's > .05).

Psychophysiological data

To manage the effects of expectations following the initial game, baseline measures of SCL were examined for order effects. No main effect of group [$F(2, 29) = 0.26, p = 0.78$], order [$F(2, 29) = 0.78, p = 0.47$], nor interaction between group and order was observed [$F(2, 29) = 0.96, p = 0.40$]. Furthermore, baseline SCLs did not differ dependent on whether wet or dry electrodes were used [$F(2, 29) = 1.63, p = 0.21$], therefore the data was combined.

There was a suggestion of a linear trend over time [$F(1, 36) = 3.70, p = 0.06$] although this fell short of significance. The trend suggested that, independent of condition and group, arousal as measured by SCL, decreased over the course of the experiment.

To examine whether participants with a TBI experienced the same physiological response to ostracism as controls, a 2 (group) x 2 (condition) x 16 (time: 10 second epochs) repeated measures ANOVA was conducted. Condition and time were within-subjects variables. It was expected that both groups would display higher SCLs during the ostracism condition when compared to the inclusion condition (Hypothesis 3), that control participants would show less attenuation of arousal over time during the ostracism condition compared to

the inclusion condition (Hypothesis 4), and that these effects would be attenuated in the TBI group (Hypothesis 5).

Figure 6 displays SCLs for the **control group (A)** and the **TBI group (B)**. Visual inspection suggests that, as expected, towards the end of the game the control group displays higher SCLs during the ostracism condition when compared to the inclusion condition. In contrast the TBI group appears to be displaying a different pattern of response towards the end of the game. That is, the TBI group appears to have higher SCLs when they are being included rather than when they are being ostracized. However, according to statistical analysis there was no evidence that participants were displaying different SCLs over time dependent on condition (Hypothesis 3), [condition x time: $F(1, 36) = 0.06, p = .81, \eta^2 = 0.002$; group x condition x time: $F(1, 36) = 0.21, p = 0.65, \eta^2 = 0.006$]. In Figure 7, the average SCLs for both groups in the two conditions are depicted. There was also no evidence that the TBI group experienced different physiological reactions to ostracism, overall, than did control participants (Hypothesis 5): $F(1, 36) = 0.89, p = 0.35, \eta^2 = 0.02$].

FIGURE 6 ABOUT HERE

FIGURE 7 ABOUT HERE

Relationship between the self-reported measures and the autonomic experience of ostracism

There were no significant correlations found between the psychophysiological measures (average SCL over time) and the self-reported measures (average needs) for the inclusion condition or the exclusion condition. This was the case when groups were examined separately and combined (all p 's > 0.05)

Discussion

The Cyberball paradigm, with associated physiological measures, was employed to examine the level of arousal in individuals with a brain injury during a simulated social interaction. These are the first data to explore the physiological correlates associated with social exclusion in a group of people with brain injury. These data, while based upon small samples, and in need of replication, suggested a trend for dissociation between self-reported distress and arousal, as measured by skin conductance levels.

Participants in both groups were cognitively aware of their level of inclusion in each condition which is consistent with past research using this paradigm in clinical groups [23,39]. When examined across groups, the predicted negative effects of ostracism on fundamental needs were observed. The control group reported lower levels of belonging, self-esteem, control and meaningful existence following ostracism compared with inclusion. The TBI group displayed an overall similar pattern of needs fulfilment, however, only self-esteem and control remained significantly lower. This is inconsistent with Kelly et al., [12] where it was observed that control was not significantly affected in the TBI group, whereas belonging was. Of particular significance to this study and in replication of a previous study [12], it was observed that the TBI groups' self-reported experience of ostracism was different of that to controls. That is, the TBI group self-reported less of an overall reduction in fundamental needs from when they were included to when they were excluded, and this result appears to lie in the TBI group feeling less included in the inclusion condition. It is interesting to note that the attenuated self-reported emotional response to ostracism appears to be unique to TBI and is not seen in other disorders known to have social dysfunction. For example, children with Autism Spectrum Disorder are shown to have the same emotional response to ostracism as controls [40,41], as are people with a diagnosis of Schizophrenia [42], despite displaying distinct neurophysiological and fMRI signalling responses compared with controls.

With regards to mood effects, when examined across groups, participants were observed to experience more negative moods following ostracism and more positive moods following inclusion. In replication of a previous study [12] both groups were similarly affected by the two conditions.

Despite differences in self-reported experience, SCLs were not indicative of distinct patterns of physiological activity underlying reactions to social exclusion for the TBI group when compared with the control group. SCLs for the TBI group appeared to decrease over time regardless of condition, and in fact there was no difference found between SCLs for the inclusion versus ostracism conditions. The same was true for the control group, however, the difference between conditions failed to reach significance. Had this finding of reached significance it would have been consistent with that seen in healthy controls (university students) in a previous study with larger n [23]. The current study had a mean age of 48.23 years whilst the previous study had a mean age of 19.98 years, thus it is possible that the effects of the Cyberball manipulation are diluted somewhat with an older age group [43,44]. It is also possible that lack of power due to a small sample size and greater variability in SCL for the TBI compared with control participants is affecting these results.

The immediate effects of ostracism, as well as the longer-term consequences of social isolation on emotional wellbeing are now well understood [45-47]. Furthermore, a number of commonly observed behaviors and strategies for coping with ostracism are also well documented [48-50]. However, a comprehensive understanding of what response path is likely to be chosen and what predicts that choice still eludes the field[30].

While findings here are preliminary, we have shown that the TBI group were aware of their level of exclusion and still reported feeling social pain (albeit to a lesser degree). We also cannot rule out the possibility that TBI participants are in fact showing the predicted

impoverished physiological response to social exclusion. This dissociation between self-report and physiological arousal may help predict whether a pro-social or antisocial reaction to ostracism is likely. In this population, it might actually predict whether *any* active strategy is initiated, particularly if they are receiving less punishment (deflation in fundamental needs) when being excluded from the group. Williams [30] postulated four types of responses to social exclusion; 1) to conform to more socially acceptable behaviors, 2) to force recognition of the self by becoming aggressive, 3) to shut down both emotionally and cognitively, and, 4) to withdraw oneself to avoid further ostracism and social pain. There is little direct evidence of what might be occurring physiologically when a person is driven to engage in one of these behaviors, however, converging evidence provides some insight. Gower and Crick [51] found that lower resting states were related to aggression. Within the current sample, the resting SCLs in the TBI group were equivalent to those in the control group, suggesting that aggressive responses may be *less* likely in this sample and certainly this is consistent with our finding that the TBI group reported a similar level of anger as the control group following rejection. Furthermore, anecdotal evidence from clinical work with this group supports their passive response to being isolated from the group, something which would be worth exploring further within an experimental setting. While it was not possible to report heart rate activity here, generally speaking, increases in skin conductance levels are observed when heart rate slows [52], possibly suggesting that, increases in skin conductance during ostracism *might* lead to more pro-social responses. However, this remains to be tested.

Whilst our data are not able to provide evidence which speaks to the effects of longer-term social exclusion on mental illness such as depression, the observed dissociation between cognitive and physiological awareness might provide some clues. There are a range of different coping mechanisms employed following social exclusion. The degree to which these strategies help re-establish self-esteem, belonging, meaningful existence and control,

have long-term consequences for relationships and mental and physical health[53]. It may be argued that individuals with a brain injury have come to expect a degree of ostracism or stigmatization from society, therefore, they can still be aware that they are in fact experiencing social exclusion, and that they are in fact feeling the effects of ostracism, however, they have physiologically habituated to what is experienced in everyday life. Support for this postulation comes from a participant who wrote: *“Game prompted feelings of being unworthy, similar to what experienced in everyday life”*

Recent theories attempting to explain behaviors following rejection include the concept that the severity with which one responds to rejection will depend on their ‘rejection sensitivity’, or how much they expect to be rejected. For example Sommer and Rubin[54] propose that social expectancies are related to self-esteem. That is, those with high self-esteem are more likely to draw closer to other social supports, while those with low self-esteem, a common artefact of TBI [55,56], are more likely to further distance themselves from others.

Unfortunately, avoidant coping styles and low self-esteem have been associated with higher levels of depression, anxiety, and psychosocial dysfunction in individuals with a brain injury [57,58]. Given individuals with a TBI are cognitively aware that they are being excluded, are feeling the negative consequences of ostracism, though not as fully, and possibly may not be experiencing a normal physiological response to social exclusion, we must question whether they are likely to be driven to engage in appropriate behaviors to re-engage with social groups. Furthermore, over time with low self-esteem and possible emerging depression – learned helplessness is inevitable. As one participant said: *“Looking at it from a broader perspective, seemed perfectly fair”*. This statement may also go some way to explaining why participants in the TBI group were feeling less included, even when the group was being inclusive.

As alluded to above, limitations of the current study include the inability to predict the likely response, or coping strategy, employed by both healthy adults and adults with a brain injury. Future studies in this population should aim to include experimental measures of the responses to ostracism, and specifically, to determine whether physiological measures can predict coping strategies. For example, research using another rejection paradigm has had the researcher, or a confederate, drop pencils on the ground to see if the ostracized person would be more, or less likely to display the pro-social behavior of helping to retrieve the pencils [59]. Others have tested the likelihood of the ostracized individual donating money[60] or mimicking postural changes[61]. Investigating the associations between physiological variables including heart rate changes and the likelihood of response will yield insights relevant to the development and implementation of targeted treatment approaches to autonomic deficits in adults after a brain injury. Whilst there is now enough evidence to support routine clinical assessment of social cognition (though there is evidence to suggest this is not happening [62]), more research is needed to establish evidence for social skills interventions in this field [63].

While it was anticipated that this study would be able to provide evidence for the premise that attenuated self-reported distress following ostracism in people with TBI was in part related to impaired physiological response, our data was unable to statistically support this. Given the trends seen in the data it would be worthwhile to replicate this study in a larger sample with the addition of measures of emotional coping strategies and real-life observation of behavioral strategies to regain inclusion in the social group.

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Figure 1

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