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Neural activity and emotional processing following military deployment: Effects of mild traumatic brain injury and posttraumatic stress disorder

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ABSTRACT

Posttraumatic Stress Disorder (PTSD) and mild traumatic brain injury (mTBI) are common comorbidities during military deployment that affect emotional brain processing, yet few studies have examined the independent effects of mTBI and PTSD. The purpose of this study was to examine distinct differences in neural responses to emotional faces in mTBI and PTSD. Twenty-one soldiers reporting high PTSD symptoms were compared to 21 soldiers with low symptoms, and 16 soldiers who reported mTBI-consistent injury and symptoms were compared with 16 soldiers who did not sustain an mTBI. Participants viewed emotional face expressions while their neural activity was recorded (via event-related potentials) prior to and following deployment. The high-PTSD group displayed increased P1 and P2 amplitudes to threatening faces at post-deployment compared to the low-PTSD group. In contrast, the mTBI group displayed reduced face-specific processing (N170 amplitude) to all facial expressions compared to the no-mTBI group. Here, we identified distinctive neural patterns of emotional face processing, with attentional biases towards threatening faces in PTSD, and reduced emotional face processing in mTBI.

1. Introduction

Posttraumatic Stress Disorder (PTSD) is a common consequence of war exposure, affecting approximately 12–16% deployed United States military veterans (Hoge & Castro, 2006). PTSD is characterised by intrusive memories and distress to trauma reminders, and sleep and concentration problems. Up to 25% of combat veterans report sustaining a mild traumatic brain injury (mTBI) during deployment (Vasterling, Verfaellie, & Sullivan, 2009). PTSD in combat veterans often occurs following blast exposures, with a co-occurring risk of mTBI (Hoge et al., 2008). The overlapping etiology and symptoms of mTBI and PTSD causes complications in identifying their separate effects (Carlson et al., 2011). Despite this, longitudinal studies reveal that sustaining an mTBI during deployment significantly increases PTSD-risk (Bryant, 2011; Yurgil et al., 2014).

PTSD patients show attentional biases towards threat in eye tracking and dot probe studies (Felmingham, Rennie, Manor, & Bryant, 2011; Kimble, Fleming, Bandy, & Zambetti, 2010; Olatunji, Armstrong, McHugo, & Zald, 2013). Consistent with heightened threat processing, neurobiological evidence suggests PTSD is associated with hyper-activity of amygdala, insula and dorsal anterior cingulate cortex in response to threatening stimuli, and hypo-activity of frontal regulatory networks (Pitman et al., 2012; Williams et al., 2006). mTBI also shows deficits in ventromedial prefrontal activation (Vasterling et al., 2009) and impairments in white matter tract integrity (MacDonald et al., 2011; Sponheim et al., 2011; Stevens et al., 2012). This suggests impaired prefrontal functioning associated with mTBI may exacerbate hypofrontality in PTSD, leading to greater emotion dysregulation and exaggerated neurobiological deficits in comorbid mTBI and PTSD (Bryant, 2008; Williamson, Heilman, Porges, Lamb, & Porges, 2013).

To date, few neuroimaging studies have examined the independent or overlapping effects of PTSD and mTBI. A meta-analysis of fMRI studies conducted in mTBI and PTSD suggested that the middle-frontal gyrus is implicated in both disorders (Simmons & Matthews, 2012). A recent study reported reduced amygdala volume in a comorbid PTSD and mTBI group, but this group was compared to a combined non-PTSD and non-mTBI control group (Depue et al., 2014). Imaging studies are limited by low temporal resolution (Simmons & Matthews, 2012).

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Event-related Potentials (ERPs) are high-resolution indices of electrical brain activity providing an index of cortical function and processing speed. Early components of the ERP (P100, N100) are thought to reflect automatic attentional processing (Naataanen, 1990), whereas later components (Vertex positive potential (VPP), N200, P300) are thought to reflect conscious processing (Jeffreys & Tukmachi, 1992; Polich & Kok, 1995). Earlier ERP studies of attention tasks revealed reduced P300 amplitudes (reflecting impaired attention allocation) in PTSD and mTBI samples (Elting et al., 2008; Felmingham, Rennie, Gordon, & Bryant, 2012). Emotional ERP studies in PTSD typically revealed an increase in P300 amplitude to threat or trauma-relevant stimuli (Karl et al., 2006), whereas ERP studies in mTBI typically reveal reduced amplitudes and slower ERP components to emotional faces (Duncan, Summers, Perla, Coburn, & Mirsky, 2011).

Two recent ERP studies have examined cortical function in PTSD comorbid with mTBI relative to single disorder conditions. The first compared a comorbid mTBI-PTSD veterans group with mTBI (without PTSD) veterans using an inhibitory motor processing task (Shu, Onton, O'Connell, Simmons, & Matthews, 2014). They found greater N2 amplitudes, reflecting greater inhibitory processing, in the comorbid mTBI-PTSD group compared to the mTBI group only, and greater N200 negativity correlated with greater PTSD severity. The second ERP study employing a facial empathy task found larger emotional face processing ERPs in the comorbid mTBI-PTSD veteran group when compared to the mTBI alone group, and greater N300 amplitudes correlated with increased PTSD symptoms (Shu, Onton, Prabhakar, et al., 2014).

These studies, although highlighting the effect of PTSD over and above mTBI, do not identify the independent effects of these disorders. Furthermore, no ERP studies have examined the effects of mTBI and PTSD on neural activity when processing differing facial expressions (including angry, fearful, happy and neutral expressions). This is important as mTBI has not been associated with attentional biases towards threat, rather, individuals with mTBI have shown difficulty recognizing and discriminating emotional expressions (Bornhofen & McDonald, 2008). Finally, previous ERP studies were cross-sectional and subject to selection bias.

The current study examined the independent effects of mTBI and PTSD on neural processing (using ERPs) of different emotional facial expressions (angry, fearful, happy and neutral) in a military sample pre and post-deployment, controlling for pre-deployment mTBI exposure. To examine the effects of mTBI, a post-deployment mTBI group was compared to a no-mTBI group whilst matching PTSD symptom level, and to examine the effects of PTSD, a separate non-mTBI sample was studied comparing those with high and low post-deployment PTSD symptoms. It was hypothesized that the high-PTSD group would demonstrate a post-deployment attentional bias (reflected in larger ERP amplitudes) towards threatening faces (angry, fearful), which would not exist in the mTBI group.

2. Materials and methods

2.1. Participants

Seventy-four participants of Australian Defence Force personnel deployed to the Middle East Area of Operations (MEAO) (70 males, 4 females, aged 19–49 years (M = 29, SD = 6.9)) were selected from personnel who completed pre and post-deployment (within four months of return) electrophysiological recordings in the MEAO prospective health study.

PTSD symptoms were assessed using the PTSD Checklist (PCL-M; Weathers, Litz, Huska, & Keane, 1994), and mTBI was assessed by the incidence of head injury that resulted in loss of consciousness greater than five minutes, or altered mental states during deployment as per previously published criteria for screening for mTBI in OEF/OIF veterans (King, King, & Vogt, 2008; U.S.G.A. Office., 2008). Specific criteria included experiencing: blast, rocket propelled grenade attack, motor vehicle accident, fragment/bullet wound, or fall which resulted in loss of consciousness or altered mental states (confusion, attention difficulties) during deployment (U.S.G.A. Office, 2008). The no-mTBI group were chosen on the basis of no reported injury or blow to the head during deployment. It should be noted that this classification of mTBI was made on the basis of self-reported symptoms and experience of events in line with screening criteria used for OEF/OIF veterans, but objective clinical assessments from the deployment were unavailable. Sixteen participants were identified as having experienced an mTBI during current deployment, and were matched to a no-mTBI group (with PTSD symptom severity matched according to total PCL-M score). To analyse the effect of PTSD symptoms, in the remaining no-mTBI sample, 21 participants were classified as having high PTSD symptoms (with a total PCL-M score of 30 or above) and were compared to a group with low PTSD symptoms (n = 21). On the basis of these criteria participants were allocated to one of four groups: high PTSD symptoms with no-mTBI (n = 21), low PTSD symptoms with no-mTBI (n = 21), mTBI (n = 16) and no-mTBI (n = 16). Two separate analyses were conducted, one examining the effects of mTBI vs no-mTBI, and a second analysis examined the effects of high PTSD symptoms (compared to low) in a sample with no-mTBI during deployment. Participants in both analyses were matched on age, war exposure and total months deployed at post-deployment, with the mTBI compared to no-mTBI groups also being matched on their total PCL-M scores.

In an effort to reduce the influence of pre-existing factors, selected participants were closely matched on key pre-deployment variables including history of prior mTBI (U.S.G.A. Office, 2008), pre-deployment PTSD symptomatology (PCL-M) and psychological distress rating (K10; Kessler et al., 2002), number of prior military deployments and number of months previously spent on deployment, total number of prior combat experiences and total number of prior life-time trauma exposures. Participants reporting pre-deployment mTBI of greater than moderate severity were excluded from analyses in the current study.

This study received approval from the Australian Defence Human Research Ethics Committee (ADHREC) and the University of Adelaide Human Research Ethics Committee (UA HREC). Written informed consent was obtained prior to participation.

2.2. Self-report measures of PTSD symptoms, psychological distress, and war exposure

PTSD symptom severity was assessed using the PCL-M, which provides an ordinal range of symptom severity with a recommended cutoff of 30–34 when screening post-combat military personnel (Bliese et al., 2008). Psychological distress was assessed using the K10 at pre and post-deployment (Kessler et al., 2002). War exposure was assessed using the Deployment Risk and Resilience Inventory (King et al., 2008).

2.3. Facial emotion processing task

Participants completed an emotional face passive viewing task whilst cortical electrical activity was recorded using ERPs as part of the standardized paradigms from the Brain Resources LabNeuro platform. Emotional face stimuli were selected from a standardized set of facial emotion stimuli (Gur et al., 2002) including fearful, angry, happy and neutral facial expressions. Each stimulus was a greyscale image matched for size and luminance that was presented to participants on a computer screen. Data were recorded under two conditions: conscious and preconscious.

During the conscious condition, blocks of eight stimuli per emotion (fear, angry, happy and neutral) were presented for 500 ms in pseudo-randomized order. There were four repeat blocks for each expression, making a total of 32 stimuli per expression. The inter-stimulus interval was 700 ms, making a total stimulus asynchrony of 1200 ms. This design was used to elicit neural activation representative of conscious emotional processing.