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An electrocortical investigation of voluntary emotion regulation in combat-related posttraumatic stress disorder

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ABSTRACT

Posttraumatic stress disorder (PTSD) – a debilitating disorder characterized by severe deficits in emotion regulation – is prevalent among U.S. military veterans. Research into the pathophysiology of PTSD has focused primarily on emotional reactivity, showing evidence of heightened neural response during negative affect provocation. By comparison, studies of brain functioning during the voluntary regulation of negative affect are limited. In the current study, combat-exposed U.S. military veterans with ($n=25$) and without ($n=25$) PTSD performed an emotion regulation task during electroencephalographic (EEG) recording. The late positive potential (LPP) was used as a measure of sustained attention toward, and processing of, negative and neutral pictures, and was scored prior to and after instructions to either maintain or down-regulate emotional response using the strategy of cognitive reappraisal. Results showed that groups did not differ in picture-elicited LPP amplitude either prior to or during cognitive reappraisal; reappraisal reduced the LPP in both groups over time. Time-dependent increases in LPP amplitude as a function of emotional reactivity maintenance were evident in the non-PTSD group only. This latter finding may signal PTSD-related deficits in sustained engagement with emotion-processing over the course of several seconds.

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1. Introduction

Lifetime prevalence of posttraumatic stress disorder (PTSD) is approximately 7% among U.S. adults, but the disorder is far more common among U.S. military veterans. Some estimates indicate that up to 13% of veterans meet PTSD diagnostic criteria in the months that follow combat deployment (Castro, 2014), making the disorder one of the most common injuries suffered by U.S. veterans returning from overseas (Thomas et al., 2010). PTSD is characterized by symptom heterogeneity, including reoccurrence of trauma memories, emotional withdrawal, alterations in arousal and emotional reactivity, and persistent negative changes in cognition and mood (American Psychiatric Association, 2013). In spite of PTSD's varied presentation, recent meta-analyses and review papers endorse emotion dysregulation as a core feature of the disorder (Etkin and Wager, 2007; Frewen and Lanius, 2006). In addition, clinical studies have found that self-reported deficiency in emotion regulation in PTSD is predictive of increased symptom severity (Badour and Feldner, 2013; Boden et al., 2012) and inferior social functioning (Klemanski et al., 2012). Together, this research suggests that the study of emotion dysregulation may be central in understanding PTSD; however more information is needed on the biological mechanisms that support this aspect of the disorder.

Much of the neuroimaging work in PTSD to-date has sought to determine whether individuals with PTSD exhibit heightened neural activation in response to aversive stimuli (Bryant et al., 2008; El Khoury-Malhame et al., 2011; Felmingham et al., 2010; Hayes et al., 2012; Hendler et al., 2003; Morey et al., 2009; Protopopescu et al., 2005; Rauch et al., 2006; Shin and Liberzon, 2010;

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Simmons and Matthews, 2012; White et al., 2014). For instance, compared to non-traumatized (Bryant et al., 2008; El Khoury-Malhame et al., 2011; Felmingham et al., 2010; Protopopescu et al., 2005) and traumatized peers without PTSD (Hendler et al., 2003; Morey et al., 2009), those with PTSD have been found to exhibit heightened amygdala activity when exposed to both generic and trauma-related aversive stimuli. Greater engagement of the amygdala has also been found to correlate with severity of PTSD symptoms (White et al., 2014). Based on these findings, one possibility is that symptoms of emotion dysregulation in PTSD stem from heightened reactivity to aversive information. Yet another possibility is that symptoms of emotion dysregulation result from deficient regulatory control over emotional stimulus processing. Therefore, to fully understand the mechanisms of emotion dysregulation in PTSD, additional work on neural functioning during the voluntary regulation of emotional reactivity is needed.

Voluntary emotion regulation refers to a conscious attempt to change the intensity and/or duration of an emotional reaction (Gross and Thompson, 2007). Cognitive reappraisal is a highly effective emotion regulation strategy in which individuals modulate the emotional salience of a stimulus by changing its meaning (Ochsner et al., 2002). In uncovering the neural correlates of the strategy, studies in healthy individuals have found that cognitive reappraisal is associated with increased engagement of multiple regions in the prefrontal cortex (PFC), including the dorsolateral PFC (dlPFC) (Goldin et al., 2008; Phan et al., 2005), ventrolateral PFC (vlPFC) (Ochsner et al., 2002; Wager et al., 2008), dorsomedial PFC (dmPFC) (Banks et al., 2007; Phan et al., 2005), and ventromedial PFC (vmPFC) (Urry et al., 2006) in addition to the anterior cingulate cortex (ACC) (Eippert et al., 2007; Hermann et al., 2014) (see Buhle et al. (2014), Ochsner et al. (2012) for reviews). During reappraisal, amygdala activation is also reduced (Buhle et al., 2014) and reductions in amygdala responding have been found to correlate with reappraisal-related increases in prefrontal cortical activity (Banks et al., 2007). These data suggest that cognitive reappraisal may exert its effects on emotional reactivity by way of PFC engagement.

Neuroimaging studies of cognitive reappraisal in PTSD have found that PTSD may be characterized by deficits in prefrontal regions implicated in the successful down-regulation of negative affect. For instance, Rabinak et al. (2014) found that, compared to combat-exposed U.S. military veterans without PTSD, those with PTSD showed a focal deficit in dlPFC engagement when asked to reduce their response to negative pictures using cognitive reappraisal. In an earlier study, New and colleagues (2009) found that, compared to their non-traumatized counterparts, traumatized females showed reduced recruitment of prefrontal brain regions during cognitive reappraisal; however, recruitment of these regions did not differ for traumatized individuals with versus without PTSD (New et al., 2009). In this study, individuals with PTSD also showed less activation of the PFC when asked to *increase* negative affect, compared to traumatized individuals without PTSD and healthy controls. This prior work then suggests that PTSD and/or trauma-exposure may be characterized by reduced recruitment of prefrontal regions during the cognitive reappraisal of negative stimuli. Additionally, PTSD may be uniquely characterized by aberrant neural activation during the up-regulation of emotional response.

Event-related potentials (ERPs) have excellent temporal resolution and can be used to assess the neural correlates of affective processing. For instance, the late positive potential (LPP) is an ERP component that begins approximately 300 milliseconds (ms) after stimulus onset and is larger for emotional than neutral stimuli (Codispoti et al., 2006; Cuthbert et al., 2000; Foti et al., 2009; Hajcak et al., 2012; MacNamara et al., 2009; Schupp et al., 2000). The LPP persists throughout stimulus presentation duration, lasting up to several seconds or longer (Cuthbert et al., 2000; Hajcak and Olvet, 2008). The LPP is initially evident at centro-parietal regions but becomes more frontal later on during stimulus presentation (Hajcak et al., 2012; MacNamara et al., 2009). In addition to being sensitive to the overall emotional nature of stimuli, the LPP is also sensitive to individual differences in the perceived salience of stimuli. For example, the LPP is larger for personally-salient stimuli such as pictures of food among food-deprived individuals (Stockburger et al., 2009) and pictures of one's own face (Tacikowski and Nowicka, 2010) or that of a relative or close friend (Grasso and Simons, 2011). Among individuals with anxiety, the LPP may be larger in response to threat-related (Kujawa et al., 2015; MacNamara and Hajcak, 2010) and disorder-specific stimuli (e.g., images of spiders in spider phobia) (Leutgeb et al., 2009; Michalowski et al., 2009). Further, the LPP is also sensitive to "top-down" manipulations of stimulus meaning. For instance, the LPP is smaller for neutrally- as compared to negatively-described pictures (Foti and Hajcak, 2008; MacNamara et al., 2009) and is smaller when participants are asked to reduce the emotional salience of pictures using the strategy of cognitive reappraisal (Hajcak and Nieuwenhuis, 2006; Moran et al., 2013; Moser et al., 2010, 2009; Parvaz et al., 2012). Some studies also document larger LPPs when participants are asked to increase emotional picture salience (Gardener et al., 2013; Moser et al., 2010, 2009; Sarlo et al., 2013). Given this research, the LPP appears as a valid neural 'assay' by which to assess emotion regulation in the context of both healthy and emotion-dysregulated individuals. However, despite its widespread use in healthy samples (Hajcak and Nieuwenhuis, 2006; MacNamara et al., 2009; Moran et al., 2013; Moser et al., 2010, 2009; Parvaz et al., 2012), only one study to date has employed the LPP as a measure of emotion-processing during willful emotion regulation in PTSD.

Recently, Woodward et al. (2015) examined group differences in LPP amplitude during voluntary regulation in military veterans with PTSD and non-traumatized controls. In this study, participants viewed negative and neutral pictures; prior to the presentation of each negative picture, participants were shown a color-coded cue that either instructed them to "*think of something to tell yourself that helps you feel less negative about the photo*" (Woodward et al., 2015; p. 669 'rationalize' condition) or "*notice your beating heart and your angry or fearful thoughts, and do not resist these reactions in any way … let the emotion flow over you like a wave*" (Woodward et al., 2015; p. 669 'notice' condition). In other words, in the rationalize condition, participants were instructed to cognitively down-regulate their emotional response, though the specific strategy (e.g., distraction, reappraisal) was not indicated. By contrast, in the notice condition, participants were instructed to attend to their emotional response – a phenomenon that has been shown to *increase* the LPP (Hajcak et al., 2009). In a third, control, condition, participants were instructed to "respond freely" to negative pictures (i.e., to refrain from changing their affective response in any way). Results showed that there was no effect of group and no group × condition interaction. Importantly, however, there was also no overall effect of condition on the LPP. That is, the LPP was not modulated by condition in either the PTSD or the non-PTSD group. Without evidence that the regulation strategies used by participants in Woodward et al. study (2015) modulated the LPP, it is difficult to interpret the absence of a group effect. Further, despite a picture presentation duration of 10 s, Woodward et al. (2015) assessed the LPP using peak amplitudes corresponding to the LPP within a 250–750 ms window post-picture presentation, thus also limiting understanding of the time-course of sustained emotion regulation.

In order to address these gaps in knowledge and more broadly address the relative paucity of emotion regulation work in PTSD, the current study examined the effects of cognitive reappraisal on