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Independent Component Analysis of Self-Referential Processing in

Women with Posttraumatic Stress Disorder

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Honors Psychology Thesis

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Abstract

Posttraumatic stress disorder (PTSD) is a condition than can develop after exposure, or repeated exposure, to a traumatic event. Recent changes to the diagnostic criteria for PTSD reflect a new emphasis on the dysregulation of emotions related to self-appraisal and self-referential processing (SRP). SRP concerns stimuli that are experienced as strongly related to one's own person and can be measured using valenced stimuli that relate to the participant's concept of self. These paradigms are referred to as self- referential processing tasks. The current study used data from functional magnetic resonance imaging (fMRI) to investigate the activation of brain areas related to the self-referential processing of women. Activation patterns in women with PTSD were compared to those of healthy control women. Both participant groups completed the Visual-Verbal Self-Other Referential Processing Task (VV-SORP-T) to locate regions of interest in self- and other-referential processing in response to valenced social emotional stimuli. It was hypothesized that analyses would show between-group differences in three networks: (1) default mode network, (2) salience network, (3) executive control network. Analysis of the fMRI data was conducted using Group Independent Component Analysis of fMRI (GIFT) toolbox, software courtesy of Medical Image Analysis Lab, for use with the Matrix Laboratory Toolbox (MATLAB). One-way analysis of variance (ANOVA) was used to investigate between-group differences in the different conditions. Significant results found greater activation of the defualt mode network for the PTSD group. Significant differences were also found in the visual cortex and cerebellum. This study provides novel evidence for the role of the cerebellum in self-referential processing.

Independent Component Analysis of Self-Referential Processing in Women with

Posttraumatic Stress Disorder

Posttraumatic stress disorder (PTSD) is a condition than can develop after single or repeated exposure to a traumatic event (American Psychiatric Association (APA), 2013). More than half of the Canadian population will be exposed to some traumatic event in their lifetime (Koenigs & Grafman, 2009). Lifetime prevalence of PTSD is approximately 1 in every 11 Canadians (Van Amerigen, Mancini, Patterson & Boyle, 2008**).** Recent research and changes to the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) criteria for PTSD reflect that the understanding of both the causes and effects of PTSD are shifting. This disorder was historically considered a fear-based anxiety disorder (APA, 2000). However, recent evidence suggests that fear may be less integral than previously thought (Lee, Scragg & Turner, 2010). Novel theories of PTSD place a new emphasis on emotions related to the appraisal of self, such as shame (Budden, 2009).

Regions of Interest

Neuroimaging research has identified a number of regions of interest associated with PTSD. Three of the most well-examined areas are the amygdala (Phelps, Delgada, Nearing & LeDoux, 2004; Rajendra et al., 2012), the ventromedial prefrontal cortex (vmPFC; Koenigs & Grafman, 2009; Milad, Rauch, Pitman & Quirk, 2006), and the anterior cingulate cortex (ACC; Dickie, Brunet, Akerib & Armony, 2013). The amygdala is a subcortical region located in the anterior temporal lobe that extends into the brainstem and hypothalamic regions to assist in the processing of physiological, autonomic and musculoskeletal components of an emotional response (Ledoux, Iwata, Cicchetti & Reis, 1988). The amygdala mediates the acquisition and

expression of conditioned fear responses as well as enhances the emotional components of memory (Koenigs & Grafman, 2009).

The mPFC is the medial wall of the anterior frontal lobes. The ventral region, or vmPFC, is connected to the amygdala by dense white matter tracts which aid in the bidirectional communication of these regions (Koenigs & Grafman, 2009). In a typical brain, the mPFC is involved in extinguishing a conditioned fear response from the amygdala (Richardson, 2009). Experiments in animal studies suggest that exposure to chronic stress may lead to dysfunction in the circuitry of the brain responsible for extinction of a fear response. Specifically, this dysfunction is decreased activation of the vmPFC in the PTSD population (Phelps, Delgado, Nearing, & LeDoux, 2004). The vmPFC also supports some core aspects of social-cognitive processing such as judging the characterisitcs of others (Mitchell, Banaji & Macrae, 2005; Mason, Banfield & Macrae, 2004).

The ACC is located at the frontal region of the cingular cortex and surrounds the frontal region of the corpus callosum. Its main functions are based on cognitive and emotional components **(**Drevets & Raichle, 1998; Bush, Luu & Posner, 2000). Diminished activation or failure to activate the ACC in a PTSD population has been noted in a variety of experimental paradigms such as during the presentation of traumatic narratives (Shin et al., 2007; Bremner, et al., 1999a; Lanius et al., 2001), combat sights and/or sounds (Bremner et al., 1999b) and fearful facial expressions (Shin et al., 2006; Williams et al., 2006). Previous studies have shown that cortical thickness in the ACC predicted symptom improvement, further suggesting it's role in PTSD (Dickie et al., 2013).

Since it's inception in the DSM-III, PTSD was considered an anxiety-based disorder with onset occurring after exposure to an event that evoked feelings of helplessness, fear or horror

from the individual who experienced it (APA, 1980). This continued into the DSM-IV-TR, further emphasizing the role of fear in PTSD (APA, 2000). Many studies have provided support for the role of the amygdala in the acquisition and expression of fear. First, animal studies have shown that impaired fear inhibition predicted PTSD (Goswami et al., 2013; Jovanovic et al., 2010). Anatomical studies of the brain revealed structural differences in the amygdala in the PTSD population compared to healthy controls (Shin & Liberzon, 2010; Woon & Hedges, 2009). Also, neuroimaging studies consistently found greater activation in this region for PTSD participants over controls (Shin, Rauch & Pitman, 2004), contributing to the theory that the amygdala is perhaps the most strongly implicated structure underlying PTSD (Rajendra et al., 2012). Furthermore, areas of the brain that show deactivation unique to PTSD, as compared to other anxiety disorders, are the ACC and vmPFC (Shin & Liberzon, 2010). Considering the inhibitory role these regions play, the hypoarousal explains the dysfunctional hyperarousal of the amygdala, further indicating fear as the primary PTSD emotion.

The Role of Social Emotions

Fear is not the sole emotion proposed as underlying PTSD. Although activation in the amygdala is consistently seen in this population, its activation is more frequently found to be robust in other anxiety disorders such as social anxiety and specific phobia (Etkin & Wagner, 2007). In addition, there are studies that have shown evidence for the role of social emotions in PTSD (Lee, Scragg & Turner, 2010). Social emotions are those in which the generation requires the self-relevant appraisal of another's thoughts, feelings and/or actions (Britton et al., 2006). Social emotions can be experienced, recalled, imagined and anticipated (Hareli & Parkinson, 2008). Social emotions are also valenced. Positive social emotions include admiration, love, and pride whereas negative social emotions include guilt, envy and shame, among others (Britton et

al., 2006). Social emotions can be distinguished from non-social emotions on a behavioural (Hareli & Parkinson, 2008) and neurobiological (Britton et al., 2006) level.

The most impactful evidence in support of the role of social emotions in PTSD involves the experience of shame (Budden, 2009). Shame is a social emotion that is made up of a group of negative feelings that range from mild embarrassment to severe humiliation. Shame also reflects an anxiety or self-reflection about negative judgment, unwanted exposure, inferiority, failure and defeat (Budden, 2009). Therefore, in order to experience shame, SRP occurs. Studies have shown that the most widely reported emotions in PTSD are shame, guilt, anger, sadness and mistrust (Glover, 1988; Resick & Schnicke, 1992; Reynolds & Brewin, 1999). Shame and anger were also reported to be emotions recalled from the most intense moment of trauma, as opposed to fear and terror (Grey, Holmes & Brewin, 2001; Reynolds & Brewin, 1999). Finally, studies involving traumas relating to violent crime or childhood abuse found that shame was the only symptom that predicted PTSD symptoms after one month and beyond six months (Andrews, Brewin, Rose & Kirk, 2000).

Shame can be adaptive as it plays a role in the regulation and protection of the social self and enables us to anticipate exposure and the loss of personal boundaries (Lewis, 1987; Schore, 1994). However, during traumatic events, the social self may be under attack and personal boundaries can be destroyed. When this occurs, peri-traumatic shame can become post-traumatic shame (Budden, 2009). Therefore, significant behavioural data indicates that shame is another core emotion of PTSD.

One of the most convincing arguments that fear is not the only emotion involved in PTSD is in the recent changes to the DSM-V. The DSM-V (APA, 2013) reflected the recent theories suggesting fear was not as essential to PTSD as once thought. First, PTSD is no longer

listed in the chapter of *Anxiety Disorders*, which includes disorders such as panic disorder, specific phobia, social phobia and generalized anxiety disorder. A new chapter was added to the latest version entitled *Trauma- and Stressor-Related Disorders*. This chapter includes disorders such as PTSD, adjustment disorder and reactive attachment disorder. In the previous version, the DSM-IV-TR (APA, 2000) required that the individual experience a traumatic event that caused them to feel helplessness, horror or fear. The emphasis has now been placed on the reaction of the individual to the event rather than the traumatic event itself. In addition, the DSM-V has widened its inclusion criteria to include those who indirectly experience trauma, either by learning it happened to a family member or friend, or repeated extreme indirect exposure to aversive details of a traumatic event. This may include paramedics, police officers and others. For these individuals, fear may not be the most prominent emotion felt in reaction to the traumatic event(s). Finally, Criterion D4 of the DSM-V describes symptoms related to persistent negative trauma-related emotions, which include fear, horror, anger, guilt or shame (APA, 2013). In this criterion we see a reflection of the heterogeneity of emotional experiences in response to traumatic event currently reflected in the PTSD research.

      These changes in the DSM criteria provides evidence for the increasing importance of social emotions in the PTSD research. However, it should be noted that up to and including the DSM-IV-TR, fear was considered essential to the development of PTSD. Therefore, the DSM is a dynamic tool that changes criteria periodically, based on strong empirical evidence. This represents the clinical implications of research such as the current study to further delineate the underpinnings of this disorder.

Intrinsic Connectivity Networks in PTSD

Intrinsic connectivity networks (ICNs) are large-scale networks linked to characterisitc functions (Fox et al*., 2005; Corbetta, Patel & Shulman, 2008). These networks correspond with white matter tracks and have direct behavioural correlates (van den Heuvel et al., 2009; Fox et al., 2007). The current study investigated between-group differences in three ICNs: (1) default mode network (DMN), (2) executive control network (ECN) (3) salience network (SN). Their role in PTSD is discussed further in the following sections.

Default Mode Network. The DMN is stimulus-independent network (Sripada et al., 2012). It encompasses aspects of internally-focused thought and autobiographical memory (Spreng, Mar & Kim, 2009; Toro, Fox & Maus, 2008; Qin & Northoff, 2011). Core components of this network include the vmPFC and hippocampus, both of which have been shown to be hypoactive in PTSD during certain tasks (Etkin & Wagner, 2007). The DMN is also proposed to be involved in tasks involving social-cognitive functioning such as the procesing of information that relates to the minds of others and aspects of the self (Mitchell, Banaji & Macrae, 2005).

Executive Control Network. The ECN is associated with higher-level cognitive functions such as planning, decision-making, working memory and goal-directed behaviour (Seeley et al., 2007; Sridharan, Levitin & Menon, 2008). It includes areas such as the dorsolateral prefrontal cortex and lateral parietal regions (Sripada et al., 2012). Recent research has shown that, compared to healthy controls, participants with PTSD have weaker connectivity within areas involved in the ECN and SN related to switching between the ECN and DMN (Daniels et al., 2010).

Salience Network. The SN is an ICN involved in the detection and subsequent orienting to salient stimuli (Seeley et al., 2007; Dosenbach et al., 2007; Cauda et al., 2011; Sridharan,

Levin & Menon, 2008). It has been proposed that the SN may mediate between the DMN and

ECN (Menon, 2011) by assessing the salience of stimuli and maintaining a healthy balance

between internal mental activity, external focus and task execution (Sripada et al., 2012) Areas

of the SN include the insula and the amygdala, both of which have been found to be hyperactive

in PTSD (Shin & Liberzon, 2010; Etkin & Wagner, 2007).

The Current Study

The current study is seeking to validate the role of social emotions in the dysfunction of

social emotional processing in women with PTSD. The VV-SORP-T is a paradigm used in fMRI

research that using a priming methodology to probe specifically for brain regions underlying

how valenced words are processed in relation to the self and to others. The neuroimaging data

had been previously acquired from women with and without PTSD (Frewen, Lundberg,

Brimson-Théberge & Théberge, 2013). The previous published study on this data (Frewen et al.,

2013) identified regions of interest that varied with individual difference in the self-report

measures of the VV-SORP-T for the healthy control group. The current study will use fMRI data

from both control and PTSD participants to address an additional research question. Specifically,

this study will explore the differences in activation between the two groups in response to the

VV-SORP-T.

Research into the neural correlates of PTSD have both theoretical and clinical

implications. First, the recent changes in the DSM criteria are evidence that continued research is

necessary to the dynamic nature of diagnostic criteria. In addition, the increased appreciation for

the role of social emotions in the experience of PTSD has clinical implications, particularly in

how it relates to treatment. Evidence-based treatments for PTSD have historically been centered

on the theoretical understanding of fear as the core PTSD emotion (Shin & Liberzon, 2010; Shin

et al., 2006; Rajendra et al., 2012; Williams et al., 2006). With mounting evidence suggesting the role of other emotions, new treatment models are being considered for those who experience emotions other than fear as their primary emotion, as evidenced in work by Budden (2009) and Maguen and Burkman (2013). Therefore, neuroimaging research has implications on the theoretical understanding of mental health disorders as well as clinical implications relating to the treatment of those disorders. This study aims to contribute to the understanding of social emotional processing dysfunction in women diagnosed with PTSD.

Hypotheses. Differential activation was hypothesized between control and PTSD groups in three core networks: (1) default mode network; (2) salience network; (3) executive control network. The PTSD group was expected to show greater activation of the SN relative to the control group. The PTSD group was also hypothesized to show less activation of the DMN and ECN relative to the control group.

Method

Participants

Control Group. Twenty-four women between the ages of 18 and 52 years were included in the healthy control group. Participants were recruited from the general community using print and online advertisement. Healthy control women must have scored normative levels of trait self-esteem and self-critical thinking as determined by the Rosenberg Self-Esteem Scale (Rosenberg, 1965) and the Cognitive Distortion Scale (Briere, 2000), respectively. Participants were excluded from the study for current or past psychiatric history (Structured Clinical Interview for DSM-IV (SCID; First, Spitzer, Gibbon & Williams, 1995), current substance use, head injury with loss of consciousness, left-handedness, pregnancy, metal piercings and surgical implants.

Clinical Group. Twenty women between the ages of 18 and 55 years were recruited using fliers in hospitals, London Health Sciences Centre Traumatic Stress Service and the general community using online and print advertisement. The presence of PTSD was necessary for the clinical group and was determined by the Clinician Administered PTSD Scale (CAPS; Weathers, Keane & Davidson, 2001). Participants were excluded from the study for head injury with loss of consciousness, left-handedness, current substance use, pregnancy, metal piercings and surgical implants.

Materials

VV-SORP-T. The VV-SORP-T is designed for use with fMRI and compares the neural correlates of valenced SRP with valenced other-referential processing (ORP) using a priming methodology (Frewen & Lundberg, 2012). Its procedure has been previously published in studies on similar populations (Frewen et al., 2011, Frewen & Lundberg, 2012, Frewen et al., 2013). The VV-SORP-T provides measurements of fMRI BOLD signals, participant self-reports of affective responses, and reaction times. This measure is influenced by differences in trait self-esteem as lower self-esteem is correlated with negative affect level during negative self-referential processing (Frewen & Lundberg, 2012).

The VV-SORP-T contains three major components: (1) a paper-and-pencil survey rating of self- and other-referential adjectives, (2) the experimental scanning component, (3) post-scanning affective response ratings. The survey involves the descriptiveness of negative and positive traits of the self and others. This measure is done approximately two weeks prior to the participant's scanning date. Participants are asked to rate ten positive and ten negative words on how they "described themselves in general" and "how they describe other people in general" (Frewen et al., 2013). Ratings were made on an 11-point scale (0 – 10) with (0) being "Not at

all", (5) being "Moderately" and (10) being "Completely". The adjectives included social and achievement-based adjectives and included the same word list as used in Frewen and Lundberg (2012) and Frewen et al. (2011). This measure is also correlated with the Rosenberg Self-Esteem Scale ($r = .73$; Frewen & Lundberg, 2012). Frewen & Lundberg also reported the word sets to be statistically comparable in terms of length in letters, frequency of use within the English language relative Hyperspace Analogue of Language (HAL) norms (Lund & Burgess, 1996). No differences were observed in arousal rating relative to the Affective Norms for English Words (Bradley & Lang, 1999).

The second component of the VV-SORP-T is the completion of an experimental task in scanner. Prior to scanning, participants completed a full practice run, consisting of three runs of eight blocks. Participants also had their photographs taken in a neutral expression using an electronic camera against an office wall. These photos were standardized to match in essential aspects to those used in the development of the NimStim set of facial expressions (Tottenham et al., 2009). Pictures included in the other-referential conditions were taken from the NimStim set and were matched as closely as possible for ethnicity, hair colour and length. To control for picture novelty, participants were habituated to the photos for six to ten seconds.

Participants were instructed to do three things while completing the experimental portion of the VV-SORP-T: (1) rehearse statements internally and read words, (2) press response buttons on a keypad and (3) "pay close attention to how you are feeling throughout the different parts of the task". Participants viewed a fixation cross, presented for twelve seconds in between blocks, until they were presented with the word "SELF" or "OTHER" (for three seconds). This cued which type of picture they were about to be presented with. Upon seeing their own or another's photograph, also presented for three seconds, they silently rehearsed to themselves "I am" or

"She is", respectively. They then pressed a keypad button with either their index or middle finger. Participants were then presented with a single positive or negative word for three seconds, asked to silently read the word and then pressed another keypad button with their other finger (counterbalanced). Four additional pictures and words sets were then presented, following the same pattern. The picture remained identical and the words changed, remaining of the same valence (positive or negative). Therefore the stimulus presentations were blocked in terms of the reference (self or other) and valence (positive or negative) creating four trial types: self-negative, self-positive, other-negative and other-positive. The different conditions were presented to the participants in a randomized order. To encourage introspection, participants were not instructed to press the button as fast as possible. Instead they were informed the button press was for the benefit of the researchers, to ensure the participants were paying attention during the task.

The third and final part of the VV-SORP-T is a post-task rating questionnaire about affective responses that was completed immediately after scanning. It consisted of open-ended and rating-scale questions about the participant's response to the different conditions. Percentage rating scales asked for a response from 0% (Not at all) to 100% (Strongly) with 50% indicating "Moderately". Participants were asked "how much you felt certain specific feelings in response to each picture and word type combination". Negative feelings included anger, sadness, anxiety-fear, disgust and bad about self. Positive feelings included happy and good about self. This provided another measure of individual differences in self-esteem-related processes.

Procedure

All procedures were approved by the Health Sciences Research Ethics Board of Western University in London, Ontario, Canada. Participants were assessed for inclusion criteria and completed a short questionnaire battery approximately two weeks before their scanning date. On

the day of scanning, participants completed a single-block practice version of the VV-SORP-T paradigm and three blocks of the paradigm while undergoing fMRI. Before completing the VV-SORP-T, while undergoing fMRI, a resting-state functional scan of each participant's brain was also acquired. Immediately after scanning, participants completed the affective response rating. The length of the experiment was approximately seventy-five minutes.

Imaging was conducted at the Robarts Research Institute in London, Ontario, Canada. Image acquisition and preprocessing has been previously published in Frewen et al. (2013) and were as follows. Imaging data was collected using a 3.0 Tesla whole-body fMRI scanner (Magnetom Tim Tri, Siemens Medical Solutions, Erlangen, Germany) with the manufacturer's 32-channel phased array head coil. Orthogonal scout images were acquired and used to establish a tri-dimensional T1-weighted anatomical image of the head with 1mm isotropic resolution (MP-RAGE, TR/TE/TI = 2300/2.98/900ms, flip angle = 9 degress, FOV (X, Y, Z) = 256 x 240 x 192mm, acc. factor = 4, total acq. time = 3 min 12 s). The angle of the transverse plane passing through the anterior and posterior commeasures mid-sagittaly was determined using the anatomical volume. This was used as the source image for inter-individual spatial normalization. A set of 64 contiguous, 2 mm thick imaging planes for BOLD fMRI were set parallel to the AC-PC plane and located to ensure coverage of the top of the brain. BOLD fMRI images were collected using the manufacturer's standard gradient echo EPI pulse sequence (single-shot blipped EPI) using an interleaved slice acquisition order and tri-dimensional prospective acquisition correction (3D-PACE). EPI volumes were collected with 2 mm isotropic resolution and the following parameters: FOV = 192 x 192 mm, 94 x 94 matrix, TR/TE = 3000/20ms, flip angle = 90 degrees, 64 slices, 178 measurements.

Data Preparation and Statistical Analyses

The imaging data, having already been preprocessed (Frewen et al., 2013), was analyzed with the use of available software courtesy of Medical Image Analysis Lab using MATLAB. GIFT toolbox was used to investigate the research questions regarding ICNs and identified significant independent components (ICs) in response to the VV-SORP-T by extracting source signals related to the paradigm. Independent component analysis was used over voxel-based approaches to negate the issue of multiple comparisons. Spatial maps from Functional Imaging in Neuropsychiatric Disorders Lab (FIND Lab; Shirer et al., in press) were used to test for correlations between significant components and networks under investigation. One-way ANOVAs were used to investigate differences between groups for each condition.

Results

GIFT identified ten ICs as being significantly different between control and PTSD groups in response to the VV-SORP-T. IC 9 was correlated with the dorsal DMN (t (1) = -2.34, $p < .05$). No significant differences were found between groups for the SN or the ECN. Additional components were identified that were not spatially correlated with the three networks and are listed in Tables 1 – 4 by the condition in which there were found to be significant differences between groups. Functional maps from GIFT are located in the Appendix.

Table 1

Other-Negative

Independent Component	Control > PTSD	PTSD > Control
9		-2.34*
10	3.23**	
13	2.00*	
15	2.93**	

Note: t-values * $p < .05$ level. **$p < .01$.

Table 2		
Other-Positive		
Independent Component	Control > PTSD	PTSD > Control
2	2.05*	
3		-3.02**
10	2.48*	
15	3.04**	
16		-2.12*
19		-2.57*

Note: t-values * *p* < .05 level. **p* < .01.

Table 3		
Self-Negative		
Independent Component	Control > PTSD	PTSD > Control
2		-1.98*
6	2.20*	
10		-3.01**
11	2.12*	

Note: t-values * *p* < .05 level. **p* < .01.

Table 4		
Self-Positive		
Independent Component	Control > PTSD	PTSD > Control
10		-2.69**
15		-2.48*

Note: t-values * *p* < .05 level. **p* < .01.

Discussion

Default Mode Network

The DMN is represented by IC9 in Table 1. It was hypothesized in this study that, consistent with previous studies (for meta-analysis see Etkin & Wagner, 2007), the DMN would show less activation in the PTSD group as compared to the control group. Contrary to previous findings, this component showed greater activation for the PTSD group in the other-negative

condition. This was the only condition in which significant differences for the DMN were found between groups. Regions of the DMN, such as the mPFC, have been proposed to have a role in theory of mind, the ability to attribute the mental states of others (Völlm et al., 2006). The DMN also plays a role in autobiographical memory and these processes share overlapping neuronal networks with stimuli that evoke empathy (Völlm et al., 2006). It is possible that this activation is part of an empathetic response on the part of the PTSD participants in response to the pairing of a stranger's picture with a negative word. This may produce a self-reflection of their own negative judgments and an empathetic response engaging both theory of mind and autobiographical memory.

Visual Cortex

The visual cortex is represented by IC13 in Table 1. This component was more active for the control group, as compared to the PTSD group, in the other-negative condition. This was the only condition for which this component showed significant differences between groups. This result is interesting in light of research that provides evidence for subtle sensory processing deficits in PTSD (Mueller-Pfeiffer et al., 2013; Clark et al., 2009). A recent study by Mueller-Pfeiffer et al. (2013) investigated visual processing in participants with PTSD using fMRI. Participants were engaged in a picture-viewing task in which the stimuli varied in their valence (positive, negative or neutral). Results showed decreased activation for PTSD participants, compared to healthy controls, in the ventral visual stream regardless of picture valence. Areas that showed decreased activation for the PTSD group have been found to play a role in the identification and recognition of complex visual array such as faces and body parts (Spiridion, Fischl & Kanwisher, 2006). The authors attributed this result to the potential of multiple, simultaneous sensory stimuli to overwhelm PTSD participants (Mueller-Pfeiffer et al., 2013;

Stewart & White; 2008). This explanation seems less likely in the current study as this difference was only seen in the other-negative condition. If the deficits in the visual processing of PTSD participants seen in the current study were caused by environmental influences, this deactivation would be expected across all conditions. The existence of this deactivation in the other-negative condition suggests there is unique processing of this type of stimuli for PTSD participants. Taken in combination with the increased activation of the DMN for PTSD participants in the same condition suggests the possibility that in the other-negative condition, PTSD participants were recruiting visual areas less while engaged in more internally-focused processing.

Cerebellum

The cerebellum is represented by IC2 in Tables 2 and 3 and IC10 in Tables 1 – 4. IC2 was found to be more active in the control group in the other-positive trial and significantly more active for the PTSD group in the self-negative trials. The activation pattern of IC10 was of particular interest as this component showed a double dissociative pattern for reference type. Other-referential trials produced greater activation in the control group whereas self-referential trials produced greater activation in the PTSD group. The cerebellum is traditionally considered in its role in the modulation of motor activity (Shutter & van Honk, 2009). Although the cerebellum may have likely played a role in the finite motor task of button-pressing in the VV-SORP-T, it is unlikely to be the cause of the activation patterns of IC2 and IC10 as the motor requirements did not change across conditions. However the possibility of a third factor involved in the interaction of emotion and motor activity cannot be ruled out.

Areas of the cerebellum have consistently been seen to activate in studies of emotion and affect (Kober et al., 2008), possibly in a regulatory role (Shutter & van Honk, 2009). More specifically, there is evidence that the cerebellum plays a role in observing and reacting to

another's negative emotions and control of one's own negative emotions relative to positive emotions (Schraa-Tam et al., 2011). Furthermore, cerebellum abnormalities have been observed in disorders associated with emotional dysregulation (Shutter & van Honk, 2009). The cerebellum has been proposed to have a regulatory effect in emotion and affect via its role in the cortico-cerebellar-thalamic-cortical circuit (CCTCC; Shutter & van Honk, 2009). This circuit is proposed to monitor and regulate mental states via connections between the cerebellum and limbic system and projection to cortical regions (Shutter & van Honk, 2009; Andreasen, 1999).

Due to the double dissociative pattern of IC10, the impact of reference type on the cerebellum is of particular interest. Schraa-Tam et al. (2012) used fMRI to investigate the role of the cerebellum as participants observed and imitated pictures of faces expressing positive and negative emotional states. The results showed that positive emotional faces produced mild activations in the cerebellum whereas negative emotions produced strong activations. The author's concluded that the cerebellum is required for observing and reacting to the expressions of another's, particularly negative, expressions. This finding is consistent with the results from the current study wherein the control group showed greater activation in response to the other-referential trials. Also in accordance is the greater activation differences observed in the other-negative trials as compared to the other-positive trials. The study by Schraa-Tam et al. and others like it (Shutter & van Honk, 2009) include mostly other-referential stimuli, or neutral scenes and not self-referential stimuli. Therefore, the role of the cerebellum in self-referential tasks is much less documented and future research into this area is needed.

Future Directions

The analyses of the current data set could be expanded in two ways. First, as discussed above, the VV-SORP-T includes measurements of the participant's reaction time during the

fMRI task as well as self-repot measures of affective responses to condition type. Future research on this data should take into consideration these measures in addition to the imaging data to create a greater picture of the participant's mentation during each condition. In addition, this data set could be further analyzed for functional network connectivity to compare the temporal relationship among the components already identified by the independent components analysis.

Furthermore, in light of the significant results found for the cerebellum, novel studies in the future should investigate the role of this region in self-referential processing in addition to other-referential processing tasks. Increased research in this area may further support the cerebellum as a brain region important in social emotional processing and the possibility of it's function, or dysfunction, as a neural underpinning of PTSD.

Appendix
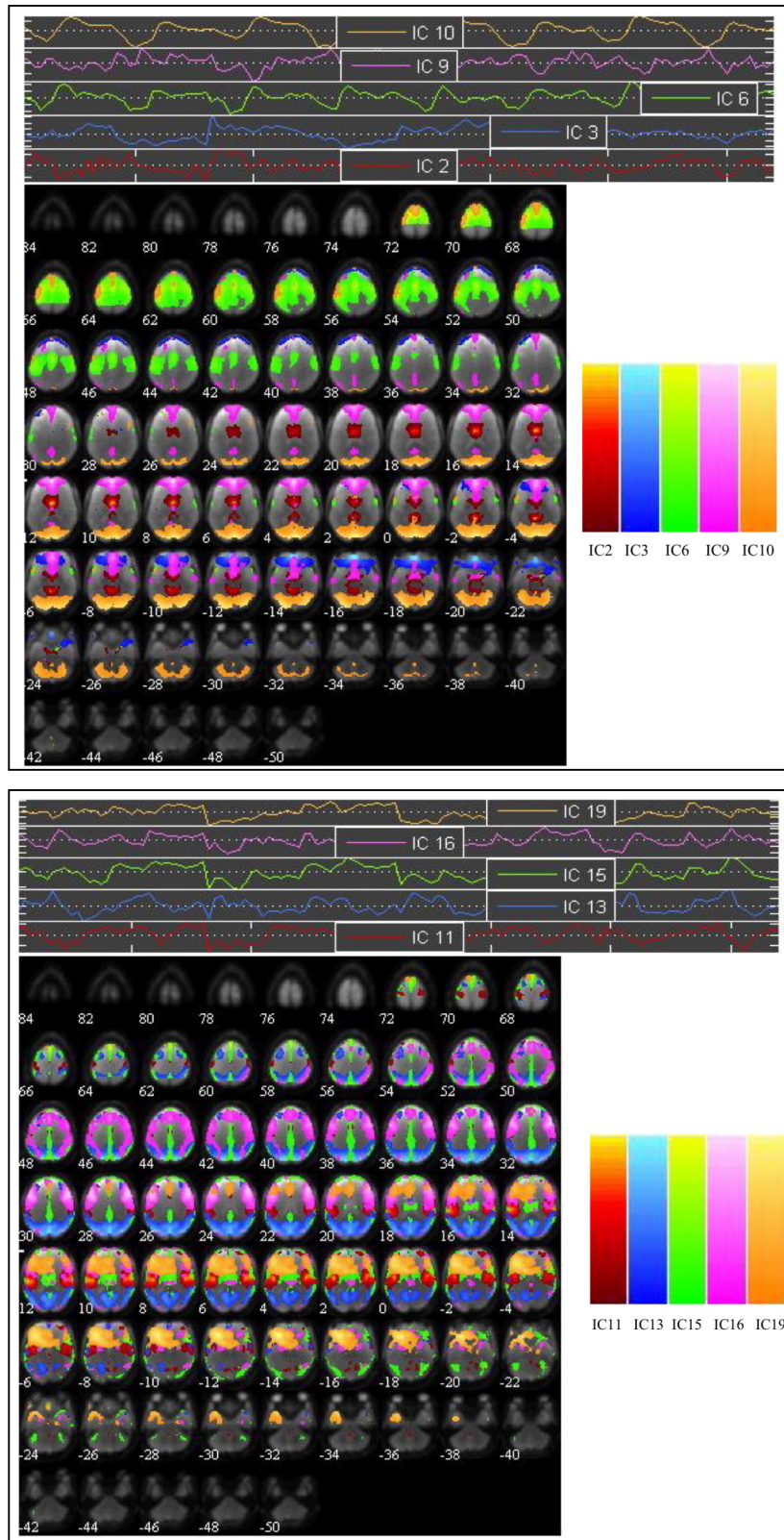
Functional maps of ten significant ICs between groups.

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