Violence-related PTSD and neural activation when seeing emotionally charged male–female interactions

Dominik A. Moser,1,2 Tatjana Aue,3 Francesca Suardi,1,2 Hana Kutiliková,2 Maria I. Cordero,2,4 Ana Sancho Rossignol,5 Nicolas Favez,1 Sandra Rusconi Serpa,1,2 and Daniel S. Schechter2,5

1Faculty of Psychology and Education, University of Geneva, Geneva, Switzerland, 2Child and Adolescent Psychiatry, University of Geneva Hospitals and Faculty of Medicine, Geneva, Switzerland, 3Swiss Center for Affective Sciences, University of Geneva, Geneva, Switzerland, 4Faculty of Health, Psychology and Social Care, Manchester Metropolitan University, and 5Faculty of Medicine, University of Geneva, Geneva, Switzerland

Post-traumatic stress disorder (PTSD) is a disorder that involves impaired regulation of the fear response to traumatic reminders. This study tested how women with male-perpetrated interpersonal violence-related PTSD (IPV-PTSD) differed in their brain activation from healthy controls (HC) when exposed to scenes of male–female interaction differing in emotional content. Sixteen women with symptoms of IPV-PTSD and 19 HC participated in this study. During magnetic resonance imaging, participants watched a stimulus protocol of 23 different 20 s silent epochs of male–female interactions taken from feature films, which were neutral, menacing or prosocial. IPV-PTSD participants compared with HC showed (i) greater dorsomedial prefrontal cortex (dmPFC) and dorsolateral prefrontal cortex (dPFC) activation in response to menacing vs prosocial scenes and (ii) greater anterior cingulate cortex (ACC), right hippocampus and ventromedial prefrontal cortex (vmPFC) activity in response to emotional vs neutral scenes. The fact that IPV-PTSD participants compared with HC showed lower activity of the ventral ACC during emotionally charged scenes regardless of the valence of the scenes suggests that impaired social perception among IPV-PTSD patients transcends menacing contexts and generalizes to a wider variety of emotionally charged male–female interactions.

Keywords: Parental PTSD; emotion regulation; fMRI; human interaction; interpersonal violence

INTRODUCTION

Among adult women, intimate partner violence (IPV) is a leading trigger of post-traumatic stress disorder (PTSD) (Pico-Alfonso, 2005). PTSD is characterized by symptoms of reexperiencing, avoidance/numbing and hyperarousal in response to having experienced a traumatic event (American Psychiatric Association, 2000). In the Diagnostic and Statistical Manual of Mental Disorders—Fourth Edition (DSM-IV–TR), PTSD had been classified as an anxiety disorder (American Psychiatric Association, 2000), but has recently been reclassified as a form of ‘stress and trauma related disorder’ in the DSM-V (American Psychiatric Association, 2013). This reclassification is consistent with specific neural activation patterns in response to environmental triggers and corresponding stress physiology. Meta-analysis has shown that PTSD to increased activity in structures such as the amygdala and insula, similar to what has been found for other anxiety disorders (Etkin and Wager, 2007; Hayes et al., 2012). PTSD, more specifically, was also associated with less activation of the ventromedial prefrontal cortex (vmPFC) (Dickie et al., 2008, 2011; Bluhm et al., 2012) and rostral anterior cingulate cortex (ACC) (Kim et al., 2008; Offringa et al., 2013). Broad evidence suggests that the dorsal–caudal regions of the ACC and mPFC are involved in the appraisal of negative emotion (Kalisch et al., 2006; Maier et al., 2012), while ventral–rostral portions of the ACC and mPFC have a regulatory function in relation to the limbic regions that are involved in generating emotional responses (Etkin et al., 2011; Motzkin et al., 2015).

Previous studies have shown that increased activity in limbic regions such as the amygdala is often inversely related to vmPFC activation (Sripada et al., 2012; Stevens et al., 2013; Killgore et al., 2014).

This suggests that not only isolated brain regions but circuits that are related to emotion regulation processes are altered among individuals suffering from PTSD as compared with non-PTSD healthy controls (HC). Behavioral studies have also linked PTSD to diminished empathic resonance (Nietlisbach et al., 2010), diminished mentalizing and emotion recognition (Poljac et al., 2011; Mazza et al., 2012) as well as greater levels of alexithymia (Declercq et al., 2010). In all, PTSD has been shown to affect brain regions that are related to both emotion expression and regulation.

PTSD is characterized by difficulties in emotion regulation particularly when new experiences remind patients of aspects of their trauma. Among patients with PTSD, there has been a multitude of imaging studies looking at PTSD and emotionally charged stimuli, which are both trauma (Shin et al., 2004; Frewen et al., 2008) and non-trauma related (Felmingham et al., 2010; Offringa et al., 2013; Thomaes et al., 2013). No study to our knowledge has used stimuli involving human interaction, though. Steuwe et al. (2014) have shown that the orientation of gaze within faces in still photographs, and in particular, whether the gaze is directed toward the participant-as-observer, modulates how interpersonal violence-related PTSD (IPV-PTSD) is related to neural activity. PTSD patients with a history of childhood abuse showed increased activation in the superior colliculus and the periaqueductal gray, as well as increased subcortical activity to direct gaze as compared with averted gaze. This pattern differed from HC who showed a top-down (dorsomedial prefrontal, temporal junction and temporal pole) pattern of activation.

Among PTSD imaging studies that have considered the perception of different facial expressions of emotion, only one study focused on an IPV-PTSD sample (Fonzo et al., 2010). This study found that IPV-PTSD patients displayed greater activation in the dorsal ACC and mPFC when they performed an emotional face-matching task for male compared with female targets. Their ventral ACC (vACC) activation was decreased in this condition—an effect that did not arise in controls. This suggested that female experience of male-perpetrated
violence may lead to alternative neural processing of male–female interaction.

Given the particular importance of intimate-partner violence among women with IPV-PTSD, it is important to go beyond static stimuli and to consider dynamic male–female interactions. Women with IPV-PTSD may have a specific reaction that is particularly attuned to cues for male aggression. These cues are often manifested as non-verbal dynamic gestures that intimidate, and that are unpredictable and crescendoing in intensity so as to suggest escalation of threat or impending violence. Thus, a film stimulus that reflects the interplay of human interaction and emotion is compelling for individuals suffering from IPV-PTSD. Therefore, this study tested how women with male-perpetrated IPV-PTSD differed in their brain activation from HC when exposed to motion-picture scenes of male–female interactions of differing emotional content. We used video stimuli of neutral, menacing and prosocial interactions. These stimuli were selected with the goal of extending the validity of previous findings on emotion perception and regulation in IPV-PTSD; they were specifically chosen because video stimuli displaying menacing male–female interactions might function as a traumatic reminder, thereby, interfering with emotion and arousal regulation.

We were interested in responses to scenes that depicted men intending to do harm to women (menacing scenes) compared with positively valenced high-arousal male–female interactions (prosocial/romantic scenes). We thus hypothesized that when watching menacing as compared with prosocial scenes, women with IPV-PTSD compared with HC would show greater activation of limbic system structures, including dACC (Burgdorf and Panksepp, 2006; Etkin and Wager, 2007; Hayes et al., 2012). This would echo prior results in response to still images of negative vs positive affective valence ( Fonzo et al., 2010).

Second, we wanted to know whether there would be a more generalized emotion-processing deficit related to IPV-PTSD. For an individual who has repeatedly experienced IPV, the interpretation of emotional communication may be negatively biased (Plana et al., 2014). Individuals suffering from IPV-PTSD may misread emotional communication in high-arousal male–female interactions regardless of whether the scene is positively (i.e. prosocial/romantic scene) or negatively (i.e. menacing scene) valenced. This misreading is linked to their hypervigilance for and overestimation of the likelihood of aggression in high-arousal situations. Thus, some neural responses should differentiate between high-arousal (both menacing and prosocial scenes, regardless of their valence) vs low-arousal interactions (neutral scenes).

**METHOD**

**Participants**

**Recruitment.** Participants were recruited via flyers posted at the University of Geneva Hospitals and the University of Geneva as well as at community centers, daycares, schools and domestic violence agencies and shelters at which mothers would have access to the study information. This magnetic resonance imaging (MRI) study was nested within an ongoing study of interpersonal violence and intergenerational transmission of related trauma and psychopathology (Schechter and Rusconi, 2014). Thirty-nine mothers of young children (12–42 months of age) who were eligible for an MRI scan participated. Two participants were excluded from analysis due to excessive motion in the scanner. Of the remaining participants, 16 were diagnosed with IPV-PTSD (mean age = 32.3 years; s.d. = 6.5 years), 19 were HC (mean age = 34.5 years; s.d. = 5.6 years) and 5 mothers did not belong in either group (i.e. had subthreshold IPV-PTSD; mean age = 32.4; s.d. = 5.2 years). Results for these latter participants are thus not presented here. Groups did not differ significantly from each other with respect to age: F(2, 39) = 0.65, P = 0.526. All participants of the IPV-PTSD group had experienced traumatic life events (i.e. domestic violence) as adults, while 42% of HC had experienced at least one type of physical or sexual form of domestic violence.

**Diagnosis.** During an initial videotaped interview, which was part of the pre-MRI protocol, IPV-PTSD participants and HC underwent a variety of psychometrics including the Clinician Administered PTSD Scale (CAPS) (Blake et al., 1995) to assess lifetime PTSD and the Post-traumatic Symptom Checklist-short version (PCL-S) to assess current PTSD symptoms.

Participants were diagnosed as having IPV-PTSD if their CAPS score was ≥55 and their PCL-S score was ≥40, and as HC if their CAPS score was <30, and their PCL-S score was <25. If one of their scores was in between those values they were classified as subthreshold IPV-PTSD. All IPV-PTSD participants would also be diagnosed with PTSD by an experienced clinician, in accordance with the DSM-IV-TR (American Psychiatric Association, 2000).

Compared with HC (mean = 4.26; s.d. = 2.00), IPV-PTSD participants (mean = 6.07, s.d. = 2.19) had a significantly lower socioeconomic status (SES): r(32) = −2.51, P = 0.017. SES was assessed with the Geneva Sociodemographic Questionnaire (Sancho Rossignol et al., 2010) and measured by the scale endorsed by the Swiss Society of Neonatology and based on a paper by Largo et al. (1989).

**Procedure**

**Procedures for Visits Before MRI.** The pre-MRI protocol consisted of an hour-long screening plus two 2 h visits. The latter included structured and semi-structured clinical interviews and a behavioral protocol with participant mothers and children. Before their participation, mothers gave informed consent. The study procedure had been approved by the University of Geneva Hospital institutional review board in accordance with the Helsinki Declaration of Human Rights (World Medical Association, 1999).

**MRI Procedure.** Participants saw 23 movies in pseudorandomized order. After each movie, participants were asked to rate the valence of the predominant emotion that the movie elicited on a scale of 1 (very negative) to 7 (very positive) and then to rate the arousal level of that emotion again on a scale of 1 (no arousal) to 7 (maximum arousal). The time limit for those judgments was 4 s. Participants practiced the rating procedure before entering the MRI scanner.

After scanning, we asked participants whether they had previously seen the movies from which the excerpts were taken. To ensure that participants had actually looked at the stimuli, we also filmed participants’ eye gaze with an eye tracker (Eye-Trac 6, Applied Science Laboratories, Bedford, Massachusetts, USA) during the scan. Because of space limitations, image acquisition and preprocessing are described in the supplementary data.

**Stimuli**

Twenty-three silent 20 s video excerpts that displayed male–female interactions were extracted from feature films. These excerpts were grouped into three conditions: eight excerpts displayed menace and high levels of negative affect, eight displayed prosocial/romantic interaction and moderately to highly positive affect and seven displayed neutral affect. The categorization of those excerpts was done by an unpublished rating study, the details of which can be found in the supplementary data.

**Hypothesis-driven analyses**

To verify whether there were any differences in how the two groups judged the arousal and valence of the respective movies, we performed
significant group within the IPV-PTSD group. Similarly, for all clusters that had revealed correlation coefficient of IPV-PTSD symptom severity with the continuous relationship of PTSD severity within the IPV-PTSD group. For all clusters revealing a related effects additionally showed continuous changes related to IPV-PTSD because it did not alter results significantly, SES was not included in vs vs PTSD severity vs PTSD and emotional human interactions SCAN (2015) 647

Behavioral ratings

An ANOVA comparing IPV-PTSD and HC groups, as to their appraisal of emotional valence evoked by the film stimuli resulted in a significant effect of film condition \( F(2, 30) = 120.1, P < 0.001 \). Results were similar to those of the aforementioned validation study in that prosocial scenes were rated as having more positive valence followed by neutral scenes. Menacing scenes were rated as having the most negative valence. There was no significant main effect of group \( F(1, 31) = 2.3, P = 0.137 \) or group \( \times \) film-condition interaction \( F(2, 30) = 1.0, P = 0.371 \).

An ANOVA comparing IPV-PTSD and HC participants with respect to appraisal of arousal also found an effect of film condition \( F(2, 30) = 37.4, P < 0.001 \). This was in accordance with results of the previous validation study as well, i.e. menacing scenes were the most arousing followed by prosocial and finally neutral stimuli, respectively. There was no significant main effect of group \( F(1, 31) = 0.5, P = 0.494 \) or group \( \times \) film-condition interaction \( F(2, 30) = 1.5, P = 0.241 \).

IPV-PTSD participants did not significantly differ from HC with respect to the number of movies they had previously seen (prosocial films seen previously: PTSD mean = 31%, HC mean = 28%, \( t(30) = −0.79, P = 0.49 \); neutral films seen previously: PTSD mean = 39%, HC mean = 32%, \( t(30) = −0.94, P = 0.36 \); menacing films seen previously: PTSD mean = 35%, HC mean = 29%, \( t(30) = −0.65, P = 0.52 \).

fmRI analysis

Main effects of group: The whole-brain analysis showed a main effect of group (IPV-PTSD participants compared with HC) in the right hippocampus. Post hoc analysis showed this to be mainly due to the IPV-PTSD participants’ greater activation response to arousing stimuli (both prosocial and menacing) compared with neutral stimuli (Table 1). HC showed higher activation than IPV-PTSD participants in a cluster that included the vmPFC and vACC. This effect was driven by an IPF-PTSD within-group contrast that showed significantly less activity during all emotional vs neutral scenes (Figure 1). Furthermore, HC displayed higher activation than the IPV-PTSD group in a cluster that included the left postcentral gyrus and superior parietal lobes, as well as in the right inferior parietal lobes, and in the left precentral gyrus. These differences were driven by the IPV-PTSD group, which showed deactivated activity during emotional scenes (i.e. lower activity than during neutral scenes). The reverse was observed in HC (Table 1).

Correlations of IPV-PTSD symptom severity with neural activation in the clusters showing a main effect of group—while mostly pointing into the expected direction—were almost altogether non-significant, the only exception concerning the cluster in the left precentral gyrus \( (r = −0.52, P = 0.045) \).

Group-by-condition interactions: The comparison of menacing with prosocial scenes revealed significant group differences in a cluster in the right insula as well as in a cluster that encompassed parts of the bilateral dorsolateral prefrontal cortex (dLPFC) and dorsomedial prefrontal cortex (dmPFC). These cluster differences were driven by the IPV-PTSD group having shown greater deactivation than HC when watching prosocial scenes and at the same time greater activation than HC when watching menacing scenes (see Table 1 and Figures 1 and 2). Another interaction within the right inferior parietal lobes was driven by activation in the HC when watching prosocial scenes; deactivation was observed in all other instances. Correlations of IPV-PTSD symptom severity with activations in all clusters revealing group-by-condition interactions failed to reach significance.

Results of the ROI analyses regarding amygdala activity did not reach significance either [right amygdala: menacing vs neutral condition, PTSD: mean = 0.179, s.d. = 0.222, HC: mean = 0.064, s.d. = 0.185; prosocial vs neutral condition: PTSD: mean = 0.147, s.d. = 0.238, HC: mean = 0.079, s.d. = 0.152; intercept: \( F(1, 33) = 14.812, P = 0.001 \); main effect of condition: \( F(1, 33) = 0.084, P = 0.774 \); main effect of group: \( F(1, 33) = 2.273, P = 0.141 \); interaction group \( \times \) condition: \( F(1, 33) = 0.63, P = 0.434 \); left amygdala: menacing vs neutral condition, PTSD: mean = 0.049, s.d. = 0.229,
Table 1 Regions that show significant differences in activation between mothers with IPV-PTSD and HC when watching scenes depicting menace and prosocial scenes combined (emotional scenes) contrasted with neutral scenes

<table>
<thead>
<tr>
<th>Cluster size</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>Region</th>
<th>This cluster also includes</th>
<th>Main effect group</th>
<th>Mean effect film condition</th>
<th>Tukey test on significant interactions</th>
<th>F(1, 33) P</th>
<th>F(1, 33) P</th>
<th>F(1, 33) P</th>
<th>P value; only values &lt; 0.05 given</th>
<th>R-value of the correlation of PTSD symptom severity and activation within IPV-PTSD group</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>30</td>
<td>-10</td>
<td>-17</td>
<td>Right hippocampus</td>
<td></td>
<td>IPV-PTSD &gt; controls</td>
<td>0.246 (0.25)</td>
<td>0.059 (0.12)</td>
<td>0.182 (0.25)</td>
<td>0.031 (0.14)</td>
<td>12.499 .001</td>
<td>0.612</td>
<td>0.40</td>
</tr>
<tr>
<td>51</td>
<td>-15</td>
<td>41</td>
<td>-14</td>
<td>Left vmPFC</td>
<td>ACC</td>
<td>Controls &gt; IPV-PTSD</td>
<td>-0.159 (0.12)</td>
<td>-0.005 (0.15)</td>
<td>-0.096 (0.19)</td>
<td>0.039 (0.14)</td>
<td>15.549 &lt;0.001</td>
<td>1.781</td>
<td>0.19</td>
</tr>
<tr>
<td>53</td>
<td>-33</td>
<td>-34</td>
<td>58</td>
<td>Left postcentral gyrus</td>
<td>Left SPL</td>
<td></td>
<td>-0.133 (0.19)</td>
<td>0.102 (0.24)</td>
<td>-0.162 (0.29)</td>
<td>0.198 (0.15)</td>
<td>15.948 &lt;0.001</td>
<td>0.003</td>
<td>0.50</td>
</tr>
<tr>
<td>33</td>
<td>-42</td>
<td>-49</td>
<td>46</td>
<td>Right IPL</td>
<td></td>
<td></td>
<td>-0.468 (0.24)</td>
<td>0.108 (0.23)</td>
<td>-0.07 (0.17)</td>
<td>0.039 (0.22)</td>
<td>13.453 .001</td>
<td>0.522</td>
<td>0.47</td>
</tr>
<tr>
<td>30</td>
<td>-60</td>
<td>-16</td>
<td>40</td>
<td>Left precentral gyrus</td>
<td></td>
<td></td>
<td>-0.154 (0.32)</td>
<td>0.418 (0.19)</td>
<td>-0.128 (0.20)</td>
<td>0.098 (0.15)</td>
<td>12.737 .001</td>
<td>0.847</td>
<td>0.36</td>
</tr>
<tr>
<td>105</td>
<td>30</td>
<td>-37</td>
<td>-29</td>
<td>Right cerebellum</td>
<td>anterior lobe</td>
<td></td>
<td>0.084 (0.21)</td>
<td>0.259 (0.21)</td>
<td>-0.187 (0.25)</td>
<td>0.315 (0.20)</td>
<td>19.475 &lt;0.001</td>
<td>17.725 &lt;0.001</td>
<td>2.466</td>
</tr>
</tbody>
</table>

Main effect group
IPV-PTSD > controls

Interaction group × film condition

(continued)
### Table 1 Continued

<table>
<thead>
<tr>
<th>Cluster</th>
<th>xyz</th>
<th>Region</th>
<th>This cluster also includes</th>
<th>Main effect film condition</th>
<th>Mean menace vs neutral</th>
<th>Mean prosocial vs neutral</th>
<th>Main effect group</th>
<th>Main effect film condition</th>
<th>Group × film-condition interaction</th>
<th>Tukey test on significant interactions</th>
<th>V-value of the correlation of PTSD symptoms severity and aduaction within IPV-PTSD group</th>
<th>P-value; only values &lt; 0.05 given</th>
</tr>
</thead>
<tbody>
<tr>
<td>501</td>
<td>-9</td>
<td>50 28</td>
<td>dmPFC</td>
<td></td>
<td>0.063 (0.17)</td>
<td>0.088 (0.17)</td>
<td>-0.137 (0.21)</td>
<td>0.092 (0.13)</td>
<td>3.235</td>
<td>0.081</td>
<td>37.042</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>1744</td>
<td>27</td>
<td>8 55</td>
<td>Right dIPFC</td>
<td></td>
<td>0.202 (0.22)</td>
<td>0.245 (0.26)</td>
<td>-0.040 (0.26)</td>
<td>0.031 (0.17)</td>
<td>0.731</td>
<td>0.399</td>
<td>50.965</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>32</td>
<td>3</td>
<td>17 22</td>
<td>dACC</td>
<td></td>
<td>0.090 (0.18)</td>
<td>0.058 (0.20)</td>
<td>-0.065 (0.22)</td>
<td>0.057 (0.15)</td>
<td>0.001</td>
<td>0.972</td>
<td>21.858</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>573</td>
<td>-51</td>
<td>35 -2</td>
<td>Left dACC</td>
<td></td>
<td>0.176 (0.20)</td>
<td>0.137 (0.22)</td>
<td>-0.028 (0.18)</td>
<td>0.015 (0.11)</td>
<td>0.218</td>
<td>0.644</td>
<td>31.856</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>16099</td>
<td>42</td>
<td>-76 19</td>
<td>Right Occipital lobe</td>
<td></td>
<td>0.633 (0.24)</td>
<td>0.659 (0.17)</td>
<td>0.042 (0.19)</td>
<td>0.080 (0.10)</td>
<td>0.497</td>
<td>0.486</td>
<td>376.080</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>667</td>
<td>-21</td>
<td>8 64</td>
<td>Left Superior frontal gyrus</td>
<td></td>
<td>0.262 (0.17)</td>
<td>0.125 (0.19)</td>
<td>-0.064 (0.25)</td>
<td>-0.060 (0.25)</td>
<td>1.028</td>
<td>0.318</td>
<td>42.579</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>176</td>
<td>-36</td>
<td>-22 19</td>
<td>Left insula</td>
<td></td>
<td>-0.385 (0.23)</td>
<td>-0.308 (0.26)</td>
<td>0.047 (0.15)</td>
<td>0.004 (0.15)</td>
<td>3.175</td>
<td>0.084</td>
<td>14.787</td>
<td>0.001</td>
</tr>
<tr>
<td>45</td>
<td>39</td>
<td>-19 19</td>
<td>Right insula</td>
<td></td>
<td>-0.153 (0.22)</td>
<td>-0.165 (0.13)</td>
<td>0.074 (0.16)</td>
<td>0.174 (0.17)</td>
<td>0.069</td>
<td>0.090</td>
<td>14.756</td>
<td>0.001</td>
</tr>
<tr>
<td>82</td>
<td>9</td>
<td>-7 28</td>
<td>(med) cingulate</td>
<td>Limbic lobe</td>
<td>-0.080 (0.15)</td>
<td>0.082 (0.22)</td>
<td>0.174 (0.27)</td>
<td>0.646 (0.40)</td>
<td>3.561</td>
<td>0.068</td>
<td>12.947</td>
<td>0.001</td>
</tr>
<tr>
<td>254</td>
<td>-6</td>
<td>-22 64</td>
<td>Paraacentral lobule</td>
<td>Right SMA;</td>
<td>-0.187 (0.24)</td>
<td>-0.187 (0.19)</td>
<td>-0.007 (0.19)</td>
<td>0.079 (0.15)</td>
<td>4.811</td>
<td>0.035</td>
<td>22.128</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>38</td>
<td>51</td>
<td>-28 1</td>
<td>Right STG</td>
<td></td>
<td>0.019 (0.19)</td>
<td>0.046 (0.20)</td>
<td>0.105 (0.15)</td>
<td>0.095 (0.13)</td>
<td>0.816</td>
<td>0.450</td>
<td>13.795</td>
<td>0.001</td>
</tr>
<tr>
<td>32</td>
<td>-45</td>
<td>-70 46</td>
<td>Left angular gyrus</td>
<td></td>
<td>-0.125 (0.19)</td>
<td>-0.125 (0.19)</td>
<td>-0.084 (0.15)</td>
<td>-0.022 (0.18)</td>
<td>3.296</td>
<td>0.079</td>
<td>17.902</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>40</td>
<td>45</td>
<td>-64 49</td>
<td>Right angular gyrus</td>
<td></td>
<td>-0.22 (0.25)</td>
<td>-0.186 (0.30)</td>
<td>0.031 (0.29)</td>
<td>0.063 (0.10)</td>
<td>0.063</td>
<td>0.084</td>
<td>15.896</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>36</td>
<td>60</td>
<td>-1 7</td>
<td>Right precentral gyrus</td>
<td></td>
<td>-0.112 (0.22)</td>
<td>-0.116 (0.27)</td>
<td>-0.037 (0.15)</td>
<td>0.090 (0.24)</td>
<td>0.466</td>
<td>0.500</td>
<td>9.878</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Legend for interaction tests: A = IPV-PTSD menacing-neutral vs IPV-PTSD prosocial-neutral; B = IPV-PTSD menacing-neutral vs HC menacing-neutral; C = IPV-PTSD menacing-neutral vs HC prosocial-neutral; D = IPV-PTSD prosocial-neutral vs HC menacing-neutral; E = IPV-PTSD prosocial-neutral vs HC prosocial-neutral. Abbreviations: ACC = Anterior Cingulate Cortex; dACC = dorsal Anterior Cingulate Cortex; dIPFC = dorsolateral Prefrontal Cortex; dmPFC = dorsomedial Prefrontal Cortex; IPL = Inferior Parietal Lobule; OFC = Orbitofrontal Cortex; PCG = Posterior Cingulate Cortex; SMA = Supplementary Motor Area; STG = Superior Temporal Gyrus; vmPFC = ventromedial Prefrontal Cortex.
HC: mean = 0.065, s.d. = 0.194; prosocial vs neutral condition: PTSD: mean = −0.026, s.d. = 0.306, HC: mean = 0.065, s.d. = 0.194; intercept: F(1, 33) = 2.005, P = 0.166; main effect of condition: F(1, 33) = 0.57, P = 0.45; main effect of group: F(1, 33) = 0.97, P = 0.332; interaction group × condition: F(1, 33) = 0.71, P = 0.405.

DISCUSSION
We studied whether women with IPV-PTSD differ from HC in their experience of specifically menacing and more general emotional human interactions.

Menacing compared with prosocial conditions
The dorsal areas of the mPFC and ACC showed a greater difference in activation in response to menacing vs pro-social scenes among IPV-PTSD participants as compared with HC; this difference in the dorsal mPFC and ACC was thus specific to the stimulus' valence. The dACC and dmPFC have been linked to appraisal of negatively biased emotion (Etkin et al., 2011), and more generally to cognitive strategies of emotion control (Kalisch, 2009). IPV-PTSD participants as compared with HC also had greater dlPFC activation when watching scenes depicting menacing vs prosocial scenes. The dlPFC plays a role in many executive functions and has been linked to emotion regulation of both positively and negatively valenced stimuli (Vinkikainen et al., 2010; Vrticka et al., 2012).

We speculate that IPV-PTSD subjects recruited the dlPFC in addition to the dmPFC and dACC in an effort to attain additional regulatory control so as to counteract the potential dysregulating effect of the menacing stimulus-as-stressor. Individuals suffering from IPV-PTSD likely activate the dorsal PFC (both medial and lateral) to downregulate their own arousal in response to the perception of violent social interactions. We can imagine that if such an arousal response has already been triggered by the film stimuli, in real-life situations, these individuals' cortical regulatory function may be strained by the increased demands of the situation to a level beyond that which can be regulated by the dorsal PFC. The latter would possibly impair the implementation of socially adaptive conflict-resolution strategies.

This study also found that the right posterior insula showed greater activation among IPV-PTSD participants when seeing menacing vs prosocial scenes. The latter is consistent with previous research, in which the insula showed increased activation among PTSD patients (Etkin and Wager, 2007; Hayes et al., 2012). The posterior insula has been demonstrated to be hyperactivated among PTSD participants on viewing emotionally negative scenes (Mazza et al., 2013). Consistent with this picture, insula activation has also been linked to flashbacks (Whalley et al., 2013) and pain sensitivity among PTSD subjects (Strigo et al., 2010).

More generally, the insula has been implicated in homeostasis involving salience and the default mode networks (Sripada et al., 2012). Even though the referenced study concentrated more on the anterior than posterior insula, our own finding seems consistent with it, suggesting that to women with IPV-PTSD, menacing male–female interactions are particularly threatening to the self-regulation of emotion and arousal.

Emotional compared with neutral scenes
In our study, IPV-PTSD participants compared with HC displayed lower activity in the vACC and vmPFC during all emotional (i.e. menacing and prosocial) scenes compared with neutral scenes. The ventral part of the mPFC and ACC has been linked to the regulation of limbic activation underlying emotional expression more generally (Etkin et al., 2011). This finding of corticolimbic dysregulation...
This emotion-processing deficit is also consistent with our observation that when IPV-PTSD participants watch emotional vs neutral scenes, they show greater activation of the right hippocampus compared with HC. This result extends previous research on PTSD (Etkin and Wager, 2007), in which connectivity of the posterior hippocampus to the default-mode network (i.e. posterior cingulate cortex, precuneus and pregenual ACC) (Buckner et al., 2008) has been shown to differentiate PTSD patients from HC and from generalized anxiety disorder patients (Chen and Etkin, 2013). The increased difference in hippocampal activity between emotional and neutral stimuli among IPV-PTSD participants may represent a higher level of salience of the former stimuli due to their association with traumatic memory traces (Brohawn et al., 2010). The rationale for this is that any kind of emotionally charged male–female interaction, regardless of its valence, may be generalized to signify a potential threat to women with male-perpetrated IPV-PTSD because many of them previously had intimate relationships with men who had later become perpetrators. We speculate that it is those with a history of IPV who experience greater situation specificity and thus do not generalize male behavior in the same way as women with IPV-PTSD do. The hippocampal activation noted may also play a role in IPV-PTSD women’s routine appraisal of their partners’ (or other male) behavior.

While the hippocampus played a significant role in this study, the amygdala did not. Our data show that both groups similarly activated the right amygdala while viewing both the menacing and prosocial film clips, while the left amygdala differed in no group between arousing and neutral scenes.

**Implications of our findings**

This study, having used human dynamic interactive stimuli, supports the generalizability of previous studies that used still-image stimuli and found that mPFC and ACC activation is consistent with corticolimbic dysregulation (Bryant et al., 2008; Kim et al., 2008; Fonzo et al., 2010, 2013). Our findings provide further evidence that those studies can indeed be related to how IPV-PTSD impacts the participant’s perception of human interactions.

We saw a clear functional dissociation of IPV-PTSD-associated processing of the dorsal compared with the ventral part of both the mPFC and the ACC. IPV-PTSD participants showed a specificity of emotional valence in the dorsal PFC; the more negative the valence of presented films, the more IPV-PTSD participants activated the dorsal PFC. In the vACC/vmPFC on the other hand, their activity was better predicted by arousal (Figure 1). We esteem that when an individual suffers from IPV-PTSD, the dorsal and ventral parts of the mPFC and ACC change their specific function with respect to emotion perception and regulation. This may be related to a previous study that found that vmPFC activation and alexithymia (emotional awareness) were positively correlated among HC, and negatively correlated among PTSD participants (Frewen et al., 2008), suggesting that functionality in the vmPFC changes in relation to socioemotional content. We speculate that changes of vmPFC/vACC function may occur owing to an increased need for cortico-limbic downregulation in IPV-PTSD participants.

We did not find a difference as to how the groups assessed the valence and arousal levels among the film scenes by post hoc questionnaires. Group differences in fMRI activation, despite the absence of group differences on subjective report, suggests that women with IPV-PTSD differ from HC in their neural functioning and processes of emotion perception and regulation in response to human interaction in ways that are beyond conscious experience. We also found that most of the effects related to group differences or group × film-condition interactions we observed were not accompanied by a significant correlation with IPV-PTSD symptom severity within the IPV-PTSD patients.
group. This may be task specific, as several previous studies showed evidence for continuous effects of PTSD on brain activation (Shin et al., 2004; Simmons et al., 2008; Fonzo et al., 2010; Moser et al., 2013).

Because our study was part of a wider mother–child study, our participants were all mothers of toddlers, the latter being dependent on their caretaker’s help for emotion regulation. The majority of IPV-PTSD mothers had a history of childhood abuse and subsequent partner violence that had been frequently witnessed by their children. Children of women who witnessed and/or experienced IPV as children, have an elevated risk of experiencing IPV as adults (Cannon et al., 2009; McIntyre and Widom, 2011). How group differences in dIPFC, mPFC, ACC and insula activation relates to maternal sensitivity is thus a research area that we are additionally pursuing. Maternal sensitivity is related to mothers’ appraisal of their child’s emotional communication (Schechter and Rusconi, 2014). Maternal sensitivity among IPV-PTSD mothers may be linked to their emotion perception in response to adult male–female interaction stimuli in the present experiment. This is consistent with a generalization of a fear-conditioned response to their toddlers’ developmentally determined emotion dysregulation (Schechter et al., 2012, 2014; Moser et al., 2013); such a response might be adaptive to a violent environment, but may come at the expense of parental sensitivity (Schechter et al., 2010; Sturge-Apple et al., 2012).

Limitations

Because a sizeable part of the control group had not experienced traumatic domestic violence, we cannot exclude the possibility, that some of the group differences found in our analyses were due to differences in previous life events rather than participants having or not having developed IPV-PTSD.

Finding continuous effects within the IPV-PTSD group was not a primary goal of the article. The fact that we did not find continuous effects of symptom severity within the IPV-PTSD group may be due to the fact that the chosen methods in this study were better suited to finding discrete (i.e. categorical) rather than continuous effects of IPV-PTSD.

CONCLUSION

This study has shown that women with IPV-PTSD have a characteristic pattern of activation, specifically involving the dmPFC, dIPFC and dACC when seeing scenes of menacing compared with prosocial male–female interaction. This pattern suggests that emotion perception and appraisal, which are essential to social interaction, are significantly affected among women with IPV-PTSD when film-stimuli signal menace. Additionally, emotional male–female interaction scenes regardless of the valence of the emotions in IPV-PTSD are related to heightened right hippocampal activation, suggesting higher personal relevance of these stimuli (Zhu et al., 2012). IPV-PTSD mothers compared with HC also tended to deactivate the VACC during all emotional scenes, independent of their valence. This finding supports the likelihood of a more general emotion regulation deficit among IPV-PTSD patients for moderate- to high-arousal interactions.

SUPPLEMENTARY DATA

Supplementary data are available at SCAN online.

Conflict of Interest

None declared.

REFERENCES


