Hyperresponsivity to Threat Stimuli in Domestic Violence Offenders: A Functional Magnetic Resonance Imaging Study

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Objective: While spouse abuse research has almost exclusively adopted a social perspective, an increasing body of imaging research is documenting neural contributions to violence.

Method: To test the hypothesis that wife batterers are hyperresponsive to threatening stimuli, echo-planar functional magnetic resonance imaging was employed to assess brain function of 10 male batterers and 13 male matched controls during viewing of 4 types of visual stimuli: neutral, positive affect, aggressive-threat, and aggression against women. The study was conducted from September 2005 to August 2006.

Results: Compared to controls, batterers showed significantly higher neural hyperresponsivity to the threat stimuli in the hippocampus, fusiform gyrus, posterior cingulate gyrus, thalamus, and occipital cortex ($p < .001$). To a lesser extent, they also showed increased activation to the aggression against women stimuli, particularly in the precuneus bilaterally ($p < .001$), and also increased activation to positive affect stimuli in right hemisphere orbitofrontal, anterior cingulate, and inferior parietal cortical regions ($p < .001$).

Conclusions: Findings indicate an affect-processing abnormality in wife batterers and suggest that hypersensitivity to mildly threatening affective provocations by their spouses may represent a neurobiological predisposition to spouse abuse in some men.

J Clin Psychiatry 2009;70(1):36–45

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The project was supported by the CRCG of The University of Hong Kong, General Research Fund of the Research Grant Council of Hong Kong, the Project Fund of Hong Kong Psychological Society (Division of Clinical Psychology), and the National Natural Science Foundation of China (30828012). The authors are indebted to the assistance and support from the Social Welfare Department, the Government of Hong Kong Special Administrative Region, China.

The authors report no additional financial or other relationships relevant to the subject of this article.

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While there has been extensive research on the effects of spouse abuse on its victims, there has been a relative dearth of research on the perpetrators of violence, and almost no research on neurobiological risk factors in particular. The dominant perspective is that physical abuse of the spouse is a rational, instrumental act aimed at regulation, control, and conflict resolution.[1] An alternative perspective is that there may be internal risk factors that play a significant role in predisposing some men to resort to violence for conflict resolution in the home. In this context, spouse abuse is listed as a V code (V61.12) in the *Diagnostic and Statistical Manual of Mental Disorders*, Fourth Edition, Text Revision.[2] Therefore, although not a clinical disorder as such, spouse abuse is a condition that is a focus of clinical attention. To date, studies of the correlates of spouse abuse have almost exclusively focused on demographic factors, prior exposure to violence, and psychopathology,[3] with very little research on neurobiological or neurocognitive factors.[4,5]

An increasing body of imaging research is documenting neurobiological impairments in violent and psychopathic individuals. One positron emission tomography (PET) study demonstrated that murderers have reduced prefrontal but increased occipital cortical glucose metabolism during a cognitive challenge task, as well as increased activation of the right thalamus, hippocampus, amygdala, and midbrain.[6] A review of imaging research in aggressive, psychopathic, and antisocial populations documents 5 independent studies showing cingulate functional and structural abnormalities, together with

12 independent findings of functional abnormalities to widespread temporal lobe regions and 3 studies showing parietal lobe impairments.[7] Brain impairments are hypothesized to be more characteristic of impulsively aggressive individuals compared to proactively (regulated) aggressive individuals. For example, prefrontal impairments have been found to be specific to impulsive, affective murderers, with normal prefrontal metabolism in predatory, controlled murderers.[8] Similarly, one recent functional magnetic resonance imaging (fMRI) study has shown that men with intermittent explosive disorder (reactive aggression) have increased amygdala but reduced orbitofrontal activity in response to angry faces.[9] A significant gap in this imaging literature on antisocial populations, however, is the distinct lack of studies on spouse abusers.

A relatively novel perspective developed by George et al.[10] suggests that perpetrators of domestic violence are hypersensitive to environmental stimuli, resulting in increased negative affect (fear and anxiety), poor emotion-regulation, and reacting out of proportion to the social context. Batterers are particularly thought to overreact to social scenarios that could be interpreted as threatening (e.g., slights, visual or verbal signs of disapproval), experience heightened physiologic reactivity to the perceived threatening stimulus, and react in a disproportionate defensive-aggression mode.[5] The only prior imaging study of spouse abusers utilized PET with a cognitive activation task (auditory continuous performance task) and observed reduced correlations between structures forming thalamo-cortical loops, with findings interpreted as reflecting poor control of fear-induced aggression.[5] This pioneering study is nevertheless limited by the use of a cognitive challenge task—affective stimuli linked to fear-induced aggression would provide a stronger test of the threat-hyperresponsivity hypothesis.

This study reports neural responses of batterers and controls to visual stimuli that differ in emotional content. Viewing emotionally arousing pictures activates the visual pathway consisting of the occipital, temporal, and parietal regions (for an example, see Stark et al.[11]), in particular, the secondary occipital, medial parietal precuneus, and the inferior temporal cortex.[12] Viewing disgust-inducing pictures also activates the occipital-parietal-temporal region.[11] Studies have also shown that negatively and positively valenced emotional pictures activate the amygdala.[13,14] Based on this conceptualization together with findings from prior studies of violent populations in general and impulsive-aggressive populations in particular, it was hypothesized that spouse abusers would show overresponsivity to threat stimuli in non–prefrontal cortical and subcortical regions, but to our knowledge there are no prior brain imaging studies on this group addressing this research question. It was predicted that batterers will be particularly overresponsive to aggressive-threat stimuli compared to controls. If this abnormality is selective, they would not show this same pattern of reactivity to positive affect stimuli. Stimuli depicting acts of violence toward women were also presented to assess for possible sensitization of the batterers to being selected on the basis of their spouse abuse status. If significant sensitization were present, neural reactivity would be strongest of all in this condition.

METHOD

Participants

Participants consisted of 10 male Chinese batterers and 13 male matched controls recruited in Hong Kong. Nine of the 10 batterers were known to the Family and Child Protective Service Units of the Social Welfare Department by referrals either from the Police Department or from the Integrated Family Service Centres because of their spouse battering. One batterer was recruited from the community according to his self-report of physically abusive acts to his wife as well as his score on the Revised Conflict Tactics Scales (CTS-2).[15] The 13 matched controls were a community sample who had not perpetrated during the course of their lives any act of physical abuse to their wives as reported in the CTS-2.[15] Subjects were excluded for any medical histories that may affect cognitive functioning, including drug or substance abuse. Ethical approval was obtained from The University of Hong Kong's Research Ethics Committee. Written informed consent was obtained from those subjects who volunteered for this fMRI study (conducted from September 2005 to August 2006) after participating in a prior behavioral study (S.-C.C., T.M.C.L., A.R., unpublished research report, July 2007).

As expected, the batterers were significantly less satisfied in their marital life and had a significantly higher divorce or separation rate compared to controls. Other demographic and cognitive variables, including age, years of education, years of marriage, unemployment rate, intellectual functioning, trait anger, impulsivity, and depression, were matched for the 2 groups (Table 1).

Picture-Viewing Tasks

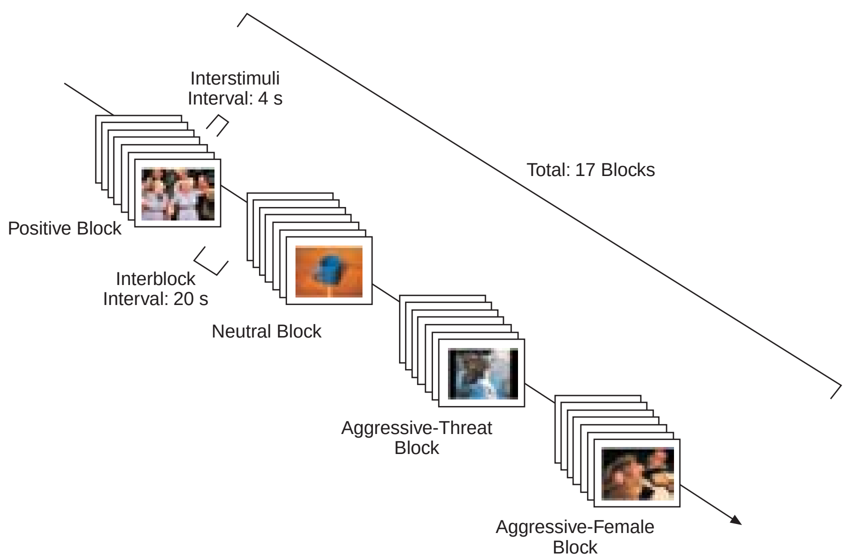
Affective pictures. The target pictures were selected from the International Affective Picture System, a standardized collection of visual pictures designed to evoke a neutral, a positive, or a negative emotional state.[21] Pictures were classified into neutral, positive, and violent conditions by a panel of 6 clinical psychologists blind to the purpose of this study. Fourteen neutral (N), 14 positive (P), and 14 violent pictures gaining the consensus of the whole panel were chosen. Among the 14 violent pictures, 7 involved a female victim and were designated as aggressive-female (AF) pictures. The 7 pictures depicting threats of aggression and lacking women were designated

Table 1. Demographic, Cognitive, and Psychological Characteristics of the Controls and the Batterers

Characteristic	Controls (N = 13)[a]	Batterers (N = 10)[a]	df	t or χ^2 Value	p Value
Demographic					
Age, y	47.08 (6.25)	43.80 (5.10)	21	t = 1.35	.192
Years of marriage	17.08 (7.80)	13.20 (6.12)	20	t = 1.28	.216
Unemployed, N (%)[b]	0 (0)	2 (22.2)	1	χ^2 = 3.18	.075
Separated or divorced, N (%)	0 (0)	3 (30.0)	1	χ^2 = 4.49	.034
Cognitive					
Intellectual functioning[c]	41.23 (12.74)	48.40 (10.92)	21	t = –1.42	.170
Years of education	9.85 (2.04)	10.70 (4.11)	21	t = –0.66	.520
Psychological					
Trait anger[d]	16.15 (3.13)	19.10 (5.28)	21	t = –1.67	.109
Depression[e]	8.15 (7.43)	8.89 (8.10)	20	t = –0.22	.828
Impulsivity[f]	65.46 (7.37)	66.90 (6.84)	21	t = –0.48	.637
Marital satisfaction[g]	101.69 (24.41)	62.11 (19.98)	20	t = 4.01	.001

[a]Values are expressed as mean (SD) except where noted.
[b]Employment data were available for only 9 batterers.
[c]Intellectual functioning was measured by Raven's Standard Progressive Matrices.[16]
[d]Trait anger was measured by the State-Trait Anger Expression Inventory.[17]
[e]Depression was measured by the Beck Depression Inventory.[18]
[f]Impulsivity was measured by the Barratt Impulsiveness Scale.[19]
[g]Marital satisfaction was measured by the Marital Adjustment Test.[20]

Figure 1. Schematic Representation of the Blocked Design Picture-Viewing Task That Consists of 8 Neutral, 3 Positive, 3 Aggressive-Threat, and 3 Aggressive-Female Picture Blocks[a]



[a]The participants pressed a button each time when the picture appeared on the screen.

as aggressive-threat pictures (AT). For example, as seen in Figure 1, the AT picture involves a man pointing a gun at an object not seen in the picture, but in the AF picture, a man is pointing his gun right at a female victim.

Design. The picture-viewing task was carried out in a block design. There were 17 blocks of pictures in total: 8 neutral (N), 3 positive (P), 3 aggressive-threat (AT) and 3 aggressive-female (AF) blocks. Positive, aggressive-threat, and aggressive-female blocks were presented in a pseudo-randomized order. They were preceded by a neutral block (N) in each block presentation in order to reduce any carry-over effect of emotion. The interblock interval was 20 seconds when a fixation cross was presented. There were 7 target pictures in each 28-second block, displayed in a randomized order. Pictures were presented for 4 seconds. To ensure that participants were focusing on the pictures, they were required to press a button when the picture appeared on the screen (see Figure 1).

Procedure

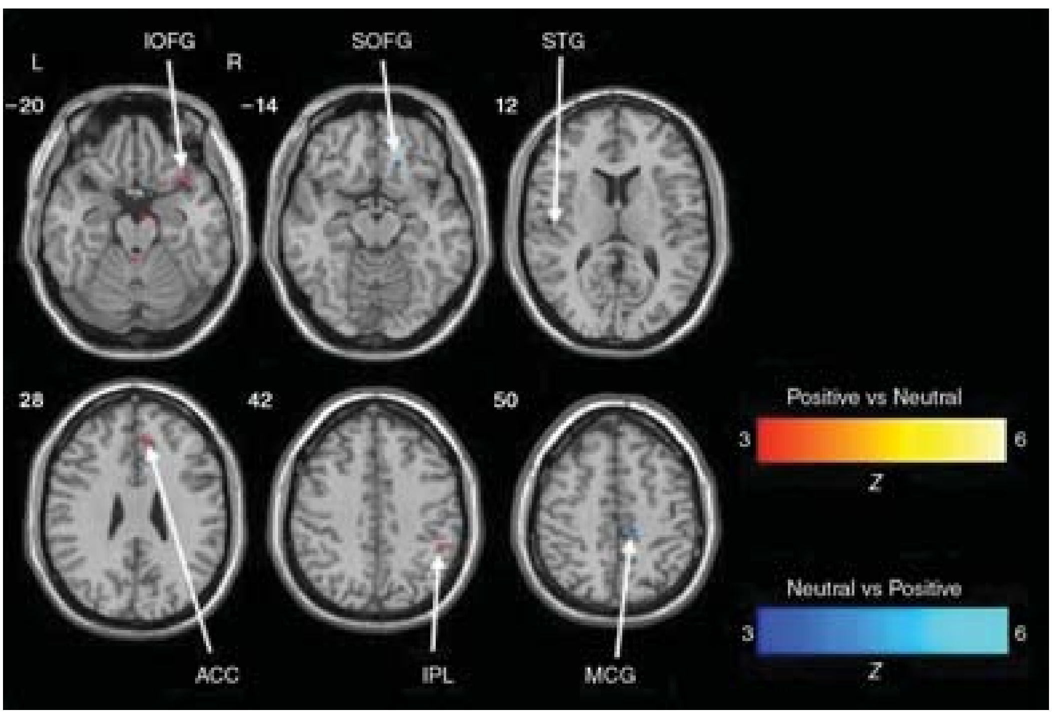
The neural activity of the subjects was monitored using a 3T Philips Achieva scanner. To ensure that the subjects were familiar with the task, a practice session was given using a short version of the picture-viewing task with a

Table 2. Between-Group Differences in Regional Activation for the Positive Versus Neutral Pictures (p < .001, minimum 10 contiguous voxels)

Comparison	BA	Side	Coordinate[a] x	y	z	Volume[b]	Z
Batterer versus control							
Inferior orbitofrontal gyrus	47	R	32	18	–20	15	3.63
Anterior cingulate cortex	32	R	6	38	28	16	3.54
Inferior parietal lobe	40	R	44	–42	42	10	3.66
Control versus batterer							
Superior orbitofrontal gyrus	11	R	16	30	–14	10	3.58
Middle cingulate gyrus	5	R	10	–28	50	17	3.59
Superior temporal gyrus	41	L	–48	–22	12	14	3.48

[a]The activation coordinates were labeled using the Automated Anatomical Labeling software,[24] which was implemented into the toolbox available for SPM2. All of these programs applied the standard MNI templates.
[b]Volume expressed as number of voxels; the size of each voxel = 8mm^3.
Abbreviations: BA = Brodmann's area; L = left hemisphere; R = right hemisphere; SMP2 = Statistical Parametric Mapping software, version 2.

Figure 2. Activation Maps of the Between-Group Comparison for Positive Versus Neutral Pictures Contrast[a]



[a]Height threshold: p < .001; extend threshold: 10 contiguous voxels. Red numbers at top left denote the z axis (in mm) of the displayed slice.
Abbreviations (anatomical labels): ACC = anterior cingulate cortex, IOFG = inferior orbitofrontal gyrus, IPL = inferior parietal lobe, L = left, MCG = middle cingulate gyrus, R = right, SOFG = superior orbitofrontal gyrus, STG = superior temporal gyrus.

different set of stimuli. After practice, the subject was briefed about the scanning procedures and experimental conditions to minimize his anxiety and enhance task performance. Following the briefing, the subject lay supine on the scanning table and was fitted with plastic ear-canal molds. The subject's head was immobilized by a tightly fitting, thermally molded, plastic facial mask that extended from the hairline to the chin. Target stimuli were rear-projected onto the screen. The subject was required to complete the picture-viewing task while scanning. These subjects also performed the Stroop tasks, findings of which are reported elsewhere.[22]

A single-shot T2*-weighted gradient echo-planar imaging (EPI) sequence was used for the fMRI scans (slice thickness = 4 mm with 1 mm gap, in-plane resolution = 1.8 mm × 1.8 mm, and TR/TE/θ = 4000 ms/30 ms/90°).

Table 3. Between-Group Differences in Regional Activation for the Aggressive-Threat Versus Neutral Pictures Contrast ($p < .001$, minimum 10 contiguous voxels)

Comparison: Batterer Versus Control	BA	Side	Coordinate[a] x	y	z	Volume[b]	Z
Postcentral gyrus	4	L	–16	–36	66	28	3.77
Superior parietal lobe	5	L	–18	–70	54	12	3.66
Superior temporal gyrus	22	L	–58	4	–2	15	3.61
Middle temporal gyrus	21	R	54	–16	–18	14	3.39
Inferior temporal gyrus	20	L	–46	–72	–6	18	3.50
Hippocampus	…	L	–26	–6	–20	41	3.75
Hippocampus	…	L	–20	–16	–14	10	3.49
Fusiform gyrus	37	L	–32	–74	–14	23	3.69
Lingual gyrus	17	L	–26	–84	–6	79	3.89
Middle occipital gyrus	18	R	30	–82	2	36	3.81
Middle occipital gyrus	18	L	–30	–64	30	150	4.04
Inferior occipital gyrus	19	R	44	–76	–4	17	3.57
Posterior cingulate gyrus	23	L	–8	–44	22	50	3.76
Thalamus	…	R	12	–30	2	97	3.77

[a]The activation coordinates were labeled using the Automated Anatomical Labeling software,[24] which was implemented into the toolbox available for SPM2. All of these programs applied the standard MNI templates.
[b]Volume expressed as number of voxels; the size of each voxel = $8 mm^3$.
Abbreviations: BA = Brodmann's area; L = left hemisphere; R = right hemisphere; SPM2 = Statistical Parametric Mapping software, version 2.
Symbol: … = not applicable.

The field-of-view was 230 mm × 230 mm, with an acquisition matrix of 128 × 128. Thirty-four contiguous slices oriented perpendicular to the sylvian fissures were acquired to cover the whole brain. The anatomical MRI was acquired using a T1-weighted, 3-dimensional, gradient-echo pulse sequence. This sequence provided high-resolution (1 mm × 1 mm × 1 mm) images of the entire brain.

Data Analysis

Matlab (The Math Works, Inc., Natick, Mass.) and Statistical Parametric Mapping software, version 2 (SPM2; Wellcome Department of Cognitive Neurology, London, United Kingdom) were used for image processing. Each subject's raw data were realigned to correct for head motion, and the mean EPI images of the individuals were coregistered with their T1 anatomical images. The T1 images were spatially normalized to the MNI (Montreal Neurological Institute) template, and the transformation parameters were applied to all EPI images of the same subject. During the normalization process, individual data were resliced into 2 mm isotropic voxels. The resulting images were then spatially smoothed (8 mm kernel). Individually preprocessed EPI images were entered into the regression analysis using the general linear model in SPM2.[23] The boxcar function of the experimental paradigm was convoluted with the canonical hemodynamic response function in SPM for constructing regressors.

Four regressors—neutral condition, positive condition, aggressive-threat condition, and aggressive-female condition—were constructed, with low-frequency noise in the signal removed prior to the regression analysis. After the regression analysis, 3 contrasts of positive versus neutral, aggressive-threat versus neutral, and aggressive-female versus neutral were generated for each subject. Individual contrast images were submitted to second-level t statistics using a random-effects model. To examine differences between the 2 groups, group data were thresholded with cluster correction at $p < .001$, cluster size > 10 voxels.

RESULTS

Positive Pictures

Batterers showed significantly greater activation than controls in the right inferior orbitofrontal gyrus, the right anterior cingulate gyrus, and right inferior parietal lobe. Controls relative to batterers showed stronger activation of the right superior orbitofrontal gyrus, the right middle cingulate gyrus, and the left superior temporal gyrus (Table 2 and Figure 2).

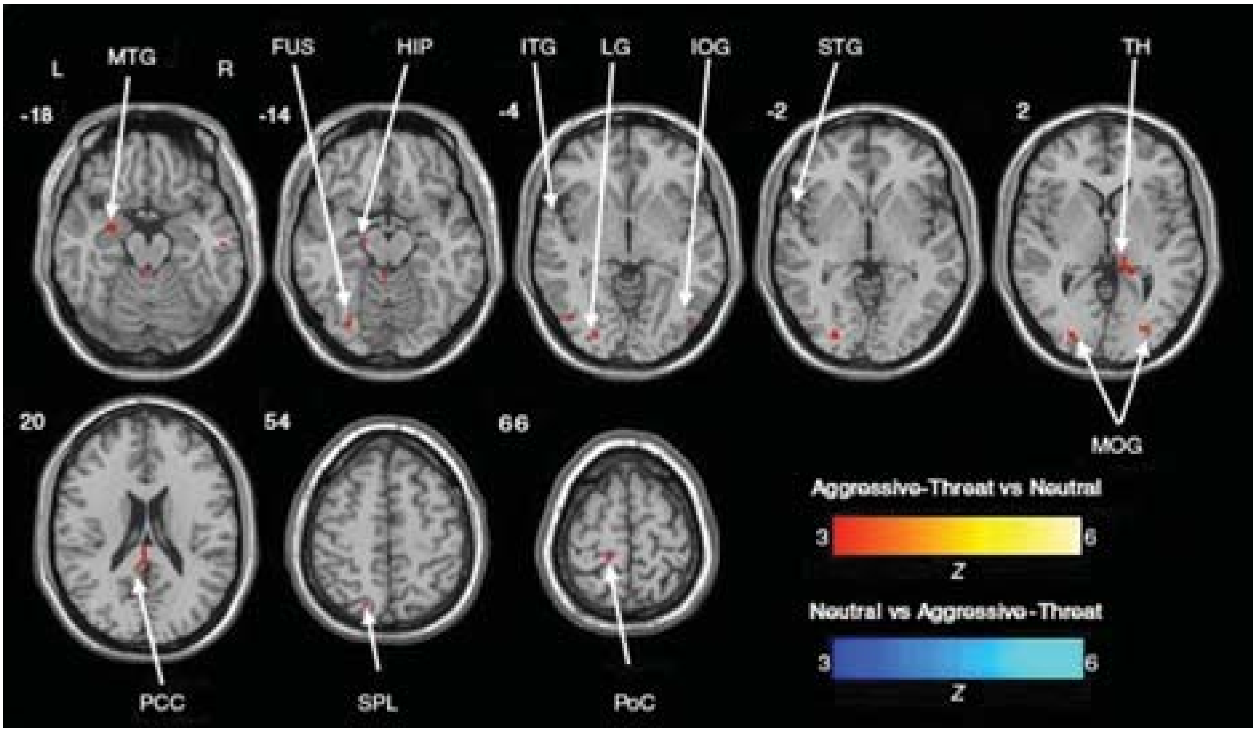
Aggressive-Threat Pictures

Batterers compared to controls showed stronger activity in the parietal cortex (postcentral gyrus, left superior parietal lobe), temporal cortex (left superior temporal gyrus, right middle temporal gyrus, left inferior temporal gyrus, bilateral hippocampus, left fusiform gyrus), occipital cortex (left lingual gyrus, bilateral middle occipital gyrus, right inferior occipital gyrus), left posterior cingulate gyrus, and right thalamus. Controls in contrast did not show stronger activation than batterers in *any* brain region (Table 3 and Figure 3).

Aggressive-Female Pictures (with a female victim)

Batterers compared to controls showed greater activation in the frontal cortex (right precentral gyrus), the parietal cortex (right supramarginal gyrus, bilateral

Figure 3. Activation Maps of the Between-Group Comparison for Aggressive-Threat Versus Neutral Pictures Contrast[a]



[a]Height threshold: $p < .001$; extend threshold: 10 contiguous voxels. Red numbers at top left denote the z axis (in mm) of the displayed slice.
Abbreviations (anatomical labels): FUS = fusiform gyrus, HIP = hippocampus, IOG = inferior occipital gyrus, ITG = inferior temporal gyrus, L = left, LG = lingual gyrus, MOG = middle occipital gyrus, MTG = middle temporal gyrus, PCC = posterior cingulate gyrus, PoC = postcentral gyrus, R = right, SPL = superior parietal lobe, STG = superior temporal gyrus, TH = thalamus.

precuneus), the temporal cortex (right middle temporal gyrus, left fusiform gyrus), and the occipital cortex (left superior occipital gyrus, right inferior occipital gyrus). Controls in contrast did not show stronger activation than batterers in any brain region (Table 4 and Figure 4).

DISCUSSION

The key finding of this study is that spouse abusers are hyperresponsive to threatening stimuli in widespread occipital, temporal, parietal, cingulate, and thalamic regions compared to controls. This hyperresponsivity was relatively specific to threatening stimuli and was not found for positive affect stimuli. Furthermore, hyperresponsivity was relatively greater for threatening stimuli than for stimuli depicting violence against women, suggesting that the overresponsivity to threat was not a function of sensitization of batterers to stimuli associated with their clinical batterer status. To the authors' knowledge, this study and our previous fMRI study[22] are the first studies of brain reactivity (using any physiologic method) of spouse abusers to affective stimuli and the first of any kind to demonstrate hyperreactivity to threatening stimuli. The findings challenge an exclusively social perspective on spouse abuse and suggest the possibility of a neurobiological predisposition to battering.

Viewing aggressive-threat pictures was associated with stronger activation of occipital-temporal-parietal regions in the batterers compared with the controls. Since the occipital-temporal and occipital-parietal areas are exceptionally sensitive to object and spatial recognition, respectively,[25,26] this finding may be interpreted in terms of greater visual arousal (in terms of object and spatial perception) when exposed to threatening stimuli. It is hypothesized that such neural oversensitivity to visually threatening stimuli may predispose some men toward reactive aggression (S.-C.C., T.M.C.L., A.R., unpublished research report, date) and consequent wife battering.

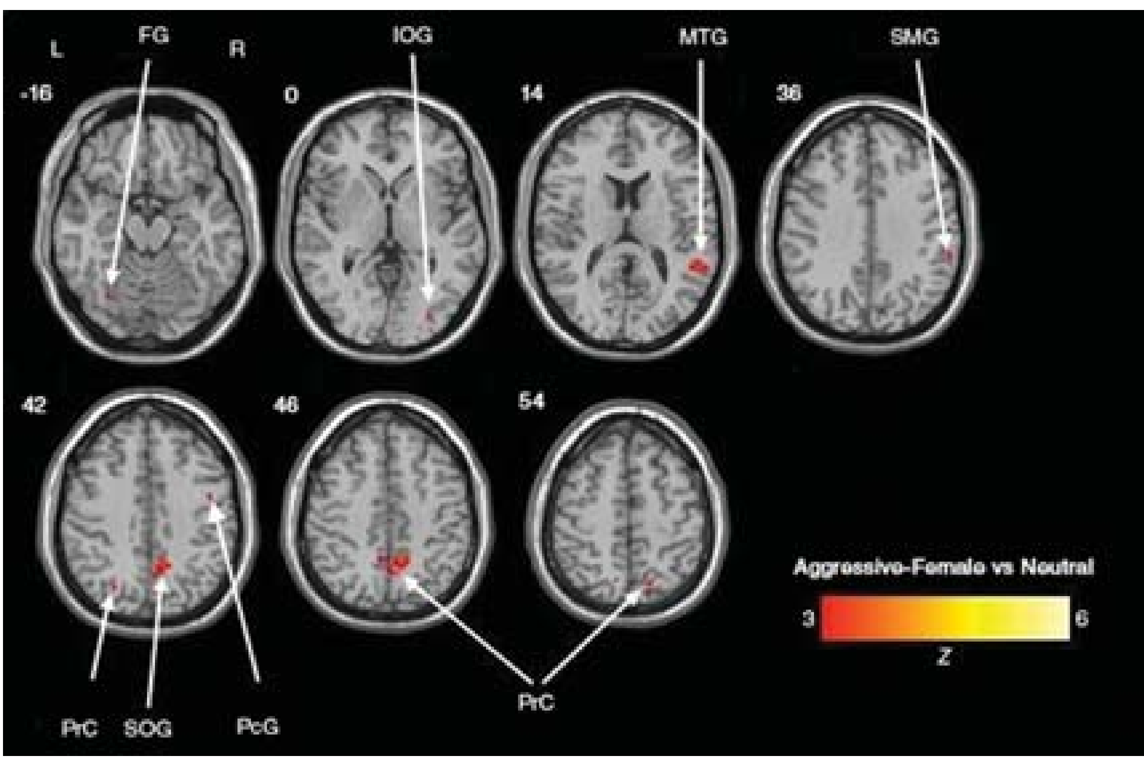
Increased activation to threat involved multiple regions, including the left posterior cingulate cortex and hippocampus bilaterally. The posterior cingulate is associated with the episodic retrieval of familiar places and objects[27] and, together with the hippocampus, is associated with episodic memory retrieval.[28] It is possible that when confronted with mildly threatening stimuli, spouse abusers are more likely to recollect prior episodes of conflictual social encounters that give rise to the anxiety and social discomfort documented in batterers by George et al.[10]

Table 4. Between-Group Differences in Regional Activation for the Aggressive-Female Versus Neutral Pictures Contrast ($p < .001$, minimum 10 contiguous voxels)

Comparison: Batterer Versus Control	BA	Side	Coordinates[a] x	y	z	Volume[b]	Z
Precentral gyrus	4	R	42	–2	42	10	3.63
Precentral gyrus	4	R	44	0	32	10	3.44
Supramarginal gyrus	40	R	58	–36	36	24	3.69
Precuneus	7	R	8	–50	46	207	4.39
Precuneus	7	R	12	–68	54	30	4.10
Precuneus	7	L	–12	–66	54	17	3.85
Middle temporal gyrus	21	R	54	–46	14	150	4.25
Fusiform gyrus	37	L	–36	–64	–16	15	3.36
Inferior occipital gyrus	18	R	28	–84	0	19	3.98
Superior occipital gyrus	19	L	–28	–70	42	14	3.67

[a]The activation coordinates were labeled using the Automated Anatomical Labeling software,[24] which was implemented into the toolbox available for SPM2. All of these programs applied the standard MNI templates.
[b]Volume expressed as number of voxels; the size of each voxel = $8 mm^3$.
Abbreviations: BA = Brodmann's area; L = left hemisphere; R = right hemisphere; SPM2 = Statistical Parametric Mapping software, version 2.

Figure 4. Activation Maps of the Between-Group Comparison for the Aggressive-Female Versus Neutral Pictures Contrast[a]



[a]Height threshold: $p < .001$; extend threshold: 10 contiguous voxels. Red numbers at top left denote the z axis (in mm) of the displayed slice.
Abbreviations (anatomical labels): FG = fusiform gyrus, IOG = inferior occipital gyrus, L = left, MTG = middle temporal gyrus, PcG = precentral gyrus, PrC = precuneus, R = right, SMG = supramarginal gyrus, SOG = superior occipital gyrus.

Not all hypotheses were supported in this study. In particular, increased amygdala activation to threatening stimuli in batterers, compared to controls, was predicted based on the theorizing of George et al.[10] that batterers experience heightened anxiety and fear out of proportion to the perceived threat, and which is amygdala-related. No such differences in amygdala activation were observed. One possible explanation of this discrepancy is that the experiment lacked sufficient ecological validity, and that future research using more personally relevant aggressive-threat stimuli would show amygdala hyperresponsivity. A second possibility is that any fear-conditioning abnormality in batterers is complex and may involve other structures involved in affective processing and fear conditioning. For example, fMRI research has indicated that the fusiform and inferior occipital gyri are functionally correlated with the amygdala when processing visual affective stimuli,[29–31] and both of these structures were more strongly activated in batterers when viewing threatening stimuli. Furthermore, thalamic input to the amygdala is critical for the processing and evaluation of sensory information, and this structure was also highly activated in batterers in the threat condition. Similarly, the hippocampus is centrally involved in contextual fear conditioning,[32] and both left and right hippocampal activity to threat was significantly higher in batterers. Consequently, while the lack of amygdala activation contradicts the proposition of George et al.[10] that batterers show dysregulated fear conditioning, a broader neurophysiological conceptualization of this perspective receives some support and suggests that further testing of this hypothesis using more ecologically valid stimuli is warranted.

Although overreactivity was greatest to threat stimuli, batterers compared to controls also showed greater activation in some regions when viewing aggressive pictures with female victims, with the strongest activation being found in the precuneus bilaterally. The precuneus has also been reported as a key station for episodic memory retrieval, in addition to its role in visual-spatial processing.[33] It may have been strongly activated in batterers because these female victim pictures evoked autobiographical memories of aggressive acts that they had perpetrated on their spouses. Aggression memory retrieval involving neural connectivity of the precuneus to the occipital gyri may have contributed to this increased visual alertness of the batterers to these stimuli, resulting in higher activation in the fusiform (face recognition) and other occipital and temporal regions.

While our use of affective stimuli linked to fear-induced aggression attempted to increase ecological validity and thereby yield a better test of the threat-hyperresponsivity hypothesis of spouse abuse, an important question concerns whether the overactivation to threat stimuli could be attributed to batterers being sensitized to female stimuli due to their batterer recruitment status. While this counter-hypothesis could explain some or even all of the activation found to aggressive pictures with female victims, it cannot easily explain the increased activation found to (nonfemale) threat stimuli in batterers in brain regions that were *not* activated in the female threat condition and which included multiple regions (superior and inferior temporal gyri, posterior cingulate, superior parietal lobe, hippocampus, thalamus, lingual gyrus, postcentral gyrus) and which encompassed 536 voxels (8 mm^3). In contrast, only 3 regions (middle temporal, inferior occipital, and fusiform) that were overactivated in batterers to the (nonfemale) threat stimuli were also overactivated in conditions depicting aggression against women, encompassing only 54 voxels. Instead, findings suggest a nonartifactual hyperreactivity to threatening stimuli in batterers.

While group difference on positive affect stimuli were less pronounced compared to threat stimuli, these more modest differences provide some further evidence of an affect-processing abnormality in spouse abusers that cannot be easily explained in terms of a sensitization counter-hypothesis. Batterers compared to controls showed *reduced* activation of the left superior temporal gyrus, the right middle cingulate gyrus, and the right superior orbitofrontal gyrus, but significantly *greater* activation in the right inferior parietal lobe, the right anterior cingulate gyrus, and the right inferior orbitofrontal gyrus. Two tentative conclusions may be drawn from these findings. First, while group differences are present on positive affect stimuli, they are not as extensive as the differences to threat stimuli and indicate that the group differences to threat stimuli were the most distinctive processing abnormality in batterers. While activation to threat stimuli was exclusively found in multiple regions in batterers (with controls never showing *increased* activation compared to batterers), for positive affect stimuli, *each* group showed increased activation in 3 regions. Second, while abnormalities tended to be more subtle for positive stimuli (representing slightly different regional activation within orbitofrontal and cingulate areas in the 2 groups), they nevertheless indicate that batterers process positive affect stimuli differently than controls. This suggests that batterers may have a more broad-ranging affective disturbance that encompasses their appraisal of positive affect events. Nevertheless, this suggestion awaits further research that attempts to replicate these positive affect differences and relate them to the dysphoria that has been claimed in some spouse abusers.[10]

Any firm implications for new treatment approaches to spouse abusers based on these initial findings would be premature at this point in time. Nevertheless, if results ultimately prove to be robust, one possible future clinical implication is that treatment programs for the batterers could usefully focus on facilitating more appropriate encoding of aggressive, threatening stimuli. Meta-analyses on spouse abuse treatment programs (predicated on the assumption that spouse abuse stems from societal sanctioning of men's control over women) have shown that they are, at best, minimally effective in reducing spouse abuse.[4] Future programs incorporating a neurocognitive-affective component aimed at reconceptualizing mild threat stimuli, combined with treatments targeting psychosocial contributions to spouse abuse, may ultimately be more effective in reducing spouse abuse.

A more general conclusion from these findings is that any neurobiological explanation of "aggressive" behavior is likely to be complex, with different risk factors likely giving rise to different subpopulations of aggressive individuals. Psychopathic and antisocial individuals have traditionally been viewed as *hypo*responsive to emotional stimuli.[34–36] In contrast, groups defined in terms of aggressive behavior in particular are *hyper*responsive to aversive stimuli.[37] Patrick and Verona[38] have similarly concluded that increased physiologic reactivity in reactively aggressive individuals in actuality serves to prepare them for action in conflictual circumstances. A further level of complexity is that the functional neuroanatomy of aggression is unlikely to be traced to 1 or 2 dysfunctional brain regions, and more likely involves multiple dysfunctional neural systems.[39,7] The current findings, which observed significant group differences in multiple brain regions as a function of task condition, provide one illustration of this complexity, and challenge simplistic explanations of dysfunctional aggression.

It should be emphasized that the observation of neurophysiological correlates of spouse abuse neither establishes a causal association nor invalidates psychosocial contributions to spouse abuse. The sample size is modest and findings require replication and extension using larger samples that can explore subgroups of spouse abusers who may differ in affective responding.[40] Consequently, we caution against the generalization of the current findings to other populations of batterers; it is conceivable, for example, that a psychopathic-like subgroup of spouse abusers may conversely show an opposed pattern of *hypo*responsivity to threat stimuli.[4,41]

Also, data were collected when batterers were relatively emotionally calm and findings may not be generalized to situations in which they are emotionally volatile. Nevertheless, this fMRI study of spouse abuse observes an affect-processing abnormality in wife batterers and suggests that hypersensitivity to mildly threatening affective spousal gestures may represent a neurobiological predisposition to spouse abuse in at least some wife batterers.

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