Original Investigation

Neural Correlates of Recall of Life Events in Conversion Disorder

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IMPORTANCE Freud argued that in conversion disorder (CD) the affect attached to stressful memories is "repressed" and "converted" into physical symptoms, although this has never been subject to scientific study to our knowledge.

OBJECTIVE To examine the neural correlates of recall of life events judged to be of causal significance in CD.

DESIGN, SETTING, AND PARTICIPANTS Case-control study. Academic research setting among 12 patients with motor CD and 13 healthy control subjects.

MAIN OUTCOMES AND MEASURES Stressful life events were assessed using the Life Events and Difficulties Schedule and rated by a blinded panel for their likelihood to cause CD based on the threat posed and the extent to which subsequent illness might allow escape from some of their consequences (termed *escape*). Recall of those events (escape condition) was compared with recall of equally threatening control events from the same epoch (severe condition) in a functional magnetic resonance imaging task.

RESULTS Relative to controls, patients showed significantly increased left dorsolateral prefrontal cortex and decreased left hippocampus activity during the escape vs severe condition, accompanied by increased right supplementary motor area and temporoparietal junction activity. Relative to controls, patients failed to activate the right inferior frontal cortex during both conditions, and connectivity between amygdala and motor areas (supplementary motor area and cerebellum) was enhanced.

CONCLUSIONS AND RELEVANCE These data offer support for the notion that the way adverse events are processed cognitively can be associated with physical symptoms in CD. Abnormal emotion (dorsolateral prefrontal cortex and right inferior frontal cortex) and memory control (hippocampus) are associated with alterations in symptom-related motor planning and body schema (supplementary motor area and temporoparietal junction).

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Conversion disorder (CD), also known as hysteria, is by no means a historical entity, accounting for 16% of neurology outpatients.[1] Although current diagnostic criteria highlight the role of physical findings,[2] etiological models remain rooted in the past, particularly freudian models postulating the "repression" of psychological conflict and its "conversion" into physical dysfunction.[3] This view of CD as psychogenic remains popular,[4] but biological research has neglected the psychogenic aspect, focusing on the neurological symptoms. Functional magnetic resonance imaging (fMRI) studies of patients with motor CD have compared brain activity[5] during attempted, planned, or imagined movement in an affected limb in contrast to the unaffected or recovered limb; results are interpreted[6] as evidence of motor network dysfunction, but these do not link symptoms to the hypothesized antecedent psychological stressors.

There is consistent evidence for an association between childhood stressors (particularly sexual abuse) and CD[7] but less consistent evidence for the importance of psychological stressors at the time of symptom onset, which may in part be because of the methodological challenges of studying life events,[8] especially using self-report checklists. A rigorous and extensive method, the Life Events and Difficulties Schedule (LEDS),[9] has been developed to assess stressful life events in psychiatric populations and has been applied successfully to functional and somatoform disorders.[10,11] Freud[3] argued not only that the key events in CD were painful, leading to their being willfully ignored (or repressed), but also that subsequent illness invariably led to some benefit or "secondary gain" for the patient. The presence of secondary gain in CD has been confirmed by some

investigators,[12-15] and the LEDS allows an operationalized rating of this aspect of events.[11]

One potential contemporary model for freudian repression is the voluntary suppression of memory, demonstrated experimentally in healthy volunteers[16] using a think-no think paradigm. This suppression was associated with a brain activity network involving the dorsolateral prefrontal cortex (DLPFC) correlated with hippocampal deactivation,[17] and with the right inferior frontal cortex (rIFC) having a key role when suppressing emotional memories.[18] We hypothesized that an analogous process would be revealed during fMRI of the cued recall of life events considered of causal significance in CD.[19] We also set out to explore whether this process would be associated with activation in symptom-salient brain areas.

Methods

Participants

The study was approved by a London, England, research ethics committee (Bromley 07/H0805/33). After complete description of the study to the participants, written informed consent was obtained. Patients with *DSM-IV* sensory motor CD (onset within 24 months) were recruited from neurology and neuropsychiatry settings in South East London, with diagnoses established by a fully trained neuropsychiatrist after appropriate neurological exclusion. Age- and sex-matched control subjects were randomly recruited from a primary care clinic in the same area. Nonfluent English speakers and individuals with psychosis, major depression, bipolar affective disorder, or a comorbid neurological disorder were excluded. Recruitment continued until a sufficient number of participants with suitable events (see below) was obtained, namely, 12 patients (8 female; mean age, 38.1 years), and 13 control subjects (10 female; mean age, 36.2 years). We had to assess 42 patients before we concluded recruitment, although many of those excluded were for pragmatic reasons (eg, the potential presence of metal clips from a previous surgical procedure). One-third of each group was taking some medication, usually antidepressants or analgesics.

Life Events Assessment

The presence of psychological stressors was assessed using the LEDS,[20] a semistructured interview that covers a wide spectrum of stressful experiences. The LEDS has several advantages over self-report checklist measures, particularly for reducing the risk of recall bias. It is investigator based, and because a participant will be biased in the reporting of his or her experience, it uses a contextual measurement of meaning. In this approach, a panel of raters (S.A., T.R.N., T.J.C., A.S.D., and R.A.K.), blinded to whether they are dealing with a patient or control subject, makes a judgment of the likely effect of the event on an average person with the plans, biography, and circumstances of the participant but ignoring the participant's report of his or her reaction to the event at the time. Of course, the measure still depends on the accuracy of reporting the facts of the event, but the LEDS has been shown to have excellent psychometric properties,[9,21,22] including high levels of interrespondent agreement on the timing and nature of events in which a patient and close relative have been separately interviewed by different researchers[9] and high interrater reliability for the contextual ratings of meaning in studies of anxiety, depression, and physical illness.[11,23-25]

The panel for this study included neurologists (S.A.) and psychiatrists (T.R.N., T.J.C., A.S.D., and R.A.K.) with expertise in CD and in the use of the LEDS, who were trained on the contextual measures used. There were between 3 and 6 members present for each rating. First, a rating of the threat of events was made, on a scale of 1 to 4, reflecting the severity of the likely consequences of the event (a severe event was rated 1 or 2). Second, the panel rated the event's escape potential,[26] a refined version of secondary gain, defined as the extent to which a subsequent illness might reduce the effect or consequences of the stressor, affording a socially sanctioned means to avoid a difficult situation. For example, a spouse's sudden death would offer minimal escape potential because the individual's subsequently becoming ill would do little to alleviate the stressor; however, a partner threatening to break off a relationship would have substantial escape potential because the individual's becoming ill might prevent the partner's feeling able to abandon the individual when he or she was unwell. This escape component was blindly judged "as if the individual had developed CD," so that events concerning patients and controls could be rated identically. Our group has previously shown that such escape events are substantially more common in CD than among control subjects and that this becomes increasingly significant toward the time of symptom onset, supporting the causal significance.[26,27] The panel reached a consensus on events of likely causal significance based on the threat, escape, and proximity of the event to the illness (or the epoch end in controls). Participants who had both a severe escape event (referred to as the *escape event* hereafter) and at least 1 severe nonescape event (referred to as the *severe event* hereafter) underwent imaging.

Premorbid IQ was estimated with the National Adult Reading Test. Mood was assessed with the Hospital Anxiety and Depression Scale and memory with the Autobiographical Memory Inventory.

fMRI Task

Three weeks before imaging, a follow-up interview was conducted to obtain details of the severe and escape events, as well as of a third neutral event from the same epoch, to generate 72 length-matched statements (24 for each type of event). One-quarter of these were rendered incorrect by changing incidental facts to maximize immersive recall when later asked in the imaging system if true or false. Three blocks of 8 statements were presented in counterbalanced order between conditions (severe, escape, and neutral). Each block began with a 3-second header title. Each statement was shown for 11 seconds, for a total of 88 seconds per block, excluding the period of the header. Reaction times (RTs) for true or false responses (by a button press in the less symptomatic hand) were recorded. After each block, participants rated how upsetting the last 8 sentences had been by moving a cursor on a visual analog scale (VAS) (very upsetting was rated as 0, and not upset-

Table 1. Participant Characteristics, Psychopathology, and Memory Scores

Variable	Patients (n = 12)	Controls (n = 13)	*P* Value
Female sex, No. (%)	8 (67)	10 (77)	.67[a]
Age, mean (SD), y	38.10 (11.26)	36.20 (9.14)	.66[b]
Hospital Anxiety and Depression Scale, mean (SD)			
Depression score	11.00 (6.67)	5.77 (4.09)	.03[b]
Anxiety score	12.81 (6.24)	9.15 (3.67)	.09[b]
Estimated IQ on the National Adult Reading Test, mean (SD)	100.17 (13.78)	109.54 (12.70)	.09[c]
Autobiographical Memory Inventory, mean (SD)			
Semantic score	60.35 (2.85)	59.32 (4.60)	.51[c]
Episodic score	24.81 (4.26)	26.31 (1.31)	.24[c]

[a] Fisher exact test.
[b] *t* Test.
[c] Mann-Whitney test.

ting at all as 10). To minimize carryover effects, the order of presentation was pseudorandomized between participants.

Image Acquisition and Preprocessing

Magnetic resonance imaging was performed on a 3-T system (Signa HDX; GE Medical Systems) with an 8-channel radiofrequency coil. During the task, a temporal series of 291 gradient-recalled, echoplanar image volumes was acquired (repetition time/echo time of 3000/35 milliseconds, 14:33 minutes total, 49 near-axial sections, and 3.4 × 3.4 × 3.0 mm). A high-resolution echoplanar image (1.875 × 1.875 × 3.3 mm) was acquired for coregistration and normalization.

Data were processed using Statistical Parametric Mapping (SPM8; http://www.fil.ion.ucl.ac.uk/spm/) and adjusted for section timing, realigned to the first image of the first run, normalized to the Montreal Neurological Institute (MNI) atlas, and smoothed using an 8-mm gaussian kernel. To correct for movement artifacts, first-level analyses were performed using the SPM8 robust weighted least-squares tool.[28]

Statistical Analysis

Sex, age, IQ, mood, and memory scores were compared between groups using the Fisher exact test, unpaired *t* test, and Mann-Whitney test. Behavioral data were analyzed with the Kruskal-Wallis test and repeated-measures analysis of variance with condition (escape, severe, or neutral) as a within-group factor and group as a between-group factor using the Statistical Package for the Social Sciences (PASW Statistics 18.0; SPSS Inc).

Image Analysis

For each condition, a predicted blood oxygen level-dependent response to each block was modeled in SPM8 with a boxcar function based on the onset and duration of the block convolved with the hemodynamic response function. Because the neutral condition constituted our baseline, we computed the contrasts of escape-neutral and severe-neutral in the first-level analysis. In the second level, random-effects analysis, we compared the contrasts of the escape condition (escape-neutral) and severe condition (severe-neutral) from all 3 runs between patients with CD and healthy control subjects using a flexible factorial design. To obtain second-level within-group and between-group *z* scores, statistical maps were thresholded at a *z* score exceeding 2.3 (cluster-forming threshold), and a cluster-corrected familywise error correction threshold ($P < .05$) was calculated using gaussian random field theory.[29] We repeated the analysis using the Hospital Anxiety and Depression Scale scores as covariates to exclude confounding of group differences by depression and anxiety.

A whole-brain analysis was conducted using flexible factorial analysis of variance with condition as a within-group factor and group as a between-group factor. Regions of a priori interest, as discussed above, consisted of 6-mm-radius spheres around peak *x*, *y*, *z* coordinates of the left and right DLPFC (MNI −36, 38, 34 and 32, 38, 26, respectively) and rIFC (MNI 38, 24, 0) based on published findings,[17] and $P < .05$ (familywise error corrected) over the region of interest (ie, small-volume correction) was considered significant. We also conducted a psychophysiological interaction analysis based on a seed region identified in the whole-brain analysis to assess contextual modulation of connectivity.[30]

Results

Participant Characteristics

The patients were all symptomatic at the time of imaging, with lateralized motor deficits in 4 participants (2 left-sided and 2 right-sided) and bilateral deficits in 8 participants (5 paraparesis and 3 tetraparesis). The median duration of symptoms was 13.5 months (range, 3-36 months). Patients and controls did not differ in sex, age, estimated IQ, autobiographical memory, or anxiety scores, but depression scores were significantly higher in patients (mean, 11.0 of 21) than in controls (mean, 5.7 of 21) ($P = .03$) (**Table 1**).

Behavioral Findings

The mean true-false errors were low in all conditions (12.5% among patients and 11.7% among controls for the escape condition, 17% among patients and 12.2% among controls for the severe condition, and 12.5% among patients and 14.4% among controls for the neutral condition), with no significant effects of group or condition. The mean (SD) time elapsed from each event to the imaging day was not significantly different between groups and across conditions (15.4 [9.9] months among patients and 14.8 [13.0] months among controls for the es-

Table 2. Whole-Brain Analysis of Activation During Recall: Group × Condition Interaction [a]

Variable	Cluster Size, No. of Voxels	*t* Statistic	*z* Score	MNI Coordinates		
				x	y	z
Escape > severe condition						
Right supplementary motor area (BA 6)	1636	4.2	3.6	12	8	68
Right postcentral gyrus (BA 1)	...	3.9	3.4	30	42	72
Right postcentral gyrus (BA 4/3b)	...	3.5	3.1	28	34	54
Right superior temporal gyrus	674	4.2	3.5	52	44	20
Right angular gyrus (TPJ)	...	3.6	3.2	40	58	24
Right supramarginal gyrus (TPJ)	...	3.6	3.1	42	54	30
Escape < severe condition						
Left lingual gyrus	1369	4.8	3.9	26	46	−4
Left parahippocampal gyrus	...	4.7	3.9	22	44	0
Left hippocampus	...	2.9	2.7	28	42	2

Abbreviations: BA, Brodmann area; ellipsis, not applicable; MNI, Montreal Neurological Institute; TPJ, temporoparietal junction.

[a] Anatomical regions of peak activation in patients > controls showing significant clusters ($P < .05$, familywise error corrected).

cape condition, 20.3 [11.8] months among patients and 16.7 [11.4] months among controls for the severe condition, and 17.1 [7.1] months among patients and 15.8 [12.7] months among controls for the neutral condition).

Comparison of RTs across all conditions between patients and controls showed no main effect of group ($F_{1,23} = 0.38$, $P = .54$) and no group × condition interaction ($F_{2,37} = 0.64$, $P = .50$), but a significant main effect of condition was found ($F_{2,37} = 4.23$, $P = .03$; Greenhouse-Geisser corrected).[31] Post hoc analysis showed significantly longer mean (SD) RTs for escape events (3.14 [0.14] seconds) compared with neutral events (2.89 [0.13] seconds) ($P = .02$) across groups and a trend for longer mean (SD) RTs for severe events (3.07 [0.09] seconds) compared with neutral events (2.89 [0.13] seconds) ($P = .07$).

Subjective ratings of events (VAS scores) did not differ between groups ($F_{1,23} = 0.52$, $P = .47$), and there was no significant group × condition interaction ($F_{2,40} = 0.74$, $P = .47$). A significant main effect of condition was observed ($F_{2,40} = 41.63$, $P < .001$; Greenhouse-Geisser corrected), and post hoc analysis showed lower mean (SD) VAS scores (more upsetting) for escape events (3.3 [0.3]) compared with neutral events (5.9 [0.3]) ($P < .001$) and for severe events (2.7 [0.3]) compared with neutral events (5.9 [0.3]) ($P < .001$). Significantly higher mean (SD) VAS scores (less upsetting) for escape events (3.3 [0.3]) were found compared with severe events (2.7 [0.3]) ($P = .04$) across groups. Objective ratings of mean (SD) severity (LEDS threat scores, as judged by the panel) did not differ between escape events (1.56 [0.71]) and severe events (1.64 [0.49]) across groups ($P = .24$).

Imaging Findings

Whole-brain analysis of the group × condition interaction showed significantly increased activation in patients compared with controls during the escape-severe condition in 2 clusters (**Table 2** and **Figure 1**). The first was located in the right sensory motor cortex extending medially into the supplementary motor area (SMA). The second was located in the right superior temporal cortex extending anteriorly to the insula and posteriorly to the angular gyrus and supramarginal gyrus (temporoparietal junction [TPJ]). The opposite whole-brain contrast (severe-escape) revealed significantly decreased activation in a left temporo-occipital cluster, including the parahippocampal gyrus and the hippocampus, in patients compared with controls. No main effect of group or condition was detected. The analyses were repeated with depression and anxiety scores as covariates, without altering the results.

The hypothesis-driven analysis (a priori regions of interest) showed no main effect of group but demonstrated a significant main effect of condition in the left DLPFC, with greater activation (MNI −34, 36, 30; $P = .04$, familywise error corrected) during the escape condition compared with the severe condition across groups (**Figure 2**A). This effect was driven by the patients because the group × condition interaction revealed greater activation in the same area (Figure 2C) during the escape condition relative to controls. No significant results were found in the right DLPFC.

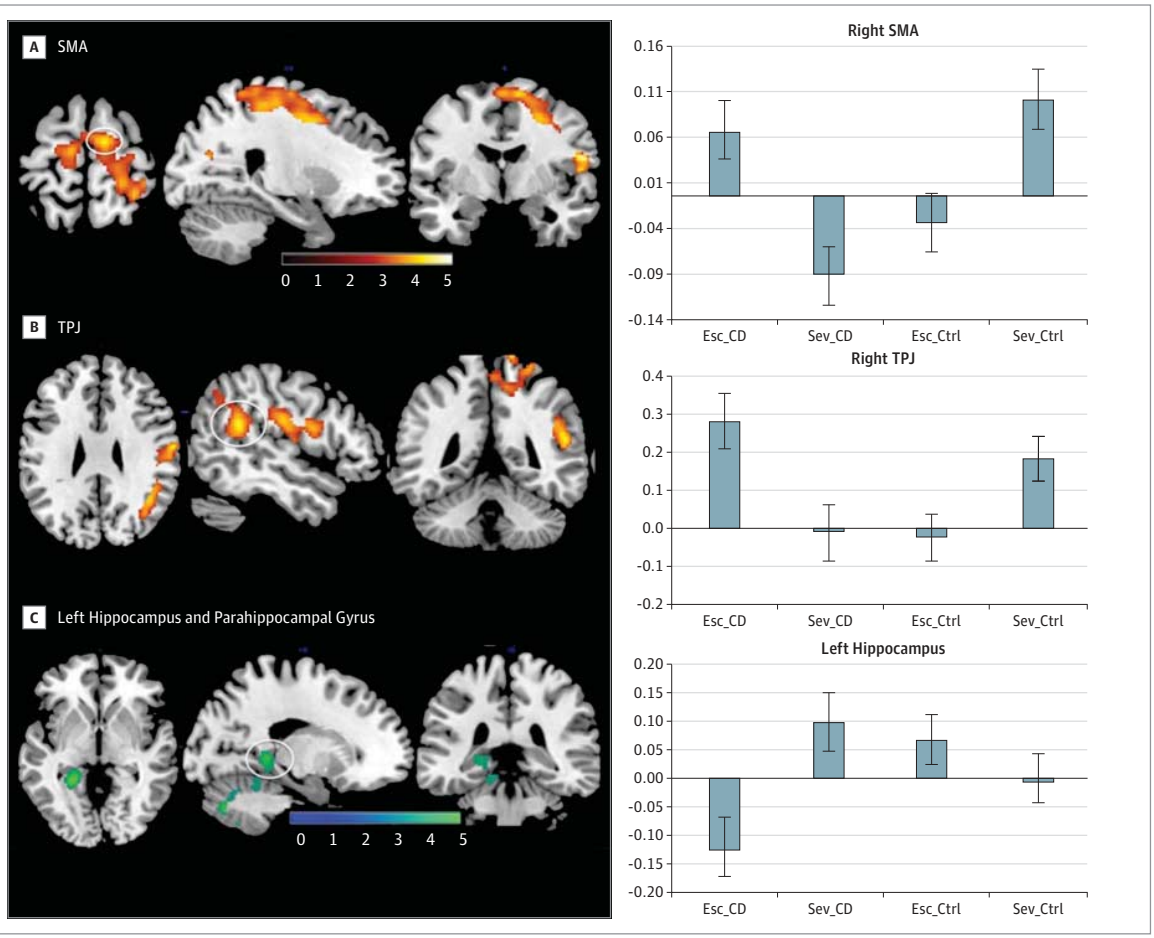
A main effect of group was significant in the rIFC. Patients showed significantly less activation (MNI 44, 28, 8; $P = .004$, familywise error corrected) than controls in this region across both conditions (Figure 2B).

Because the whole-brain interaction analysis revealed a significant peak of activation in the right SMA, we conducted a connectivity (psychophysiological interaction) analysis with the seed volume of interest as a 5-mm-radius sphere around this identified peak. This analysis revealed a significant main effect of group, with patients demonstrating greater connectivity between the right SMA and 2 significant clusters across both escape and severe conditions relative to controls. Those clusters included the left amygdala and the cerebellum and pons (**Figure 3**). No main effect of condition or group × condition interaction was found.

Discussion

The fMRI data during recall of autobiographical traumatic events revealed 4 main findings. First was increased left DLPFC activity during the escape condition relative to the severe condition in patients vs controls, together with decreased hippo-

Figure 1. Whole-Brain Analysis



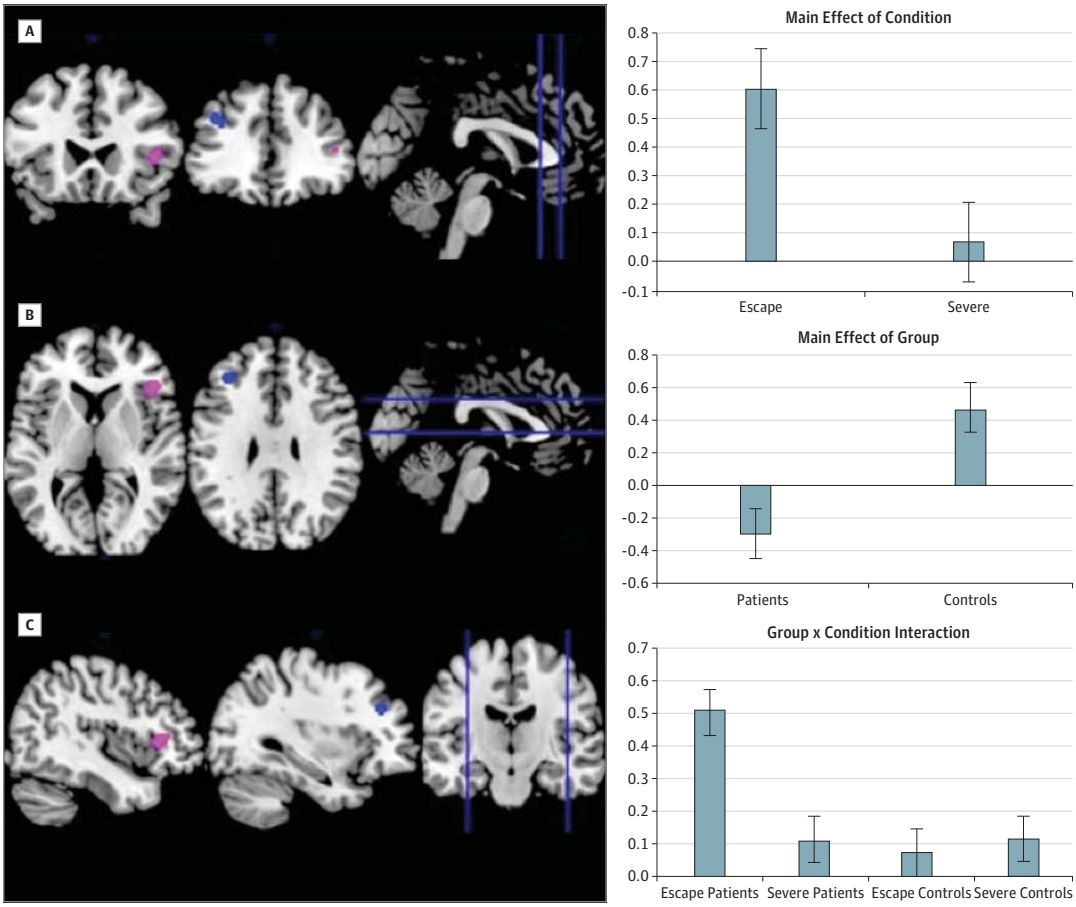
Statistical parametric maps showing significant clusters of activation ($P < .05$, familywise error and cluster corrected). Red indicates group × condition interaction in the contrast escape > severe in patients > controls showing peak activations in the right supplementary motor area (SMA) and the right temporoparietal junction (TPJ). Blue indicates group × condition interaction in the contrast escape < severe in patients > controls showing decreased activation in the left hippocampus and parahippocampal gyrus. On the right are contrast estimates (y-axis) at right SMA (Montreal Neurological Institute [MNI] 12, −8, 68), right TPJ (MNI 40, −58, 24), and left hippocampus (MNI −28, −42, 2) (as indicated in the circles on the left). CD indicates patients with conversion disorder; Ctrl, healthy controls; Esc, escape condition; and Sev, severe condition.

campal and parahippocampal activity, a pattern compatible with memory suppression. Second was increased right SMA and right TPJ activity, possibly representing symptom-salient areas. Third is decreased rIFC activity in patients relative to controls across both conditions, compatible with impaired emotional inhibition. Fourth is enhanced connectivity between right SMA and left amygdala in patients relative to controls across both conditions, suggesting abnormal limbic-motor interaction.

Suppression of Unwanted Memories: Role of the DLPFC

Escape events elicited significantly longer RTs than neutral events and were perceived as less upsetting than severe events, although both types of events were of matched objective threat. These findings are compatible with Freud's concept of repression, such that the painful aspects of the emotional stimuli presented during the escape condition are reduced at a cost of increased cognitive processing. The fMRI results confirmed differential neural processing of escape events, with increased left DLPFC during the escape condition relative to the severe condition. This is consistent with memory suppression, as in the think-no think paradigm, in which participants either think or avoid thinking of a cued stimulus.[17] Most important, this main effect of condition was largely driven by the patient group, and the results revealed a group × condition interaction in the same region of the left DLPFC, together with reduced brain activity in the left hippocampus and parahippocampal gyrus. This is additional evidence that patients process escape events in a manner akin to suppression,[17] possibly through the mechanism of "direct suppression."[32] In direct suppression, the conscious recollection of an unwanted memory (mediated by the hippocampus) is disrupted by top-down regulation (mediated by the DLFC) (both right[32] and left[17,33]); by contrast, in "thought substitution," the other principal mechanism, unwanted memories are replaced by competing

Figure 2. Region of A Priori Interest Analysis



Statistical parametric maps showing significant clusters of activation ($P < .05$, familywise error and small-volume corrected). Blue indicates left dorsolateral prefrontal cortex (DLPFC) activation. Purple indicates right inferior frontal cortex (rIFC) activation. A, Contrast estimates in left DLPFC (Montreal Neurological Institute [MNI] −34, 36, 30; $z = 2.75$; $P = .04$, familywise error corrected). B, Contrast estimates in rIFC (MNI 44, 28, 8; $z = 3.73$; $P = .004$, familywise error corrected). C, Contrast estimates in left DLPFC (MNI −32, 36, 30; $z = 2.77$; $P = .03$, familywise error corrected).

thoughts, mediated by the left caudal and midventral prefrontal cortex.[32]

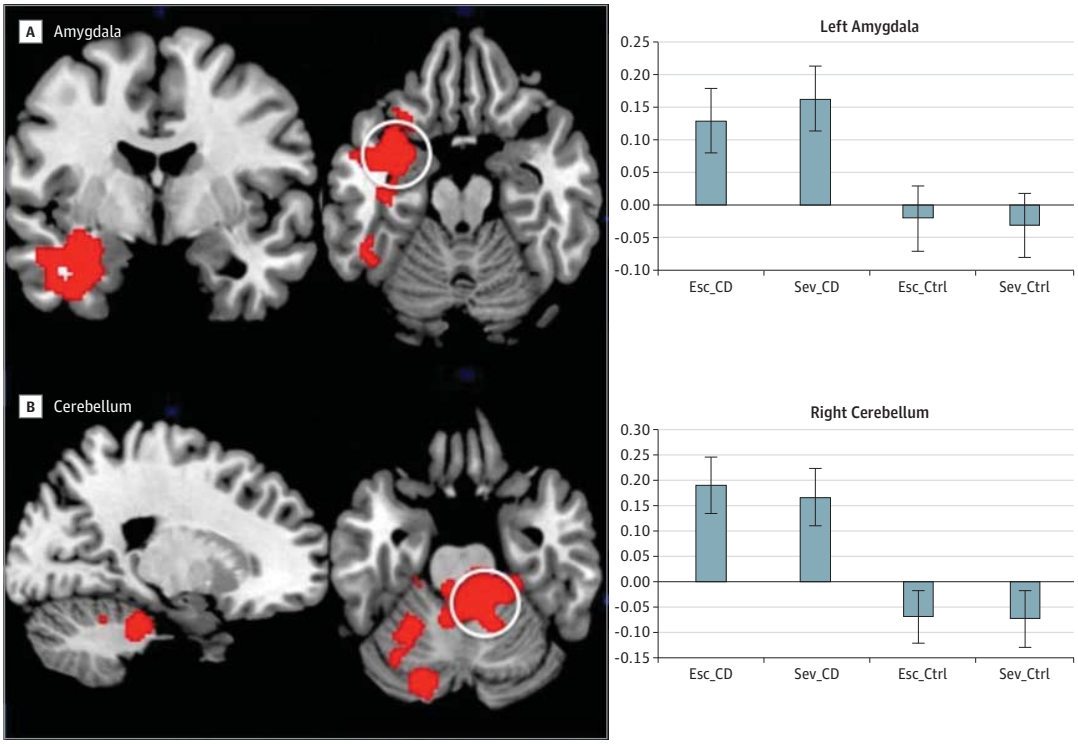
The involvement of the DLPFC in CD has been previously reported in motor CD[34-37] and interpreted as reflecting abnormal top-down influence of prefrontal regions on lower-order sensory motor functions. Although previous investigations have used motor tasks, our study is the first to date to link this region to a causally relevant task (recall of a traumatic event) and gives greater justification to an etiological interpretation, namely, that this prefrontal dysregulation arises from, or is prompted by, a painful memory.

Conversion Symptoms: Role of the TPJ and SMA

Alongside this activation pattern of memory suppression, the interaction analysis revealed increased activity in the right SMA and right TPJ in the whole-brain analysis. According to Freud's theory, the repression of memories comes at the cost of somatic symptoms, and this finding might reflect such a conversion into somatic symptoms.

The SMA is key to motor execution, and lesions in this region[38] have been associated with motor neglect, which shares some clinical similarities with functional conversion paresis. The SMA has a role in self-initiated action[39,40] and, most important, in inhibiting prepotent responses at conscious levels[41] and unconscious levels.[42] The increased SMA activity we found in patients may reflect an impaired ability to select the correct automatic motor plan at an unconscious level. Our study design did not permit us to conclude whether the increased right SMA activity represents a general process in CD or whether it is directly related to the symptom, and a subgroup analysis of the patients with left-sided (contralateral) symptoms was not feasible because of the few participants with hemiparesis in our sample. The right SMA has already been linked to CD[43]; enhanced connectivity between the right SMA and the right amygdala was found during an emotionally salient task,[43] and lower connectivity between the left SMA and bilateral DLPFC was found during a self-initiated motor task.[35]

Figure 3. Connectivity Analysis: Whole-Brain Psychophysiological Interaction Analysis



Statistical parametric maps of activation showing significant clusters ($P < .05$, cluster corrected; $\kappa > 1900$) for the main effect of group (patients > controls) across both escape and severe conditions. On the right are contrast estimates at the left amygdala (Montreal Neurological Institute [MNI] −28, 4, −30) and right cerebellum (MNI 22, −30, −28) (as indicated in the circles on the left). CD indicates patients with conversion disorder; Ctrl, healthy controls; Esc, escape condition; and Sev, severe condition.

The right TPJ is important in sensory integration and is operative in bodily self-location, self-consciousness, and self-person perspective,[44] having a key role in out-of-body experiences,[45] for example. In CD, it has been suggested that abnormal right TPJ activity is linked to abnormal multisensory integration of bodily schema.[46]

However, although this interaction effect was mainly driven by increased activity in the SMA and TPJ during the escape condition in patients, it was also partly driven by an opposite effect in controls, who showed greater activity during the severe condition (Figure 3). This challenges a specifically conversion interpretation of these clusters somewhat because healthy controls do not report functional symptoms during recall of severe events. At the least, it suggests that the activity is not sufficient in itself to produce such effects in patients and must be part of a wider process. This activity may represent a consequence, rather than a cause, of symptoms because most of our patients had long-standing sensorimotor difficulties, although it would in that case represent a consequence that was only present when events thought to be of causal significance were recalled.

Cognitive Control of Emotion: Role of the rIFC and Amygdala

We found decreased activity in the rIFC in patients relative to healthy controls across both escape and severe conditions. The rIFC is important for inhibiting prepotent responses among several modalities, including motor,[47] cognitive,[17] and possibly emotional.[48] The results of a study[18] of an emotional think-no think task suggest that the suppression of emotional memory involves 2 pathways with staggered phases: the first involves cognitive control by the rIFC over sensory components of memory representation, and the second involves cognitive control by the right middle frontal cortex over emotional components of memory representation. Our finding of decreased rIFC activity in patients relative to controls suggests that patients with CD fail in this physiological attempt to control, inhibit, or reappraise an emotional memory that requires early engagement of the rIFC.

Another clue to abnormal emotional regulation in CD comes from our connectivity analysis, which showed increased amygdala-SMA and cerebellum connectivity in patients across both conditions. This suggests that patients are more prone to emotional arousal when recalling traumatic events and that this arousal may modulate motor function. Both the SMA and the cerebellum have a role in movement planning, with the SMA involved in preparation[49] and the cerebellum involved in sensorimotor prediction.[50] A connection between amygdala activation and motor execution has been shown in healthy volunteers, suggesting a role for the amygdala in implementing protective behavior in threat situations,[51]

and has already been implicated in CD.[43] Moreover, recent evidence suggests a role for cerebellothalamocortical (including the SMA) loops in cognitive control,[52] and additional studies should explore these circuits in CD.

Strengths and Weaknesses

A strength of our study is the sample size compared with many imaging studies in CD and the relative symptom homogeneity of the patients, who all had weakness (with a preponderance of paraparesis) rather than abnormal movements or nonepileptic seizures. However, this limits the generalization of our findings to other subtypes of CDs.

Robustly assessing the response to autobiographical recall is challenging because this requires participants to reexperience a memory that cannot be verified. Most studies have used script-driven tasks to elicit autobiographical memories,[53] but we used a modified variant requiring true or false responses that has been found to generate equivalent reexperiencing[54] and allows monitoring of participants' compliance.

The process of identifying and rating of adverse life events is profoundly challenging, and although we used a validated method that minimizes recall bias from the participants and interviewer bias, the true nature of an individual's response to events and the possible causal role can never be known with certainty. Our classification of escape events is also novel, and further work to confirm the role in CD is required.

Conclusions

This study offers support for the notion that the way adverse events are cognitively processed can be associated with physical symptoms in CD. When a negative emotion is triggered by recall of a threatening event, it induces increased arousal, mediated by the amygdala.[55] This prompts cognitive control mechanisms mediated by the rIFC that act early in modulating and suppressing those aversive memories.[18] Our finding of enhanced connectivity between the amygdala and motor regions in patients with CD suggests that they have an abnormal response to emotional stress and that regulation by the rIFC is impaired. Furthermore, when subjected to a specific stressor (recall of an escape event), mechanisms to control the emotional content of the event are triggered that increase left DLPFC and decrease hippocampal and parahippocampal activation. This seemed to succeed in making the memory less upsetting, as measured by the VAS subjective scores, but at a cost because the escape events were also associated with abnormal activity in the TPJ and SMA, which may represent neural correlates of a patient's physical symptoms. This would fit with the Freud metaphor because the cognitive reappraisal of threatening reminiscences would be successful in attenuating the affect but lead to the conversion of this "energy" into physical symptoms. The fact that this pattern of brain activation is specifically induced by events of an escape nature (defined by the outcome being potentially influenced advantageously by the presence of an illness) also fits within phylogenetic or social psychological frameworks. We speculate that this mechanism might be a reflexive adaptation to threat but that in healthy individuals rapid regulation occurs. The reason why patients fail to engage their rIFC in inhibiting those primitive mechanisms still needs to be elucidated, as does the increased connectivity between emotion arousal regions (amygdala) and motor regions (SMA and cerebellum) in patients. It could be related to the illness condition itself and represent a state condition or may be a trait vulnerability that might derive from a developmental perturbation such as childhood abuse.[56]

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Acquisition of data: Aybek, Nicholson, Zelaya, Craig.
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