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ORIGINAL ARTICLE

Can we predict burnout severity from empathy-related brain activity?

S Tei[1,2,3], C Becker[4], R Kawada[1], J Fujino[1], KF Jankowski[5], G Sugihara[1], T Murai[1] and H Takahashi[1]

Empathy cultivates deeper interpersonal relationships and is important for socialization. However, frequent exposure to emotionally-demanding situations may put people at risk for burnout. Burnout has become a pervasive problem among medical professionals because occupational burnout may be highly sensitive to empathy levels. To better understand empathy-induced burnout among medical professionals, exploring the relationship between burnout severity and strength of empathy-related brain activity may be key. However, to our knowledge, this relationship has not yet been explored. We studied the relationship between self-reported burnout severity scores and psychological measures of empathic disposition, emotional dissonance and alexithymia in medical professionals to test two contradictory hypotheses: Burnout is explained by (1) 'compassion fatigue'; that is, individuals become emotionally over involved; and (2) 'emotional dissonance'; that is, a gap between felt and expressed emotion, together with reduced emotional regulation. Then, we tested whether increased or decreased empathy-related brain activity measured by fMRI was associated with burnout severity scores and psychological measures. The results showed that burnout severity of medical professionals is explained by 'reduced' empathy-related brain activity. Moreover, this reduced brain activity is correlated with stronger emotional dissonance and alexithymia scores and also greater empathic disposition. We speculate that reduced emotion recognition (that is, alexithymia) might potentially link with stronger emotional dissonance and greater burnout severity alongside empathy-related brain activity. In this view, greater empathic disposition in individuals with higher burnout levels might be due to greater difficulty identifying their own emotional reactions. Our study sheds new light on the ability to predict empathy-induced burnout.

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INTRODUCTION

Occupational burnout has become a pervasive problem in human services, particularly among medical professionals who are highly vulnerable to burnout.[1] Behavioral studies suggest a strong link between burnout and empathy.[2–6] Although empathic attitude and approach impact every aspect of medical care for patients and their families,[7,8] as many as 76% of medical professionals report symptoms of burnout that may lead to medical errors, substance abuse and even suicide.[9] Empathy often relates to a pro-social behavior and is essential to human life.[10] However, excessive empathy might be problematic because frequent exposure to emotionally-demanding situations may put individuals at risk of burnout.[2–6] Previous research has found that burnout severity is related to both increases and decreases in dispositional empathy scores.[11,12] There are two contradictory theories of burnout; while the conventional theory, 'compassion fatigue theory',[13] suggests that burnout relates to excessive empathy, the alternative theory, 'emotional dissonance theory',[14] suggests that burnout relates to reduced emotional regulation that causes a gap between felt and expressed emotions.

'Compassion fatigue theory' refers to one's exhaustion associated with caring for individuals who are experiencing significant emotional/physical pain and distress.[13] This theory suggests that more empathic medical professionals tend to be at greater risk of compassion fatigue and subsequent burnout.[15] Meanwhile, the 'emotional dissonance theory' denotes a conflict between experienced emotions and emotions expressed to conform to display rules.[16] Emotional dissonance may emerge when one's efforts to express socially-required, and in some instances occupationally-required, empathic emotions become too much of a burden and emotional responses become poorly regulated.[17] Related research has found that inexperienced nurses who hide negative emotion showed greater burnout symptoms than those who do not freely express their emotions.[18]

Also supporting the 'emotional dissonance theory', research suggests that burnout severity is related to difficulty in regulating negative arousal and difficulty describing/identifying one's own emotions (that is, alexithymia: reduced emotional awareness).[19] Indeed, emotional dissonance may be related to alexithymia because individuals with relatively greater alexithymic tendencies fail to match their experienced and expressed emotions. Despite having cognitive empathic abilities within the normal range, people with high levels of alexithymia may show reduced emotional reactions when observing others in pain, due to their limited emotional regulation abilities.[20,21] Therefore, it is possible that the 'emotional dissonance theory' could better explain burnout severity in medical professionals, in addition to the conventional 'compassion fatigue theory'.

Because occupational burnout in medical professionals may greatly depend on empathy levels,[2] the relationship between

[1]Department of Psychiatry, Kyoto University Graduate School of Medicine, Kyoto, Japan; [2]Institute of Applied Brain Sciences, Waseda University, Tokyo, Japan; [3]School of Human and Social Sciences, Department of Human Development and Sport sciences, Tokyo International University, Saitama, Japan; [4]Kokoro Research Center, Kyoto University, Kyoto, Japan and [5]Department of Psychology, University of Oregon, Eugene, OR, USA. Correspondence: Professor H Takahashi, Department of Psychiatry, Kyoto University Graduate School of Medicine, 54 Shogoin-Kawara-cho Sakyo-ku, Kyoto 606-8507, Japan.
E-mail: hidehiko@kuhp.kyoto-u.ac.jp
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burnout severity and strength of empathy-related brain activity may be the key to understanding empathy-induced burnout. However, to our knowledge, this relationship has not yet been explored. Meanwhile, some studies have shown differences in levels of empathy-related brain activity in medical professionals compared with healthy, nonmedical individuals, further speculating on the relationship between this brain activity and burnout. However, these previous studies did not implement psychological measures of burnout severity. Using functional magnetic resonance imaging (fMRI) and electroencephalography, these studies have revealed reduced empathy-related brain activity in physicians, compared with healthy controls, when viewing photographs of others experiencing physical pain.[22,23] This included activity in the anterior insula (AI), anterior cingulate cortex (ACC) and somatosensory cortex. Although burnout level was not directly examined, this reduced brain activity was speculated to reflect an adaptive strategy for resisting burnout.[23] Specifically, this reduced brain activity may enable physicians to address their patients' symptoms without becoming too emotionally involved. Importantly, however, reduced empathy-related brain activity was associated with greater empathic capabilities in physicians. Along with some other reports (described below), these findings suggest that empathy-related brain activity is not necessarily correlated with empathic capabilities. Although fMRI studies have demonstrated a positive correlation between strength of empathy-related brain activity during the experience of vicarious pain and Interpersonal Reactivity Index (IRI) empathy scores, for example,[7,24,25] a negative correlation has also been shown among individuals with psychopathy;[26] and healthy participants.[27–30]

According to a recent review, observation of others in pain induces an empathic response that mainly involves the AI, ACC, inferior frontal gyrus (IFG) and anterior medial cingulate cortex.[24] In addition, the temporoparietal junction (TPJ) may also have an important role in empathy-processing, including perspective taking,[31] in the patient–clinician relationship. For instance, in two fMRI experiments, physicians showed stronger TPJ activation when viewing a patient receiving pain compared with a no-pain condition.[7,22] We thus hypothesized that AI, ACC, IFG and TPJ activity would be correlated with self-reported burnout severity in medical professionals.

In this study, we explored the relationship between self-reported burnout severity scores and psychological measures of empathic disposition, emotional dissonance and alexithymia to test two contradictory hypotheses in medical professionals ('compassion fatigue theory' versus 'emotional dissonance theory'). Then, we tested whether increased or decreased empathy-related brain activity measured by fMRI was associated with burnout severity scores and psychological measures.

MATERIALS AND METHODS

Participants were 25 nurses in active service with less than 11 years of experience (20 females, aged 22–34, mean = 26.0, s.d. = 3.14). All participants had worked in nursing for at least 1 year. Participants were right-handed, according to the Edinburgh handedness inventory. Exclusion criteria included a history of neurological injury or disease, medical diseases or substance abuse. None of the participants met the DSM-IV criteria for any psychiatric disorders, as assessed by structured clinical interviews. Further, all participants underwent MRI scanning to rule out cerebral anatomic abnormalities. Participants were recruited via advertising from hospitals in Kyoto. All participants provided informed written consent and were paid for their participation. The institutional review board of Kyoto University approved the study.

Psychological measures

To avoid bias towards the concept of a relationship between burnout and empathy, participants completed the following four self-report measures after the fMRI scanning session. Burnout severity was assessed by the Maslach Burnout Inventory (MBI),[32] which includes two core dimensions: (1) 'emotional exhaustion' and (2) 'depersonalization'.[33] The 'emotional exhaustion' dimension measures feelings of being emotionally over-extended and exhausted by one's work. The 'depersonalization' dimension measures emotional detachment toward the recipients of one's care. In our study, the MBI served as a standardized measure for burnout and compassion fatigue because these two symptoms largely overlap.[19,34]

Empathetic disposition was assessed by the IRI,[35] which is one of the most widely used self-report measures of dispositional empathy. Following previous studies, the 'fantasy' subscale was excluded;[11] thus, three subscales were used: (1) 'perspective taking' (the tendency to cognitively adopt the perspective of another); (2) 'empathic concern' (the tendency to feel emotional concern for others); and (3) 'personal distress' (the tendency to experience negative feelings in response to the distress of others).

Emotional dissonance was assessed by the Emotion Work Requirements Scale (EWRS).[36] In this scale, higher scores imply a greater degree of emotional dissonance. In the current study, emotional dissonance was distinctly defined by EWRS scores. EWRS measures emotional deviance as a conflict between one's own emotional experience and the expression of emotions that are socially desired.[37] It is comprised of two subscales 'hide negative emotion' and 'display positive emotion' that trigger the conflict. Previous research suggests that burnout is related, in particular, to difficulty regulating negative emotions.[19] Thus, we only focused on measuring negative emotions and used the subscale 'hide negative emotion'.

An inability to identify and describe one's own emotions (alexithymia) was assessed by the Toronto Alexithymia Scale (TAS-20).[38] This measure includes the following subscales: (1) 'difficulty in identifying feelings'; (2) 'difficulty in describing feelings'; and (3) 'externally oriented thinking'. The relationships between burnout severity (MBI) and other psychological measures were examined by Pearson's r correlation analyses implemented in SPSS 21.0 (Chicago, IL, USA).

fMRI & data analysis

Video clips showing a hand in painful (pain) or nonpainful (no-pain) situations were presented to participants during the fMRI scanning. Participants were asked to passively look at the stimuli. The video clips consisted of images of other people's hands being harmed by different tools (that is, knife, hammer and icepick; 2.8 s duration each). For the no-pain condition, a similar setting to the pain condition was shown, but the tool being used was a soft brush. Each scanning session consisted of pain and no-pain conditions (six blocks each) presented in a randomized order. Each block contained six video clips and lasted a total of 16.8 s. A fixation cross was displayed for 14.4 s as a baseline condition and was inserted between each stimuli block (pain and no-pain; please see a schematic of the experimental paradigm in the Supplementary Information (Supplementary Figure S1)).

All participants participated in MRI scans using a 3-T scanner equipped with an eight-channel, phased array head coil (Trio, Siemens, Erlangen, Germany). Functional images were obtained in a T2*-weighted gradient echo-planar imaging sequence with the following parameters: TE/TR: 30/2,400 ms, flip angle = 90°, FOV = 192 × 192 mm, matrix = 64 × 64; 40 interleaved axial slices of 3-mm thickness without gaps; resolution = 3 mm cubic voxels. Imaging data were preprocessed and analyzed using SPM 8 (Wellcome Department of Imaging Neuroscience, London, UK). All functional brain volumes were realigned to the first volume, spatially normalized to a standard echo-planar imaging template, and finally smoothed using an 8-mm Gaussian kernel.

At the single subject level, we conducted *a t*-test for the contrast pain>no-pain using a general linear model. This was thresholded at $P = 0.05$ (two-tailed, family-wise error corrected: FWE). Then, at the group-level, we conducted region-of-interest (ROI)-based random effects analyses to investigate activity specifically recruited within pain-related empathy regions. A pain localizer was not used during the study; however, we used predefined ROIs informed by previous research, representing AI, IFG and ACC. These regions have been discussed as major affective components of the pain matrix, and commonly recruited during empathy-for-pain.[24] ROI analyses were performed using the PickAtlas toolbox within SPM 8, and parameter estimates were extracted from group-level clusters within the AI, IFG and ACC.[39] AI and IFG clusters were included in a single ROI because they are anatomically adjacent to each other and partly overlapped in the functional ROI implemented in PickAtlas. We also included an ROI representing the TPJ, which is crucially involved in physicians' brain response for empathy-for-pain.[7,22] As TPJ is not considered a part of the pain matrix, we purposely applied a more conservative analysis when investigating neural correlates of TPJ activity. That is, TPJ parameter estimates were extracted from the cluster obtained in the whole brain analysis. Furthermore, because it is still a matter of debate whether TPJ is a precisely identifiable cortical region,[40] we selected clusters that were anatomically overlapped with the TPJ x-y-z Talairach coordinates from a meta-analysis, centered at (±50 −55 25), specifically extending from the superior temporal sulcus to the inferior parietal lobe.[41,42] Following the conventional threshold,[43] clusters smaller than 10 voxels were not considered significant in our analyses. Furthermore, because there is no clear functional laterality regarding empathic processing, parameter estimates of ROI activity in the right and left hemispheres were averaged within each participant. Subsequently, correlation analyses were conducted on the basis of this averaged result. Using Pearson's *r* correlation analyses implemented in SPSS, parameter estimates of the pain>no-pain contrast were correlated with psychological measures.

After the scanning session, participants were asked to rate each of the video clips on the following: (1) intensity of distress (how much distress they felt from a first-person perspective); and (2) intensity of pain (objective rating of pain from a third-person perspective). Distress and pain were each rated on a 9-point Likert scale, ranging from no-distress/pain to the most extremely imaginable distress/pain. Video clips were shown in the same order as they had been seen during the fMRI scanning. The order of the two ratings was counterbalanced among participants. Subsequently, for each of the video stimuli, the difference between these two ratings (that is, distress minus pain score) was calculated and combined to give a sum score for all stimuli for each participant. This score was also used as a representation of emotional dissonance.

RESULTS

Psychological measures

There were statistically significant relationships between burnout severity (MBI) and other psychological measures (Table 1). Burnout severity (MBI) and dispositional empathy (IRI) showed a positive correlation. In addition, burnout severity showed a positive correlation with emotional dissonance (EWRS) and alexithymia (TAS). Specifically, 'emotional exhaustion' on the MBI showed a positive correlation with 'perspective taking (PT)' on IRI ($r=0.507$, $P=0.010$), 'hide negative emotion (HNE)' on the EWRS ($r=0.430$, $P=0.032$) and 'difficulty in identifying feelings (Dif)' on the TAS-20 ($r=0.637$, $P=0.001$).

fMRI data

Contrasting the strength of hemodynamic activity between pain and no-pain conditions, there were statistically significant differences within our defined ROIs. Table 2 shows the results of one-sample *t*-tests within the defined ROIs (that is, AI/IFG and TPJ), demonstrating higher activations in the pain condition relative to the no-pain condition. ACC activity was not examined because it did not meet our cluster threshold (only one voxel remained significant).

Table 2. Pain-related brain areas activated in response to painful video stimuli

Pain>no-pain area	*Talairach atlas x-y-z (mm)*	*T*	*Z*	*P (FWE)*	*Cluster k*
Lt AI/IFG	−42, 16, 0	7.80	6.24**	0.000	237
Lt AI/IFG	−42, 30, 16	6.67	5.58**	0.000	78
Lt AI/IFG	−48, 6, 32	6.33	5.37**	0.000	293
Rt AI/IFG	42, 28, 16	5.72	4.97**	0.001	417
Rt AI/IFG	34, 26, −4	5.39	4.74**	0.003	58
Lt TPJ	−56, −32, 32	8.54	6.63**	0.000	763
Rt TPJ	56, −34, 24	8.79	6.75**	0.000	762

Abbreviations: AI, anterior insula; FWE, family-wise error corrected; IFG, inferior frontal gyrus; Lt, left; Rt, right; TPJ, temporoparietal junction. $*P<0.05$, $**P<0.01$. The pain effect contrast was created by comparing the signal intensity during pain, compared with no-pain conditions.

Correlations between neural activity and behavioral measures

There were statistically significant correlations between hemodynamic activity associated with the pain>no-pain contrast and psychological scores. Neural activity in AI/IFG and TPJ showed negative correlations with burnout severity. Namely, AI/IFG and TPJ activity negatively correlated with 'emotional exhaustion' on the MBI ($r=-0.590$, $P=0.002$ and $r=-0.550$, $P=0.004$, respectively). Figures 1 and 2 show correlations between burnout severity and hemodynamic activity in AI/IFG and TPJ across all participants.

In addition, AI/IFG and TPJ activity showed significantly negative correlations with other psychological measures (that is, empathic disposition, emotional dissonance, alexithymia and the difference between distress and pain ratings; Table 3). Namely, AI/IFG and TPJ activity negatively correlated with 'perspective taking' on the IRI ($r=-0.524$, $P=0.007$ and $r=-0.431$, $P=0.031$, respectively); 'hide negative emotion' on the EWRS ($r=-0.528$, $P=0.007$ and $r=-0.504$, $P=0.010$, respectively); 'difficulty in identifying feelings' on the TAS-20 ($r=-0.399$, $P=0.048$ and $r=-0.581$, $P=0.002$, respectively); and the difference between post-ratings of distress and pain ($r=-0.419$, $P=0.037$ and $r=-0.464$, $P=0.020$, respectively). Furthermore, AI/IFG activity showed a negative correlation with 'empathic concern' on the IRI ($r=-0.432$, $P=0.031$), and TPJ activity showed a negative correlation with 'difficulty in describing feelings' on the TAS-20 ($r=-0.467$, $P=0.019$).

DISCUSSION

To our knowledge, this is the first study to investigate the neural correlates of empathy in relation to burnout in medical professionals. Burnout severity was associated with 'reduced' empathy-related brain activity. In the initial correlation analysis between

Table 1. Correlation between burnout severity and other psychological measures

	Empathy PT (IRI)	*Empathy EC (IRI)*	*Empathy PD (IRI)*	*Emotional dissonance HNE (EWRS)*	*Alexithymia Dif (TAS-20)*	*Alexithymia Ddf (TAS-20)*	*Alexithymia Eot (TAS-20)*
Burnout (MBI) Emotional exhaustion	0.507**	0.135	0.237	0.430*	0.637**	0.186	−0.141
Burnout (MBI) Depersonalization	0.387	−0.022	−0.104	0.305	0.199	−0.062	0.132

Abbreviations: MBI, Maslach Burnout Inventory; Ddf, difficulty in describing feelings; Dif, difficulty in identifying feelings; EC, empathic concern; Eot, externally oriented thinking (in Toronto Alexithymia Scale: TAS-20); EWRS, Emotion Work Requirements Scale to assess emotional dissonance; HNE, hide negative emotion; IRI, Interpersonal Reactivity Index; PD, personal distress; PT, perspective taking. $*P<0.05$, $**P<0.01$.

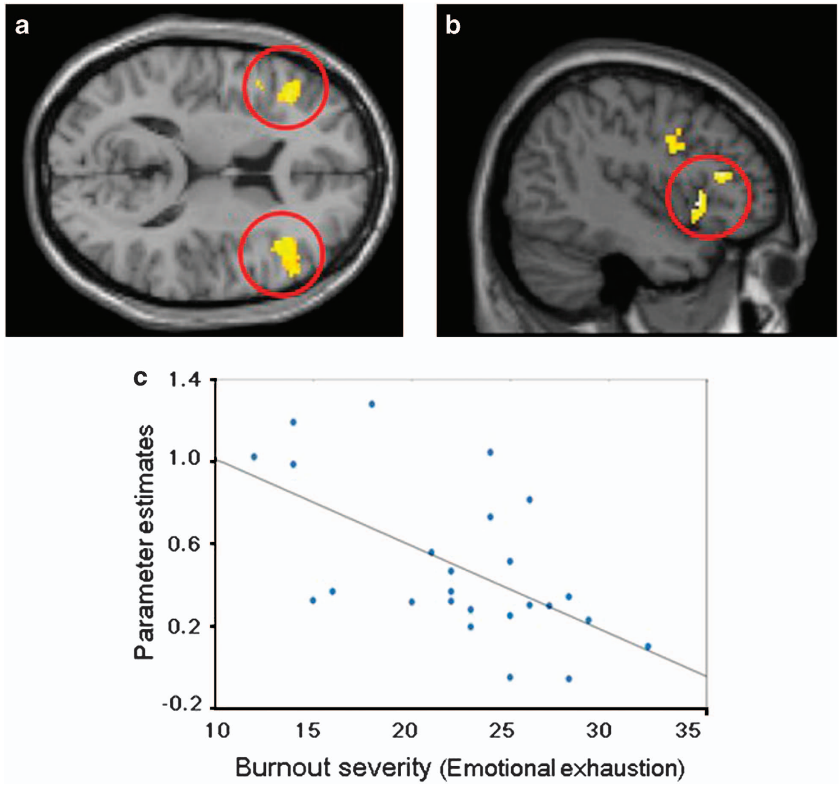

Figure 1. Correlation between burnout severity and hemodynamic activity in AI/IFG across participants. Burnout severity ('emotional exhaustion' on the MBI) was associated with decreased activation of the anterior insula and inferior frontal gyrus cluster (AI/IFG). (**a**) Image showing activation in AI/IFG within pain>no-pain contrast across participants (transverse plane). (**b**) Image showing activation in AI/IFG within pain>no-pain contrast across participants (sagittal plane). (**c**) Plots and regression line depicting the correlation between burnout severity and parameter estimates of the AI/IFG cluster activity for pain>no-pain contrast. MBI, Maslach Burnout Inventory.

self-reported psychological measures, burnout severity showed a positive correlation with empathic dispositional scores, supporting the 'compassion fatigue theory'. However, burnout severity also showed a positive correlation with trait emotional dissonance scores and alexithymia scores, which might represent a link between burnout and emotional dissonance. This positive correlation between burnout severity and emotional dissonance was no longer significant when alexithymia scores were covaried out (that is, changed from $r=0.430$, $P=0.032$ to $r=0.261$, $P=0.219$). This goes along with previous studies suggesting a link between burnout, emotional dissonance and alexithymia.[19,44–46] Meanwhile, the positive correlation between burnout severity and empathy remained significant when alexithymia scores were covaried out (changed from $r=0.507$, $P=0.010$ to $r=0.467$, $P=0.022$). Thus, the initial correlation analysis between the psychological measures supported both theories ('compassion fatigue' and 'emotional dissonance').

The brain imaging results cannot determine whether the 'compassion fatigue hypothesis' is supported or not because the relationship between empathy-related brain activity and empathic capabilities is not well understood. However, at least, the correlation between empathy-related brain activity and psychological measures showed a modest sign of emotional dissonance. Medical professionals with 'reduced' empathy-related brain activity exhibited higher burnout severity scores and greater dispositional empathy scores. This 'reduced' pain empathy-related brain activity also correlated with higher trait scores of emotional dissonance and alexithymia. We thus speculate that reduced emotion recognition (that is, alexithymia) might potentially link with stronger emotional dissonance and greater burnout severity alongside reduced empathy-related brain activity. In this view, greater empathic disposition in those with higher burnout levels may be because they have more difficulty identifying their emotional reactions. Moreover, a negative correlation between empathy-related brain activity and difference scores between post-scan ratings of the pain stimuli may also go along with higher alexithymia and emotional dissonance tendencies. Differences between distress and pain scores can be considered representations of the state of emotional dissonance; that is, participants with subjective distress scores greater than their objective ratings of pain showed weaker brain activity and stronger burnout severity.

Stronger activity in the defined ROIs (AI/IFG and TPJ) was associated with reduced severity of burnout, as measured by the MBI, emotional dissonance trait scores on the EWRS, alexithymia scores on the TAS-20 and empathy disposition scores on the IRI. IFG has been previously implicated in reducing negative arousal, inhibiting distress, facilitating response selection, encouraging optimistic thinking and supporting belief formation.[47,48] Moreover, greater activity in AI/IFG may reduce a sense of dissonance or depersonalization by enhancing ongoing awareness and sense of reality because AI/IFG contains von Economo neurons.[49] Thus, people with reduced AI/IFG activation may demonstrate relatively incomplete suppression of negative arousal and emotional conflict, thereby inducing stronger emotional dissonance, emotional exhaustion and burnout. Moreover, TPJ is involved in distinguishing between awareness of self and others during empathic behavior,[50] metalizing[51] and alexithymia.[52] Our results could imply that participants with reduced TPJ activity make a weaker distinction between one's own emotion and that of another person, thereby evoking stronger feeling of dissonance and/or reduced emotional recognition.

The relationship between burnout and empathy appears to be a more global construct than previously argued. One of the reasons

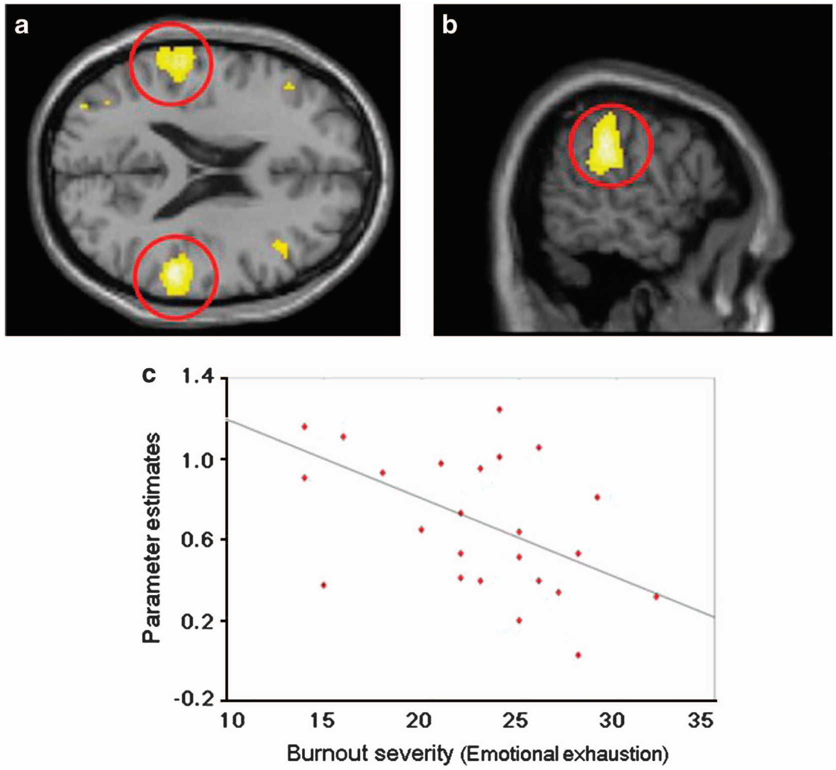

Figure 2. Correlation between burnout severity and hemodynamic activity in TPJ across participants. Burnout severity ('emotional exhaustion' on the MBI) was associated with the decreased activation of the temporoparietal junction (TPJ). (**a**) Image showing activation in TPJ within pain>no-pain contrast across participants (transverse plane). (**b**) Image showing activation in TPJ within pain>no-pain contrast across participants (sagittal plane) (**c**) Plots and regression line depicting the correlation between burnout severity and parameter estimates of the TPJ cluster activity for pain>no-pain contrast. MBI, Maslach Burnout Inventory.

Table 3. Correlation between psychological measures and mean neural activity in AI/IFG and TPJ across participants

	AI/IFG	*TPJ*
Burnout (MBI)		
Emotional exhaustion	− 0.590**	− 0.550**
Depersonalization	− 0.298	− 0.310
Empathy (IRI)		
PT	− 0.524**	− 0.431*
EC	− 0.432*	− 0.301
PD	− 0.167	− 0.378
Emotional dissonance		
(EWRS) HNE	− 0.528**	− 0.504*
Alexithymia (TAS-20)		
Dif	− 0.399*	− 0.581**
Ddf	− 0.017	− 0.467*
Eot	0.279	− 0.127
Post-scan rating		
Distress minus pain score	− 0.419*	−0.464*

Abbreviations: AI, anterior insula; Ddf, difficulty in describing feelings; Dif, difficulty in identifying feelings; EC, empathic concern; Eot, externally oriented thinking; EWRS, Emotion Work Requirements Scale to assess emotional dissonance; HNE, hide negative emotion; IFG, inferior frontal gyrus; IRI, Interpersonal Reactivity Index; MBI, Maslach Burnout Inventory; PD, personal distress; PT, perspective taking; TAS-20, Toronto Alexithymia Scale; TPJ, temporoparietal junction. $^{*}P < 0.05$, $^{**}P < 0.01$.

for the existence of the contradictory theory in burnout might be because the relationship between dispositional empathy levels and burnout severity is complex. For example, dispositional empathy scores in medical interns both increased (according to the 'personal distress' subscale of IRI) and decreased (according to other subscales of the IRI) when compared from the beginning to the end of their intern year, along with increased burnout severity.[12] Furthermore, the relationship between the strength of empathy-related brain activity and dispositional empathy is complex. Several studies have reported positive as well as negative correlations between empathy disposition measures and different brain regions.[26–30] To further distinguish this relationship, continued research is required.

Another point that warrants caution is generalizing the burnout-empathy theory to other populations. The observed relationship between burnout severity and empathy-related brain activity might only apply to inexperienced nurses because burnout can be triggered by various factors besides altered emotional regulation, such as work-life balance, salary and relationship with co-workers.[53] Moreover, the emergence of burnout symptoms may depend on occupational type. Professionals within human services are expected to manage their emotions according to occupational demands. For example, medical professionals and police officers may boost or inhibit their emotions depending on the situation, which might contribute to triggering burnout (for example, empathizing to raise a strategic smile or expressing detached reception to elicit a matter-of-fact attitude).[14,54] However, professionals from other fields, such as military service members[55] and athletes,[56] may experience burnout as a result of different psychological processes. Therefore, oversimplifying the burnout phenomenon is misleading.

In conclusion, burnout in medical professionals might be explained by reduced empathy-related brain activity. This reduced brain activity was also associated with greater difficulty in recognizing one's own emotional state, as well as with greater self-reported empathic disposition. Our results support findings from previous behavioral studies, arguing that burnout is related to weakened emotional regulation. Further, our study sheds new light on the potential to predict future burnout in medical professionals by the application of brain imaging, which may strongly complement existing psychological examinations. This approach can provide remarkable clues for understanding burnout, namely, which particular aspects of the empathic trait and state and which neuronal processes might be associated with burnout severity.

It is argued that individuals who are most vulnerable to burnout in human service work are those who are highly motivated, dedicated and emotionally involved in their work.[57] Early risk assessment of burnout in these individuals is very important because they are indispensable for providing high-quality human service.[58] Because burnout in human service has become such a critical issue,[1] further clarification of the neural mechanisms of occupational burnout is essential.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Supplementary Information accompanies the paper on the Translational Psychiatry website (http://www.nature.com/tp)