Altered default mode network configuration in posttraumatic stress disorder after earthquake
A resting-stage functional magnetic resonance imaging study

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Abstract
The neural substrates of posttraumatic stress disorder (PTSD) are still not fully elucidated. Hence, this study is to explore topological alterations of the default mode network (DMN) in victims with PTSD after a magnitude of 8.0 earthquake using resting-state functional magnetic resonance imaging (rs-fMRI).

This study was approved by the local ethical review board, and all participants signed written informed consent. Sixty-two PTSD victims from the 2008 Sichuan earthquake and 62 matched exposed controls underwent rs-fMRI. PTSD was diagnosed by Clinician-Administered PTSD Scale, and underwent PTSD Checklist-Civilian Version for symptom scoring. The DMN was analyzed by using graph theoretical approaches. Further, Pearson correlation analysis was performed to correlate neuroimaging metrics to neuropsychological scores in victims with PTSD.

Victims with PTSD showed decreased DMN functional connectivity strength between the right superior frontal gyrus and left inferior parietal lobule (IPL), and showed increased functional connectivity between the right IPL and precuneus or left posterior cingulate cortex. It was also found that victims with PTSD exhibited decreased nodal efficiency in right superior frontal gyrus and precuneus, and increased nodal efficiency in right hippocampus/parahippocampus. Apart from that, PTSD showed higher nodal degree in bilateral hippocampus/parahippocampus. In addition, the functional connectivity strength between the right IPL and precuneus correlated negatively to the avoid scores (\(r = -0.26, P = .04\)).

This study implicates alteration of topological features on the DMN in PTSD victims after major earthquake, and provides new insights into DMN malfunction in PTSD based on graph theory.

Abbreviations: ACC = anterior cingulate cortex, DMN = default mode network, IPL = inferior parietal lobule, PCC = posterior cingulate cortex, PCu = precuneus, rs-fMRI = resting-state fMRI.

Keywords: default mode network, earthquake, graph theory, posttraumatic stress disorder, resting-state functional magnetic resonance imaging

1. Introduction
Posttraumatic stress disorder (PTSD) is a severe anxiety disorder that is implicated with the exposure to life-threatening traumatic events.[11] PTSD could affect multiple domains of health. Three symptom clusters (ie, hyperarousal, re-experiencing, and avoidance) are most prominent and are considered as therapeutic focus.[2] These symptoms could cause persistent harm to personal health, compromise the quality of life, and might induce disabling conditions.[3] Understanding the neurophysiological mechanism underlying PTSD could be of benefit to the therapy. Nonetheless, the neural substrates of PTSD are still not fully elucidated.

Plenty of studies indicated aberrant internally focused thought and function of autobiographical memory in patients with PTSD, which implied malfunction of the default mode network (DMN). The DMN is probably the most intensively studied resting-state brain network, which is composed of a series of brain regions anticorrelated with the frontoparietal network, and exhibits hyperactivity at rest and hypoactivity in the presence of attention-demanding tasks.[4] The DMN could be considered as a state ready to respond to any outside challenges.[5] Apart from the widely known functions of the DMN such as self-reflection and self-awareness, studies have also linked clinical manifestations of PTSD to perturbed functional connectivity of the DMN at resting state.[6,7]

Lines of evidences have proved that compromised integrity of the DMN might be possible neural substrate in the etiology of PTSD.[6–8] Bluhm et al[6] first studied the alteration of resting-state functional connectivity of DMN in female patients with...
childhood abuse by using seed-based correlation analysis. Lanius et al.\textsuperscript{[17]} further found that the altered functional connectivity of the DMN could predict the severity of PTSD. By using similar ROI-based functional connectivity analysis, Sripada et al.\textsuperscript{[9]} studied both the DMN and salient network, and found the disequilibrium between these 2 networks in PTSD. In another seed-based DMN study, King et al.\textsuperscript{[10]} found increased functional connectivity between posterior cingulate cortex (PCC) and dorsal lateral prefrontal cortex, and between PCC and dorsal anterior cingulate cortex after mindfulness-based exposure therapy in combat veterans with PTSD. Apart from seed-based or ROI-based analysis, independent component analysis (ICA) was also widely implemented in DMN functional connectivity investigation with the advantage of bias-free concurrent multi-network analysis. Tursich et al.\textsuperscript{[11]} utilized ICA to assess the association between spontaneous activity of the DMN, salience network and central executive network, and PTSD symptom severity in distinct symptom clusters. In their study, function of the DMN was altered and correlated to depersonalization/derealization severity in PTSD. Recently, topological large-scale network analysis based on graph theory is making rapid and wide progress in neuroscience and clinical contexts,\textsuperscript{[12]} which provides a way to assess both the local and distant functional connectivity organization of the brain networks. Moreover, this method is a data driven methodology for whole brain network analyses without priori ROI or seed selection. By using this topological method, Lei et al.\textsuperscript{[3]} found the topological features of PTSD shifted to “small-worldization” and the disequilibrium between the DMN and the salience network. Further, Du et al.\textsuperscript{[8]} found persistent connectivity malfunction belonged to the DMN in major earthquake survivors after 2 years, indicating a long-term effect of earthquake on this important human brain network. Kennis et al.\textsuperscript{[14]} indicated that DMN regions had reduced degree in PTSD, but an increased degree in the PCu. Suo et al.\textsuperscript{[15]} found that the main increased nodal activities were within the DMN in pediatric PTSD patients. Nonetheless, these studies investigated the DMN in the context of the whole resting brain network, and no study has further concentrated the attention on the alteration of topological organization in the DMN of PTSD as a separate brain network. We therefore try to exclusively construct DMN of PTSD with the predefined nineteen nodes for the brain network construction related with DMN. By doing this, more detailed information of altered brain network features might be uncovered. In addition, the DMN could also be considered as a brain network and studies have found topological reorganization of the DMN in mild cognitive impairment\textsuperscript{[16]} and irritable bowel syndrome.\textsuperscript{[17]} Thus, It seems plausible that the topological organization of the DMN would also be altered in victims with PTSD after the major earthquake. Our study is the first one to assess the topological traits of the DMN in earthquake survivors, by exclusively constructing the DMN with the predefined seeds. In addition, we further correlate the neuroimaging metrics to the neuropsychological tests scores of PTSD.

2. Materials and methods

2.1. Participants

This study was approved by the local ethical committee. Written informed consents were obtained before the study from all participants who were victims from an eight-magnitude earthquake on May 12, 2008 in Sichuan Province, China. A screening PTSD survey was conducted firstly by using PTSD Checklist-Civilian Version (PCL-C).\textsuperscript{[18]} Then, Clinician-Administered PTSD Scale (CAPS)\textsuperscript{[19]} was further implemented to score the symptom severity. This study used a PCL cut off of 35 to trigger screening with the CAPS followed by inclusion with CAPS score $>50$.\textsuperscript{[20]} The diagnosis of PTSD was established according to Structured Clinical Interview for DSM-IV axis I Disorders (SCID-I).\textsuperscript{[21]} Victims consequently (9–16 months after the earthquake) underwent rs-fMRI examinations, and the inclusion criteria were listed as follows: (1) victims with PTSD and in the absence of any other psychiatric disorders according to SDIC-I; (2) right handed; (3) younger than 60 years. The exclusion criteria were: (1) any psychiatric comorbidity or psychiatric history; (2) head trauma or loss of consciousness; (3) drug, psychiatric medication or alcohol usage; (4) brain tumors, hemorrhage, infarction and severe neural degeneration; (5) MRI contraindications (such as claustrophobia). Seventy-two cases of victims with PTSD (PTSD group) accomplished the examination and all MRI data sets were collected. In addition, 86 cases of age, sex, and education level matched victims without PTSD (non-PTSD group) were recruited and also underwent the same MRI protocol. The inclusion and exclusion criteria for non-PTSD group were identical to the PTSD group, except for the exclusion diagnosis of PTSD. Further, based on the head motion parameters, we excluded the victims in both groups with head translation more than 2 mm or rotation more than 2° during MR scanning. 62 cases of PTSD and 62 cases of non-PTSD were finally enrolled in this rs-fMRI study.

2.2. Rs-MRI acquisition

All the rs-MRI data were collected by using 3 Tesla MR scanner (EXCITE, General Electric, Milwaukee) with an 8-channel phased-array head coil. Participants of PTSD and non-PTSD groups were instructed to keep awake with eyes closed and not to think anything particular during the rs-fMRI scanning. Foam pads were used to constrain the involuntary head motion of all participants. Besides, earplugs were applied for hearing protection. A gradient-recalled echo planar imaging MRI sequence was performed along the anterior commissure–posterior commissure line. The parameters of this MRI sequence were: repetition time (TR) $=2000$ ms, echo time (TE) $=30$ ms, field of view (FOV) $=220 \times 220$ mm$^2$, flip angle $=90^\circ$, matrix $=64 \times 64$, slice thickness $=3$ mm, slice gap $=1$ mm. Each brain contained 30 slices. For each participant, 200 brain volumes were acquired with time cost of 400 s.

2.3. Data Preprocessing

Statistical parametric mapping (SPM8, http://www.fil.ion.ucl.ac.uk/spm/) based on MATLAB (The Math Works, Inc., Natick, MA) platform was used to preprocess functional MRI data. First, the first 10 time points were excluded for the signal homogeneity and participants‘ adaptation to the scanning. Second, slice timing correction was performed to compensate the temporal difference between slices. Third, head motion was corrected to rule out subjects with head motion more than 2 mm translation in any axis or more than 2° rotation in any axis during data acquisition. Moreover, according to the formula provided by Liao et al.\textsuperscript{[22]} we compared the differences of translation and rotation between the 2 groups. No statistical difference was found (2-sample t test, translation $t = 0.283, P = .792$; rotation $t = 0.254$,
2.4. Nodes of DMN in both groups

Default mode network for further fMRI analysis was constructed by using a published atlas of region of interests (ROIs) released by functional imaging in neuropsychiatric disorders (FIND) laboratory of the Stanford University (http://findlab.stanford.edu/functional_ROIs.html). This ROI atlas was defined from a group-level independent component analysis of resting-state fMRI. We excluded ROIs situated on thalamus, middle cingulate cortex and cerebellum as these locations were considered not typical for DMN. Nineteen ROIs were considered as nodes or seeds for further functional connectivity and network analysis (Table 1). (See supp Figure 1, http://links.lww.com/MD/B863, Supplemental Content, which illustrates the ROIs selected in this study).

2.5. Edges of DMN in both groups

Average signal of time series in each ROI was extracted for further functional connectivity analysis. Pearson correlation coefficients were calculated between each pair of 19 nodal time series for functional connectivity analysis in each participant. Then, a square 19 × 19 correlation matrix was constructed.

Table 1

| Number | ROIs defined by FIND | Abbreviations |
|--------|----------------------|---------------|
| 1      | Dorsal DMN 01        | mPFCACC       |
| 2      | Dorsal DMN 02        | IPL-BA39-L    |
| 3      | Dorsal DMN 03        | SFG-R         |
| 4      | Dorsal DMN 04        | PCu-BA31      |
| 5      | Dorsal DMN 06        | IPL-BA39-R    |
| 6      | Dorsal DMN 08        | HPH-L         |
| 7      | Dorsal DMN 09        | HPH-R         |
| 8      | Precuneus 02         | Pdcu-BAT-dorsal|
| 9      | Precuneus 03         | IPL-BA40-L    |
| 10     | Precuneus 04         | IPL-BA40-R    |
| 11     | Ventral DMN 01       | PCC-L         |
| 12     | Ventral DMN 02       | MFG/SGM-L     |
| 13     | Ventral DMN 03       | Fusiform-L    |
| 14     | Ventral DMN 04       | OMG-L         |
| 15     | Ventral DMN 05       | PCC-R         |
| 16     | Ventral DMN 06       | PCu-BAT-ventral|
| 17     | Ventral DMN 07       | MFG/SGM-R     |
| 18     | Ventral DMN 08       | Fusiform-R    |
| 19     | Ventral DMN 09       | OMG-R         |

| BA     | DMN         | FIND    |
|--------|-------------|---------|
| mPFC   | default mode network |
| ACC    | functional imaging in neuropsychiatric disorders |
| IPL    | hippocampal/parahippocampal |
| SFG    | inferior parietal lobule |
| PCC    | posterior cingulate cortex |
| OMG    | middle occipital gyrus |
| mPFC/ACC | medial prefrontal cortex/anterior cingulate cortex |
| mPFC ACC | middle frontal gyrus |
| PCu    | precuneus |
| PCCu   | posterior cingulate cortex |
| H/PH   | head motion |
| mPFC   | medial prefrontal lobule/anterior cingulate cortex |

 Afterwards, all correlation coefficients were converted to z values by using Fisher r-to-z transformation to make the data normally distributed which would facilitate the following statistical analysis. For a weighted network, z values denote the functional connectivity strength between each pair of nodes. Each pair of functional connectivity was considered as an edge in this sub-network. In this study, 171 (C2 = 171) possible edges along with 19 nodes constructed the DMN.

2.6. Network analysis of DMN

We used Graph theorEtiCal Network analysis (GRETNA) toolbox (http://www.nitrc.org/projects/gretna/) to evaluate the topological organization of the DMN in PTSD. In this study, we mainly discussed the network efficiency, small world properties, nodal efficiency and nodal degree (ie, nodal degree in recent study) based on graph theory.

Specifically, in a brain network (G), sparsity is defined as the ratio of the existing number of edges to the number of all possible edges in the network (C2 = 171 in the present study). Network efficiency is calculated by the E(G) = Σi≠j∈E(G)/|C2|, where dij denotes the shortest path length between nodes i and j. When G represents a whole network (the DMN in this study), E(G) reflects the global efficiency (Eglob) and NC denotes the number of nodes in the whole network. Although G is a sub-network, E(G) means the local efficiency, (Eloc) and NC is the number of nodes in the sub-network. Eglob and Eloc are important metrics for assessing the ability of global and local information transmission in a brain network. In physiological conditions, human brain network would keep a balance over Eglob and Eloc which might be disrupted in pathological circumstances.

Three parameters are used to characterize the small world properties, including γ, λ, and σ. Compared with random networks, small-world networks yield similar path lengths but higher clustering coefficients, characterized by γ = Ct / Crand >> 1 and λ = Cloc / Crand ≈ 1,001 or by using small-worldness,[11] σ = λ / γ > 1. Cloc and Crand denotes clustering coefficients in real network and random network respectively. Treal and Trand represents path length of real network and random network respectively.

For a weighted network G with N nodes, the nodal efficiency could be computed by the following formula:[32] Eglobal(i) = Σi≠j∈E(G) / Lreal, Elocal(i) denotes nodal efficiency of the ith node. Nodal degree is σi(G) = Σi∈G S(i), where S(i) denotes the number of edges of the ith node.[31] In this study, nodal efficiency and degree are the average value of all nodes in the DMN.

2.7. Statistical processes

All the demographic data was compared by using SPSS 20.0 (IBM Inc. Armonk, NY). Independent two sample t tests were implemented to compare the age and education level in PTSD and non-PTSD groups. Although χ2 test was used for comparison of sex. Statistic significant level was set at P < .05.

All the rs-fMRI maps were processed by using SPM8 (statistical parametric mapping, http://www.fil.ion.ucl.ac.uk/spm/). A random-effects 2-sample t test was performed to evaluate the alteration of functional connectivity (ie, edges) between the 2 groups with age, sex, education level as covariates. False-positive adjustment (FPA) was implemented for multiple comparison correction.[34] As 171 possible edges existed in this study, we controlled for the probability of type I error for the
number of comparisons between the 2 groups (P value < 1/171 = .00584). Further, on the level of each sparsity (0.05 ≤ sparsity ≤ 0.4), we used 2 sample t-tests for comparisons of network topological traits between the 2 groups including Eglob, Eloc, g, l, s, E nodal, Sp(G) with age, sex, education level as covariates. The significant level was set at P < .01. In addition, to assess the correlation between the CAPS scores and internodal connectivity/network topological metrics in PTSD victims, we correlated the mean z values of functional connectivity and values of topological metrics that demonstrated significant difference between the 2 groups against the CAPS scores by using Pearson correlation analysis. Pearson correlation analysis was carried out by using SPSS 20.0 (IBM Inc. Armonk, NY) with a significance level of P < .05, corrected for multiple comparison by using the false discovery rate correction.

3. Results

3.1. Demographic and neuropsychological data

No statistical significance was found in age, education level and sex of the 2 groups (all P > .05). The detailed comparisons and neuropsychological data were exhibited in Table 2.

3.2. Altered functional connectivity strength of the DMN

Compared with non-PTSD, victims with PTSD showed decreased functional connectivity strength between right superior frontal gyrus and left IPL-BA39, whereas increased functional connectivity strengths were found between right IPL-BA40 and PCu-BA31 or left PCC (Fig. 1). (See supp Table 1, http://links.lww.com/MD/B863, Supplemental Content, which illustrates FC strength alteration within DMN in PTSD compared with non-PTSD).

3.3. Altered DMN topological features

In both PTSD and non-PTSD groups, the DMN showed small world properties (0.05 ≤ sparsity ≤ 0.4), characterized by γ = greal/Crand ≫ 1 and λ = lreal/Lrand ≈ 1, or σ = γ/λ > 1 (see supp Figure 2, http://links.lww.com/MD/B863, Supplemental Content, which illustrates small world properties of DMN in PTSD and non-PTSD). We also compared the global and local network efficiency of the DMN (ie, Eglob and Eloc) (see supp Figure 3, http://links.lww.com/MD/B863, Supplemental Content, which illustrates global and local efficiency in both groups). However, clustering coefficient and path length, λ, γ, σ, Eglob, and Eloc demonstrated no significant difference between PTSD and non-PTSD groups (see supp Table 2, http://links.lww.com/MD/B863, Supplemental Content, which illustrates comparison of DMN network metrics between PTSD and non-PTSD).

In terms of the nodal characters of the DMN, victims with PTSD exhibited decreased nodal efficiency in the right superior frontal gyrus (0.23 ≤ sparsity ≤ 0.3) and the PCu-BA7-Verteral (0.22 ≤ sparsity ≤ 0.28), and increased nodal efficiency in the right H/P (0.18 ≤ sparsity ≤ 0.22) compared with...
non-PTSD (Fig. 2). Apart from that, PTSD showed higher nodal degree in the left H/PH (0.08 ≤ sparsity ≤ 0.14) and the right H/PH (0.22 ≤ sparsity ≤ 0.34) compared with non-PTSD (Fig. 3) \( P < .01 \).

3.4. Pearson correlation between imaging parameters and neuropsychological metrics

Pearson analysis found negative correlation between functional connectivity strength (between right IPL-BA40 and PCu-BA31) and avoidance score \( (P < .05) \) (Fig. 4). No significant correlation was found between functional connectivity strength, and re-experiencing and hyper-arousal scores. In addition, no significant correlation was found between any investigated topological feature of DMN in PTSD and the scores of the 3 main symptoms.

4. Discussion

In the current study, to our knowledge, topological organization of the DMN in victims with PTSD after a major earthquake was analyzed for the first time. Compared with non-PTSD, we found altered functional connectivity strength, nodal efficiency and nodal degree in victims with PTSD, indicating a disturbance in the integration of DMN in PTSD. In addition, we also found negative correlation between functional connectivity strength (between right IPL and PCu) and avoidance score. These findings indicated that, as predicted, topological configuration of the DMN in victims with PTSD after major earthquake was changed, and the alteration was likely to be potential neurophysiological mechanism underlying PTSD.

4.1. Alteration of inter-seed functional connectivity strength of the DMN in PTSD

Compared with non-PTSD, survivors with PTSD showed decreased functional connectivity strength between left IPL (BA39) and right superior frontal gyrus. IPL (BA39) is overlapped with angular gyrus. This finding is in line with previous studies that PTSD presented decreased functional connectivity within the DMN.[35] On the contrary, compared with non-PTSD, survivors with PTSD showed increased functional connectivity strength between right IPL (BA40) and PCu (BA31) and increased functional connectivity strength between right IPL (BA40) and left PCC. PCu and PCC are highly connected and metabolic brain regions at resting state, and play a key role in the DMN.[36] These properties make PCu and PCC susceptible to functional malformation in the PTSD, indicating these brain regions a potential sensitive biomarker. IPL allows visospatial information processing and relates to body defense, alarming and survival,[37] which might also play a vital role in PTSD. The increased functional connectivities in these DMN regions were not reported in any prior study (adult cohort). This finding might attribute to reorganization of brain network and different method used from previous studies. Specifically, we speculated that these increased intra-DMN functional connectivities might play a compensate role in the brain network reorganization. Moreover, we found negative correlation between functional connectivity strength (between right IPL and PCu) and avoidance score, which adds to the proposal of network reorganization aforementioned. The negative correlation might indicate that patients with less severe symptom would allow more compensation for the reduced functional connectivity. Negative correlation between functional

Figure 2. Nodal efficiency comparison between PTSD and non-PTSD, significant level \( P < .01 \). Victims with PTSD showed decreased nodal efficiency in right SFG and PCu-BA7-vertral, and increased nodal efficiency in right H/PH compared with non-PTSD. \(^*\) denote significant differences between the 2 groups. BA = Brodmann Area, H/PH = hippocampus/parahippocampus, Non-PTSD = nonposttraumatic stress disorder, PCu = precuneus, PTSD = posttraumatic stress disorder, SFG = superior frontal gyrus.

Figure 3. Nodal degree comparison between PTSD and non-PTSD, significant level \( P < .01 \). PTSD showed higher nodal degree in bilateral H/PH compared with non-PTSD. \(^*\) denote significant differences between the 2 groups. H/PH = hippocampus/parahippocampus, PTSD = posttraumatic stress disorder, Non-PTSD = nonposttraumatic stress disorder.
connectivity (between the right amygdala and the left middle frontal cortex) and CAPS scores has been reported previously, which indicated the impairment of cortex-limbic circuit. However, the exact neural mechanism of the relationship between increased functional connectivity (between right IPL and PCu, 2 highly connected parietal structures) and the PTSD symptom severity remains unknown.

4.2. Alteration of topological features of the DMN in PTSD

According to graph theory, human brain is a complex network with numerous nodes and edges, and possesses small world properties, which allows effective information transfer at low cost. In conditions of neuropsychiatric diseases, the topological features of brain network might be altered. In this study, we used graph theory methods to identify the possible topological disturbance of DMN in PTSD by constructing the DMN with the predefined ROIs.

We found that the DMN in PTSD exhibited a trend to small-world brain network \( (\gamma = C_{\text{real}}/C_{\text{rand}} > 1 \text{ and } \lambda = L_{\text{real}}/L_{\text{rand}} \approx 1) \). Generally, the brain network normally functions as a small-world network with a high local specialization and global integration, whereby the brain could run effectively with relatively low energy costs. In a previous study, Lei et al. defined the whole brain network of PTSD patients with 90 nodes, and found PTSD patients showed a shift to small-world network rather than random network. Thus, it was implied that not only the whole brain network but also the DMN keep the energy-saving topological feature of small world. Moreover, no significant differences of clustering coefficient and characteristic path length were found in the DMN. In addition, no significant differences of the normalized metrics such as \( \gamma \), \( \lambda \), and \( \sigma \) between PTSD and control groups in the whole brain network. What’s more, \( E_{\text{glob}} \) (global effect) and \( E_{\text{loc}} \) (local effect) were reduced when considering the whole brain as a network in PTSD whereas they showed no difference in DMN between PTSD and non-PTSD groups in our investigation. According to this clue, we speculated that a mechanism of reorganization might exist to maintain the hyperactive function of DMN in adult PTSD. Apart from the study of adult PTSD, Suo et al. assessed the whole brain network, and found a significantly increased clustering coefficient, normalized characteristic path length, and \( E_{\text{loc}} \) in pediatric patients with PTSD, which was different with our findings. The possible reasons might be the different ROI selection and different study population.

Apart from investigation of the global topologies of DMN, we also found altered nodal efficiency and degree of the DMN between the two groups. Compared with non-PTSD group, victims with PTSD exhibited decreased nodal efficiency in right superior frontal gyrus and PCu. A recent meta analysis of neuroimaging studies on PTSD after natural disasters found perturbed function in right superior frontal gyrus. Superior frontal gyrus is part of prefrontal cortex, which is a key brain region of neural circuit underpinning PTSD, apart from amygdala and hippocampus. Decreased nodal efficiency in right superior frontal gyrus might be related to impaired prefrontal cortex-amygdala neural circuit in PTSD victims, which results in lower top-down control over the activation of amygdala. Decreased nodal efficiency in PCu indicates lower information processing in this key brain region belongs to the DMN.

Notably, we also found increased nodal efficiency in right hippocampus/parahippocampus and higher nodal degree in bilateral hippocampus/parahippocampus in PTSD victims. The hippocampus plays pivotal role in typical neural circuit in the etiology of PTSD, and is related to conditioned fear, extinction, and a key mediator of learned fear. Parahippocampus is involved in scene perception, which could be important for human to process information from the surrounding environment during natural disasters such as a major earthquake. Most structural MRI studies found decreased hippocampus/parahippocampus volume in PTSD, however, the activities of hippocampus/parahippocampus were various by using BOLD fMRI studies. One account for increased hippocampus/parahippocampus nodal efficiency and degree in this study, might lie in a compensatory mechanism. Taken together, these results were in favor of the hypothesis that the topological configuration of the DMN in PTSD victims is altered.

4.3. Limitations

There are some limitations in this study. First, we only studied PTSD caused by one kind of natural disaster, and the result interpretation should not be generalized to other traumatic events. Second, as a cross-sectional study, we can’t tell the causality between these topological alterations and PTSD, longitudinal studies are warranted in the future. Third, the data was acquired in the year 2008, so we only assessed three main manifestations of PTSD in line with DSM-IV. As time goes on, 4 main manifestations are introduced by DSM-V.

5. Conclusion

In conclusion, these findings speak to alteration of topological features on the DMN in PTSD victims after major earthquake. This study provides new insights into the DMN malfunction in PTSD based on graph theory.
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