Title page

Multilayer Network Analysis of Dynamic Network Reconfiguration in Adults with Posttraumatic Stress Disorder

Running title: Brain Network Dynamics in PTSD

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Abstract

Background: Brain functional network abnormalities are reported in posttraumatic stress disorder (PTSD). Most resting-state functional magnetic resonance imaging studies have assumed that the functional networks remain static during the scan. How these might change dynamically in PTSD remains unclear.

Methods: Resting-state functional magnetic resonance imaging data were collected from 71 treatment-naïve noncomorbid PTSD patients and 70 demographically-matched trauma-exposed non-PTSD (TENP) controls. Network switching rate was used to characterize dynamic changes of individual resting-state functional networks. Results were analyzed by comparing switching rates between PTSD and TENP, by correlation with individual PTSD symptom severity, and for diagnosis-by-sex interactions.

Results: At the global level, PTSD patients showed significantly lower network switching rates than TENP. These were observed mainly in the default-mode, fronto-parietal, and limbic networks at the subnetwork level, and in the frontal and temporal regions at the nodal level. These network switching rate alterations were correlated with PTSD symptom severity. There were no significant effects of sex.

Conclusion: These disruptions of dynamic functional network stability, reflected by lower network switching rate in the resting state, are a feature of PTSD, and suggest that the default mode, fronto-parietal and limbic networks may play a critical role in the underlying neural mechanisms.

1. Introduction

Posttraumatic stress disorder (PTSD) is a trauma-dependent disorder characterized by re-experiencing, avoidance, hyperarousal, and negative cognitions and mood, and has major financial and public health impact [1]. PTSD is now conceptualized as a brain network dysfunction syndrome [2,3], manifesting as aberrant functional connectivity, especially in the default-mode network [4]. Individual brain network abnormalities are linked with clinical symptoms [5,6] and treatment response [7,8].

Although yielding insights into the biological underpinnings of PTSD, functional connectome studies have mainly focused on static (time-invariant) patterns of connectivity. However, the brain is a dynamic system whose connectivity changes with time [9,10]. These dynamic reconfigurations are essential for efficient information communication [11], cognitive flexibility [12], and rapid response to external environment [13]. Although recent PTSD studies have reported alterations of brain dynamics such as aberrant connectivity variability [14-16] and transitions between connectivity states [17-19], the topological features of dynamic brain networks are not yet clear. Investigating the temporally fluctuating patterns in brain network topology, in particular the properties of modular switching, should advance our understanding of how dynamic interactions of network components underpin clinical symptoms in PTSD.

Using resting-state functional MRI data (rs-fMRI), we employed a multilayer network model [20] to characterize the topological dynamics of the functional connectome in a relatively large sample of treatment-naive PTSD patients without psychiatric comorbidity, compared with trauma-exposed non-PTSD (TENP) controls, and to explore associations with symptom severity. Based on the reports of aberrant transitions between

connectivity states, we hypothesized that: i) PTSD patients would show significant alterations in brain connectome dynamics compared to TENP, e.g. in the default mode network; and ii) individual alterations would be associated with PTSD symptoms. Because females have increased risk of developing PTSD [21] and there are possible differential effects of sex on brain functional alterations [22,23], we (iii) also analyzed sex-by-diagnosis interactions.

2. Materials and Methods

2.1 Participants

Individuals who survived the 8.0 magnitude earthquake in Sichuan in May 2008 were recruited between January and August 2009 and screened with the PTSD checklist-Civilian Version (PCL) [24]. At follow-up visits 8-15 months after the earthquake, the diagnosis of PTSD was based on the Structured Clinical Interview for the DSM-IV Diagnosis (SCID) [25] and symptom severity was assessed using the Clinician-Administered PTSD Scale (CAPS) [26]. Survivors scoring ≥ 35 on PCL and ≥ 50 on CAPS were included as PTSD if a diagnosis of PTSD was determined by SCID; those who scored < 35 on PCL without diagnosis of PTSD by SCID were considered TENP controls. Detailed inclusion and exclusion criteria are provided in the Supplementary Materials. Finally, 71 treatment-naive noncomorbid patients with PTSD and 70 demographically-matched TENP controls were included. This recruitment strategy ensured that participants with and without PTSD had similar earthquake experiences and demographic characteristics. Notably, we have performed several other analyses on these participants (e.g. analyses on cortical thickness [27], white matter microstructure [28],

and structural and functional connectivity [6,29,30]), with the results reported in the cited papers.

This study was approved by the Medical Research Ethics Committee of West China Hospital, Sichuan University, and informed written consent was obtained from all participants before the study.

2.2 Image acquisition

All participants underwent resting-state functional 3.0 T MRI (Excite; GE Healthcare, Milwaukee, Wis) with an 8-channel phased-array head coil. Each functional run resulted in a total scanning time of 400 s. The sequence parameters were as follows: repetition time/echo time, 2000 ms/30 ms; flip angle, 90°; number of axial sections per volume, 30; section thickness, 5 mm; no section gap; matrix, 64 × 64; field of view, 240 × 240 mm^2; and voxel size, 3.75 × 3.75 × 5. The participants were instructed to keep their eyes closed and not to think about anything in particular during the acquisition. All MR images were evaluated by an experienced neuroradiologist.

2.3 Image processing

SPM12 software (http://www.fil.ion.ucl.ac.uk/spm) was used to perform the pre-processing of fMRI image data. The initial 10 time points were deleted to establish magnetic tissue stabilization. Slice timing correction was applied to correct for intra-volume acquisition delay. The images were realigned to correct for head movement. Images were normalized using echo-planar imaging templates (voxel size [3×3×3]). Linear trends in time series were removed. Nuisance signals (including the Friston 24-parameter head motion model, the white matter signal, and the cerebrospinal fluid signal)

were regressed out. Finally, functional data were linearly detrended and temporally bandpass (0.01–0.1 Hz) filtered to eliminate effects of high-frequency noise and low-frequency drift, and smoothed (Gaussian kernel with a full-width at half-maximum [FWHM] of 4 mm). The mean framewise-displacement (FD) was used to evaluate head motion during the scans, and did not differ between TENP and PTSD (0.118±0.081 vs. 0.100±0.046 mm, P = 0.11).

2.4 Multilayer brain network switching rates

Constructing multilayer brain network: Multilayer network theory is a powerful way to represent and quantify multi-dimensional data studied from multiple perspectives [31,32]. Multilayer networks can be considered as a 'network of networks', including frequency-varying networks [33,34], time-varying networks [35-37], networks for different tasks [38], and networks from different modalities [39]. In the current study, we applied a time-varying multilayer network, in which each time-window corresponded to a layer in the multi-layer network. Nodes were defined by the Brainnetome 246 Atlas: this provides 210 cortical and 36 subcortical nodes, and includes detailed anatomic structure and accurate functional connection information [40]. The mean time series of each region in the 246 atlas were extracted by averaging rs-fMRI signals of all voxels on each node coordinates. Dynamic functional connectivity was calculated using a sliding window method [10]: Hamming windows (window size = 50 × TR = 100 s, meeting the $1/f_0$ wavelength criterion for minimum cutoff frequency 0.01 Hz [41-43]; window step = 1 × TR = 2 s) were applied to each participant's preprocessed fMRI data to obtain a series of 141 rs-fMRI signal windows. Pearson correlation coefficients were calculated between pairs of region signals in each window. This yields a dynamic network matrix (N × N ×

W) for each subject, where N (= 246) is the number of atlas regions and W (= 141) is the number of sliding windows.

Detecting time-varying modular structures: An iterative Louvain multilayer modularity algorithm was implemented to detect the time-varying modular structures of the brain network within each time window [20]. Briefly, this algorithm partitions the communities in a multilayer network by optimizing the multilayer modularity quality function Q, defined as:

$$Q_{multilayer}(\gamma,\omega)=\frac{1}{2\mu}\sum_{ijsr}\left[\left(A_{ijs}-\gamma_s\frac{k_{is}k_{js}}{2m_s}\right)\delta(s,r)+\delta(i,j)\omega_{jsr}\right]\delta(M_{is},M_{jr})$$

where *i* and *j* are node labels and *s* and *r* are layer labels. Specifically, μ denotes the total edge weight of the network, A_{ijs} the connectivity strength between nodes *i* and *j* in layer *s*, k_{is} and k_{js} the degree of nodes *i* and *j* in layer *s* (respectively), m_s the total degree of layer *s*, and $\frac{k_{is}k_{js}}{2m_s}$ the probability expected by chance of a connection between node *i* and node *j* in layer *s*. M_{is} and M_{jr} are the community assignments of node *i* in layer *s*, and node *j* in layer *r* respectively. The function $\delta(x,y)$ = 1 if $x = y$, 0 otherwise. The variable γ_s is the topological resolution parameter in layer *s*, which determines the detected module size (larger γ_s, smaller module). The temporal coupling parameter ω_{jsr} denotes the strength of inter-layer coupling for node *j* between layers *r* and *s*. This was calculated using an open-source MATLAB-based code package (https://github.com/GenLouvain/GenLouvain) with the commonly-used default setting ω = γ = 1 [35,44]. As this multilayer modularity algorithm only allows positive matrix values, negative values in the connectivity matrices were set to zero in the sliding-window matrices [35]. Mean connectivity zeroed out did not differ significantly between TENP and PTSD (50.2±0.7% vs. 50.1±0.7% per subject,

P = 0.37). As the output, a 246 × 141 (i.e. N × W) module assignment matrix was obtained for each scan, representing the temporal alterations in module assignments for all 246 nodes.

Calculating network switching rates: After obtaining the multilayer module assignment matrices, the switching rate for a node i (f_i) was calculated as $f_i = n_i/G$, where n_i is the number of times its module assignment changed between consecutive layers, and G is the maximum potential number of changes (here 141 - 1 = 140). The switching rate ranges between 0 and 1, a higher value indicating higher frequency of the node's transition between different functional modules, and thus lower temporal stability. The calculations were performed using the Network Community Toolbox (http://commdetect.weebly.com) [36]. Switching rates for the global brain network were obtained by averaging all 246 nodes. Further, to characterize the contribution of each functional network, 210 cortical nodes were taken to correspond to 7 different neural networks in the Yeo atlas (visual, somatomotor, dorsal and ventral attention, limbic, frontoparietal, and default mode network), and 36 subcortical nodes were classified as the subcortical nucleus network [45-48]. Switching rates for these 8 subnetworks were obtained by averaging the nodes belonging to each subnetwork. The overall flow-chart of analysis is shown in **Figure 1**.

2.5 Statistical analyses

Differences in demographic and clinical characteristics between PTSD and TENP were tested using two-sample t tests (continuous variables) or chi-square tests (categorical variables). Between-group differences of brain network switching rates were tested using two-sample t tests. PTSD diagnosis-by-sex interaction was analyzed using 2-way analysis of variance (ANOVA); if statistically significant interactions were observed, *post hoc*

contrasts assessed the simple main effects. Partial correlations were performed between CAPS score and the network switching rates which showed significant group differences, with age, sex, years of education, and mean FD as covariates. As all participants had experienced major life trauma, with PTSD determined by the persistence and severity of psychological symptoms, the two groups were pooled to evaluate the relationship between brain functional dynamics and PTSD symptom severity. Correlations between switching rate and symptom severity in each PTSD and TENP group were also analyzed (see Supplementary Materials). All statistics were performed at the global, subnetwork, and nodal levels. False discovery rate (FDR) corrections were applied to control for type I errors across the 8 subnetworks and 246 nodes. Results were visualized by BrainNet Viewer (http://www.nitrc.org/projects/bnv). Estimates of static functional connectivity are given in the Supplementary Materials.

2.6 Validation analyses

We investigated whether our results were affected (i) by head motion, (ii) by smoothing kernel, and by network analysis strategies, specifically the choice of (iii) multilayer network model parameters (ω and γ) and (iv) sliding window parameters (window length). First, we combined a series of strategies to minimize the effects of head motion on our results, including removal of participants (n = 9) with excess gross head motion (>2 mm in translation or >2° in rotation), and regression of 24-parameter head motion profiles [49] for each participant before constructing individual functional network. We also performed statistical analysis on network switching rates with mean FD as a covariate. Second, the choice of 4mm FWHM smoothing kernel is popular [47,50,51], and so we selected this for our primary analysis; we also examined the results of

choosing a different FWHM smoothing kernel (6mm). Third, in addition to using $\omega = \gamma = 1$ in our main analysis, we repeated the analysis using $\omega = 0.5$ and 0.75, and $\gamma = 0.9$ [50]. Fourth, we repeated our analyses using a window length of $30 \times TR = 60$ s.

3. Results

3.1 Demographic and clinical characteristics

Individuals with PTSD had significantly higher CAPS and PCL scores than TENP (all $P < 0.001$). There were no significant group differences in age, sex, years of education, or time since trauma (all $P > 0.05$, **Table 1**).

3.2 Group differences of switching at global, subnetwork, and nodal level

At the global level, individuals with PTSD had significantly lower network switching rates than TENP ($P = 0.002$, **Figure 2** and **Table 2**). At the subnetwork level, individuals with PTSD had significantly lower switching rates than TENP in the default mode ($P = 0.003$), frontoparietal ($P = 0.006$), and limbic networks ($P = 0.006$, all FDR corrected) (**Figure 2** and **Table 2**). There were no significant differences in visual, somatomotor, dorsal/ventral attention, or subcortical networks. At the nodal level, individuals with PTSD had significantly lower nodal switching rate than TENP in the left inferior frontal gyrus, left orbital gyrus, left inferior temporal gyrus, and right cingulate gyrus (all $P < 0.001$, FDR corrected) (**Figure 3** and **Table 3**). **Figure S2** shows the individual module assignments of brain regions which differed between two groups at different network layers. Mediation analysis was used to evaluate the indirect effect of network switching rate in frontal areas on CAPS score via network switching rate in temporal areas; results are given in the Supplementary Materials.

3.3 Interaction between groups and sex with respect to switching rate

Two-way ANOVA revealed no significant diagnosis-by-sex interaction in global brain network switching rate (P = 0.101), subnetwork switching rate in the limbic (P = 0.160), fronto-parietal (P = 0.170) or default mode network (P = 0.164), or nodal switching rate in left inferior frontal gyrus (P = 0.394), left orbital gyrus (P = 0.221), left inferior temporal gyrus (P = 0.692), or right cingulate gyrus (P = 0.374).

3.4 Correlations between switching rate and symptom severity

Across the whole sample, there was a significant negative correlation between CAPS score and the global network switching rate (r = -0.226, P = 0.013), and the switching rates of the limbic network (r = -0.253, P = 0.005), left inferior frontal gyrus (r = -0.236, P = 0.010), left orbital gyrus (r = -0.335, P < 0.001), left inferior temporal gyrus (r = -0.255, P = 0.005), and right cingulate gyrus (r = -0.326, P < 0.001) (**Figure 4**) (all survived FDR correction). Negative correlations falling short of conventional statistical significance were found between the CAPS scores and switching rates of frontoparietal (r = -0.177, P = 0.053), and default mode network (r = -0.183, P = 0.045).

3.5 Validation

To test the robustness of our main findings, we assessed the influence of several analysis strategies including: i) testing for head motion effects; ii) different choice of FWHM smooth kernel (6mm); iii) different temporal coupling (ω = 0.5 and 0.75) and topological resolution parameters (γ = 0.9); and iv) different sliding window length (60 s). The main results of switching rate were largely reproducible across analysis strategies (**Table S1**).

4. Discussion

Using a multilayer brain network model, this study provides evidence of PTSD-related alterations in brain modular dynamics. Whereas studies so far have mainly reported alterations of static (time-invariant) functional connectivity [3], the connectome dynamics approach used here (quantifying temporal switching among functional modules) reflects the dynamic modular reconfigurations crucial to efficient information processing [12]. We found that individuals with PTSD, relative to TENP, had significantly lower switching rates of functional brain network modules at global, subnetwork, and nodal levels. These alterations occur primarily in the default mode, frontoparietal, and limbic networks as well as frontal and temporal regions, which are associated with individual symptom severity. There were no significant interactions between groups and sex. This evidence for altered macroscopic connectome dynamics may advance our knowledge of the biological mechanisms of PTSD beyond what is possible with the static approach. We briefly discuss some of the specific findings.

Brain functional networks are often constructed as a single network or static state with a modular architecture [52]. A static functional network necessarily reflects temporally averaged properties between regions, which cannot describe the full spontaneous activity of a brain which works dynamically across multiple time scales [53]. During dynamic processes, large-scale brain regions maintain temporary stable states in a highly modular form; these transition from one stable functional state to another with rapid and distinct transitions [54]. Studying dynamic functional connectivity in the resting state could shed light on task-related brain spatiotemporal organization, because maximal (or at least optimal) metastability facilitates task-related brain systems configuration [55], and dysfunctions among different functional systems may reflect core underlying affective

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and cognitive abnormalities [56]. To characterize dynamic modular patterns, a multilayer network analysis has been proposed, in which each brain region in one network layer is connected to itself in other layers, thus providing a temporal link between adjacent time points [20,31]. This method has good test-retest reliability [57]. In the current study, globally PTSD had significantly lower brain network switching rates than TENP. Reduced temporal variability of functional connectivity seems to be a common feature in psychiatric disorders [58,59], including PTSD [14], and this can plausibly be seen as reflecting or underpinning a compromised ability to adjust behaviors and thoughts dynamically to changing conditions (including internal body/mental states as well as external environmental influences) [14].

At the network level PTSD patients had lowered modular switching in the default-mode network (strongly involved in emotional processing, self-referential mental activity and episodic memory retrieval [60,61]), the fronto-parietal network (implicated in attention control, planning and decision making [62]) and the limbic network (involved in social cognition and emotional regulation [63]). Impairments of all three networks and their functions have been documented in PTSD [2,3,30], where their common feature seems to be impaired emotional and cognitive processing. One interpretation is that PTSD patients tend to stay in that state [18], which reflects a more general hypothesis that the tendency to enter into, and inability to disengage from, a negative mood state is a feature of many psychiatric conditions [64]. Cognition deficits are a new focus in PTSD research; our lack of any cognitive evaluation should be addressed in future studies.

At the nodal level, PTSD patients had lower switching rate in the left inferior frontal gyrus, left orbital gyrus, left inferior temporal gyrus, and right cingulate gyrus. Inferior

frontal, orbital and cingulate gyrus have been implicated in emotion regulation and higher-order cognitive function [65-67]. Orbital frontal and cingulate dysfunction related to inappropriate emotional responses to trauma and behavioral responses to stimuli have been implicated in symptom formation in PTSD [67], and negatively correlated with hyperarousal [68]. Increase in frontal activation is associated with improvement in hyperarousal symptoms and psychological well-being in PTSD [69]. The inferior temporal gyrus is part of the ventral visual stream and subserves shape perception and recognition memory for patterns, faces and objects [70,71]. Increased flashback reports in PTSD patients have been correlated with reduced brain volume in the inferior temporal gyrus [72]. Additionally, our observation that the switching rate of the frontal and temporal areas were negatively related to CAPS measures of illness severity indicates that the lower the switching rate of frontal and temporal areas, the more severe the symptoms. Altogether, network switching rate changes in frontal and temporal areas are consistent findings in PTSD [73-75], and consistent with a disrupted capacity for emotional, cognitive and visual processing, which might be relevant to hyperarousal and persistent visual flashback experiences [75,76].

While switching rate showed no significant group-sex interaction, some previous neuroimaging studies of PTSD [22,23,77,78], although not all [79,80], have reported sex differences in brain alterations. The discrepancy may be explained by differences in study design, such as the control group used (non-traumatized healthy controls vs. trauma-exposed normal controls), and type and duration of trauma, as well as technical factors of data acquisition and analysis.

Our study has limitations. First, it was cross-sectional; how brain network dynamics after major life stress evolve and predict future PTSD conversion must be addressed in longitudinal studies. Second, studying participants exposed to the earthquake and free from psychiatric comorbidity increases sample homogeneity, but leaves open the question of whether our findings generalize to PTSD caused by other types of trauma and in patients with psychiatric comorbidities. Third, our research aimed to characterize brain network dynamics that distinguish stressed individuals who do and do not develop PTSD. Without a parallel group of non-traumatized individuals we cannot identify differences between these two groups and healthy controls, to identify how major life stress itself impacts brain network dynamics. Fourth, there was possible effect of degree of exposure to the earthquake, e.g. physical location at the time of the attacks on brain responses [81]. Full study of the different degree of exposure to the earthquake will require a stratified statistical analysis which is beyond the scope of the current study, although it is a focus of ongoing work. Additionally, some confounding factors, e.g. childhood trauma [82], cannot be excluded in our analysis. Recent research has also suggested that different amount of substances used may have different stress-related networks [83]; we did not include this in our evaluation. Future studies should address these issues. Due to the exploratory nature, the likelihood of our study being directly useful in clinical settings is limited.

In conclusion, this study expands understanding of the neurobiology of PTSD by comparing treatment-naïve non-comorbid adult PTSD patients with similarly stressed TENP controls and analyzing topological dynamics of the functional connectome. The findings at global, subnetwork and nodal level, mainly involving the default-mode,

fronto-parietal and limbic networks as well as frontal and temporal regions, reveal PTSD as a disorder of disrupted network integration and impaired emotion processing, in which decreased switching rate at multiple levels is related to the clinical severity of PTSD beyond the acute stress effects. This study adds to the field of psychoradiology [84-86], an evolving subspecialty of radiology aimed to guiding diagnostic and therapeutic decision-making in neuropsychiatric disorders.

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Disclosures

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Tables

Table 1. Demographic and clinical characteristics of participants [a]

Variables	TENP (n = 70)	PTSD (n = 71)	*P*
Age (years) [b]	43.3±10.0 (20-65)	44.1±10.1 (19-67)	0.66 [c]
Gender (male/female)	20/50	23/48	0.72 [d]
Years of education [b]	6.7±3.2 (0-12)	6.9±3.1 (0-16)	0.74 [c]
Time since trauma (months) [b]	11.9±2.6 (8-15)	11.4±2.3 (8-15)	0.26 [c]
PTSD checklist	27.9±6.7 (18-45)	47.5±13.1 (21-80)	<0.001 [c]
CAPS	22.4±11.2 (3-48)	64.1±9.6 (51-95)	<0.001 [c]

[a] Data are presented as mean ± SD (minimum-maximum) unless noted.

[b] Age, years of education and time since trauma defined relative to time of MRI scanning.

[c] *P* obtained by two-sample two-tailed t test.

[d] *P* calculated by two-tailed Chi-squared-test.

Abbreviations: PTSD, posttraumatic stress disorder; TENP, trauma-exposed non-PTSD; CAPS, Clinician-administered PTSD scale.

Table 2. Network switching rate at global and subnetwork levels

Network switching rate	TENP (n=70)	PTSD (n=71)	*P(T)*
Global	0.041±0.007	0.038±0.007	**0.002** (3.232)
Subnetwork			
Visual network	0.040±0.011	0.037±0.010	0.083 (1.744)
Somatomotor network	0.039±0.011	0.035±0.011	0.034 (2.139)
Dorsal attention network	0.040±0.009	0.038±0.010	0.119 (1.568)
Ventral attention network	0.040±0.011	0.036±0.011	0.045 (2.025)
Limbic network	0.044±0.011	0.039±0.009	**0.006** (2.807)
Frontoparietal network	0.044±0.010	0.039±0.009	**0.006** (2.772)
Default mode network	0.042±0.010	0.037±0.009	**0.003** (2.996)
Subcortical network	0.042±0.011	0.040±0.010	0.240 (1.181)

Abbreviations: PTSD, posttraumatic stress disorder; TENP, trauma-exposed non-PTSD.

Table 3. Regions showing lower network switching rate in PTSD compared with TENP

Label ID	Regions	MNI (x, y, z)	TENP	PTSD	*P(T)* value
31	IFG_L	−47, 32, 14	0.046±0.021	0.034±0.019	<0.001 (3.537)
47	OrG_L	−6, 52, −19	0.045±0.022	0.031±0.018	<0.001 (4.165)
99	ITG_L	−59, −42, −16	0.046±0.026	0.033±0.018	<0.001 (3.504)
178	CG_R	5, 22, 12	0.045±0.025	0.032±0.019	<0.001 (3.503)

Abbreviations: PTSD, posttraumatic stress disorder; TENP, trauma-exposed non-PTSD; IFG, inferior frontal gyrus; OrG, orbital gyrus; ITG, inferior temporal gyrus; CG, cingulate gyrus; MNI, Montreal Neurological Institute; L, left; R, right. Regions were defined according to Brainnetome 246 Atlas.

Figure legends

Figure 1. Overview of analysis strategy. The images were preprocessed. The mean values in regions according to the Brainnetome 246 Atlas were extracted to build the dynamic functional matrix for each subject. An iterative ordinal Louvain algorithm was used to track dynamic network modulation over time. Finally, network switching rate was calculated and compared at the global, sub-network, and nodal level. Abbreviations: w, window width; s, window step.

Figure 2. Difference in global and subnetwork-level switching rates between PTSD and TENP. Abbreviations: PTSD, posttraumatic stress disorder; TENP, trauma-exposed non-PTSD.

Figure 3. Difference in nodal-level switching rates between PTSD and TENP. The results were visualized using the BrainNet viewer (http://www.nitrc.org/projects/bnv). Abbreviations: PTSD, posttraumatic stress disorder; TENP, trauma-exposed non PTSD; L, left; R, right; IFG, inferior frontal gyrus; ITG, inferior temporal gyrus; OrG, orbital gyrus; CG, cingulate gyrus. Regions were defined according to Brainnetome 246 Atlas.

Figure 4. Correlation between the global, subnetwork-level and nodal-level switching rate alterations and CAPS scores in the combined PTSD (red circles) and TENP (blue circles) groups. Abbreviations: PTSD, posttraumatic stress disorder; TENP, trauma-exposed non PTSD; CAPS, Clinician-administered PTSD scale; L, left; R, right; IFG, inferior frontal gyrus; ITG, inferior temporal gyrus; OrG, orbital gyrus; CG, cingulate gyrus. Regions were defined according to Brainnetome 246 Atlas.