Alteration Functional and Effective Connectivity Between Visual and Attention-Networks in Cognitively Impaired Patients With Temporal Lobe Epilepsy

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Abstract

Purpose: This paper examines the changes in functional connectivity (FC) and effective connectivity (EC) of the visual (VIS)-network and attention network (AN) in patients with cognitive impairment caused by temporal lobe epilepsy (CI-TLE) through independent component analysis (ICA) and Granger causality analysis (GCA).

Material and methods: Resting-state functional magnetic resonance imaging (rs-fMRI) data and Montreal cognitive assessment (CoMA) were collected from 32 patients with CI-TLE and 29 age-matched healthy controls.

Results: In the VIS network of CI-TLE patients, FC decreased in the right inferior occipital gyrus (IOG) and the left lingual gyrus (LG) and in the right temporal-parietal junction (TPJ) in the Doral attention network (DAN). FC increased in the right middle frontal gyrus (MFG) and right precuneus gyrus (PG). In the DAN, FC decreased in the left superior parietal gyrus (SPG) and right inferior parietal gyrus (LG). GCA revealed the decreased EC from the left LG to the right IOG within the VIS network and from the right inferior parietal gyrus (IPG) of the DAN to the left LG of the VIS network. In contrast, CI-TLE patients demonstrated increased EC from the right SPG to the right IPG within DAN and from the right IPG of the DAN to the right TPJ of the VAN, and from the right TPJ to the left PG within VAN. Compared with healthy controls, Voxel-wise GCA in CI-TLE patients showed positive EC from the left LG to the right SPG. In contrast, increased EC was exhibited from the right TPJ to the right caudate. Pearson analysis showed a negative correlation between the CoMA scores and GC values from the right IPG to the right TPJ.

Conclusion: The results indicate intrinsic brain network connectivity dysfunction in CI-TLE patients and the causal connection abnormality in the resting-state VIS network and AN. Also, it was found that CI-TLE patients possibly have a compensatory mechanism in the above networks. These findings shed new insights on the neuroimaging marker of CI-TLE.

1. Introduction

Temporal lobe epilepsy (TLE) is the most common form of focal epilepsy in adults [1]. Up to 50% of patients with epilepsy are associated with cognitive impairment such as memory, executive, and learning [2], which severely impacts the quality of life. However, the principles and mechanisms of cognition are still not completely understood.

Resting-state functional magnetic resonance imaging (rs-fMRI) has rapidly become one of the most effective research methods to study the pathogenesis of neurological diseases since it is not affected by cognitive impairment and patient cooperation and does not require participants to perform a task. Also, it is often used for the analysis of the spontaneous fluctuations of brain-stimulating activities in resting-state networks (RSNs) [3]. Further, the rs-fMRI provides sensitive biological markings for early diagnosis of nervous system diseases as well as a better understanding of the pathological process of diseases.

Previous researches proved that cognitive impairment is closely related to brain network abnormalities in TLE [4].

Many researchers have divided the RSNs into multiple sub-networks by various methods. Effects on cognitive processing were found in TLE along with the cognitive impairment. Furthermore, in far-reaching cerebral networks, including the default mode network (DMN) [5], executive control network (ECN) [6], and language networks [7]. Some studies reported increased amplitude of low-frequency fluctuation activation (ALFF) within the cognitive function in the brain areas in CI-TLE patients. In contrast, ALFF increased in the brain area of the ECN and DMN, particularly in the middle temporal gyrus, anterior cingulate gyrus, inferior parietal lobe, middle frontal gyrus, and superior frontal gyrus. It indicates that changes in these brain activations compensate for cognitive impairment [8]. Also, it was shown that decreased FC between DMN and ECN can be an important characteristic of RSN in intractable unilateral TLE than healthy controls (HCs) [9]. Spontaneously increased fluctuations in the hippocampal functional MRI signals in cognitively impaired individuals decreased in static hippocampal FC. These alterations result in decreased hippocampal connectivity to bilateral prefrontal and parietal regions in TLE, which may be related to behavior and cognitive impairments [10]. Some studies showed that the primary visual cortex mainly includes the calcarine sulcus, cuneus, and lingual gyrus area. The secondary visual cortex mainly consists of the superior occipital gyrus, middle occipital gyrus, inferior occipital gyrus, and adjacent temporoparietal regions [11].

The visual cortex was known to be responsible for visual information processing related tasks. However, in recent studies, it was found that the visual cortex participates in the completion of the implementation and cognitive function in addition to the visual processing process, the visual space cognitive function [12]. There are two distinct attention networks (AN) involved with multimodal processing in the human brain, including the basic structure of the dorsal attention network (DAN) and ventral attention network (VAN) [13]. DAN supports '*top-down*' goal-directed focus, while VAN supports '*bottom-up*' reorienting to unexpected yet contextually relevant external and internal stimuli [14]. Each is functionally connected with visual networks. The functional connectivity (FC) within the DAN is associated with selective attention or focus and performance on-task. The VAN serves as a gatekeeper to determine if unexpected/distracting stimuli are consistent with task goals but are inhibited by a high working memory load [15]. Limited studies assessed the ANs and VIS networks in patients with CI-TLE.

Abnormal functional connectivity between the attention and VIS networks was related to cognitive dysfunction [16]. Also, many methods were explored to process resting-state data: FC, local consistency, low-frequency amplitude, and independent components analysis (ICA). Among them, the ICA is a typical rs-fMRI analytic method to determine the functional networks [17], which could reflect the FC of the brain regions. In line with the previous ICA research, evidence of the default mode network (DMN), DAN, visual-auditory, motor-sensory regions, and the self-reference system were found [18]. The FC was investigated to define the interactions between the active brain regions and functional networks using ICA while not determining causal interactions [19]. However, effective connectivity (EC) allows for discussing the relationship between the brain regions of difference [20].

Granger causality analysis (GCA), requiring no prior knowledge, has been typically used to measure EC and display causal influence flow of information among brain regions [21]. The GCA of the EC has been widely applied in nervous system diseases. For instance, Mengshi Dong et al. [22] adopted GCA to testify the inhibitory influence disrupted from the left middle frontal gyrus to the right amygdala in generalized anxiety disorder. Previous studies based on GCA indicated that Alzheimer's disease causes less efficient information transmission [23]. However, in the study, the GCA was not used to study the information flow based on rs-fMRI in CI-TLE patients.

Our study speculated that the EC between the VIS network and AN is interrupted in CI-TLE patients. In order to further understand the patient's brain network disorders, we analyzed FC and EC alteration between different regions of interest (ROIs) of the resting-state VIS network, VAN and DAN. Also, the GCA method was used to explore possible causal relationships across brain networks. We also investigated the relationship between EC in the VIS network, DAN, VAN, and Montreal cognitive assessment(CoMA) to establish whether cognitive performance variations are related to effective neural network connectivity. The results can provide new insight into the neuropathophysiological mechanisms of visual and attention network dysfunction in CI-TLE patients.

2. Materials And Methods

2.1 Subjects

In this research, the Ethics Committee of the First Affiliated Hospital of Guangxi Medical University approved the experiment; all participants and the immediate family were recruited from the First Affiliated Hospital of Guangxi Medical University clinic and from Jan. 2019 to Mar. 2021. Table 1 shows the demographic and neuropsychological data of the groups (CI-TLE and healthy controls). All patients were diagnosed based on the diagnostic criteria of the International League Against Epilepsy [24]: 1) Participants had a diagnosis of unilateral focal onset TLE based on typical clinical manifestations, and electroencephalograms (EEG), MRI images. 2) Participants were between 18 and 55 years of age. 3) All participants were right-handed. 4) The distinction between CI-TLE patients and TLE is true according to the mini-ental state examination (MMSE) score. Participants with epilepsy associated with MMSE score ≤ 26 were classified as CI-TLE. Patients were excluded if they had 1) MRI images indicating structural abnormalities, including low-grade tumors, vascular lesions, hemorrhagic stroke, and encephalopathy; 2) left-handedness; 3) a history of psychiatric disease or trauma.

2.2 Neuropsychological test

The Chinese version of the Montreal cognitive assessment (MoCA), the clock drawing test (CDT), and the semantic fluency test (verbal fluency test, VFT) were used. The same physician evaluated the cognitive function of all 61 subjects before the MRI scans. The highest score for the MoCA was 30. Any participant with a score of less than 26 was regarded as exhibiting cognitive dysfunction.

2.3 Scan acquisition

The Achieva 3.0T scanner (Philips, Amsterdam, the Netherlands) with a 12 channel head coil was used to acquire all MRI images. Resting-state fMRI refers to the patient lying in the MRI scanner in an awake state throughout the scanning process. The subjects were relaxed without any task or systematic thinking for scanning. All functional images were acquired by using an echo-planar imaging sequence with the following conditions: TR/TE= 2000/30 ms, 31 slices and 180 volumes, echo time=30 ms, repetition time=2000 ms, flip angle(FA)=90°, slice thickness=3.5mm, the field of view (FOV)=220×220mm², matrix=64×64, and the total 180 dynamics.

2.4 Data Preprocessing

All rs-fMRI images were preprocessed using the DPABI library of the Matlab platform (<http://rfMRI.org/DPABI>). The preprocessing is as follows. 1) DICOM data is first converted to NIFTI format. 2) Then, each subject's first ten time points were discarded for instability of the early scanning signals. 3) Time differences in image acquisition were corrected during slice timing. 4) head motion correction was conducted, where the images were excluded for head movement > 1.5 mm and/or rotation angle >1.5°. 5) functional images were registered to make the format size uniform, where each T1 image was segmented from the white matter, grey matter, and cerebrospinal fluid. 6) Each EPI image was spatially normalized to Montreal Neurological Institute (MNI) coordinates, and the resolution was resampled at 3 mm × 3 mm × 3 mm. 7) Lastly, the rs-fMRI data were spatially smoothed with a 6 mm full width at half-maximum (FWHM) Gaussian kernel. Gaussian core to reduce spatial noise.

2.5 ICA

Group ICA in the GIFT Matlab toolbox was used to conduct ICA (<http://mialab.mrn.org/software/gift>). The group ICA estimated 30 spatially independent components using the info-max algorithm in all participants. Subsequently, Principal component analysis was applied. According to the template selection guide [25], we selected independent components representing the VIS network and AN that play an important role in visual attention. Visual attention was derived through the ICA of rs-fMRI data. Statistical analysis of group ICA results was conducted with the REST Matlab toolbox (<http://www.restfmri.net/forum/Rest>). The best-matched independent maps were created, and the threshold was determined by the single sample T-test. Mapping of the most matching components ($p < 0.05$, corrected for false discovery rate (FDR)) was created to identify the VIS network, ventral network, and DAN. Lastly, the 2-sample t-test at the group level was conducted to study the brain areas of difference. Meanwhile, we extracted ROIs significantly correlated with the VIS networks, VAN, and DAN according to ICA data.

2.6 GCA

The principle of the GCA is that directional causal influence from time series A to time series B can be inferred if another time series can correctly predict another time series. REST-GCA software (<http://www.restfmri.net>) was adopted, and the GCA is processed as follows. First, linear drift was applied to make the causal process more stable. Then, belt-pass filtering eliminated linear low-frequency drifting (Width =

0.01~0.08 Hz, and TR=2 s, breathing, and other high-frequency noise. Lastly, the parameters of the AN and VIS were computed using GCA Toolbox.

2.7 Statistical Analysis

Statistical analysis was conducted on SPSS 22.0. Demographic and clinical data were analyzed using the two-sample t-test or χ^2 test between the groups. The data with a p-value less than 0.05 was considered statistically significant.

3. Results

3.1 Demographic and Clinical Information

Table 1 summarizes the demographic, clinical, MMSE, and MoCA scores between the CI-TLE patients and HC groups, indicating no significant difference between them in age and education($P>0.05$). In contrast, MoCA scores were significantly lower in the CI-TLE group than in the HC group ($P<0.05$). Also, the MoCA scores of the CI-TLE group were a little lower than the healthy control group ($t=-31.455$, $p<0.05$).

Table1 Demographic and clinical information of study subjects($\bar{x}\pm s$).

Variable	TLE (n=32)	HC (n=29)	t 值	p 值
Gender (M/F)	18/14	16/13	–	–
Education (years)	11. 51 $\pm$ 2. 95	12. 76 $\pm$ 3. 26	0. 143	–1. 507
Duration of epilepsy (years)	9. 13 $\pm$ 1. 23	–	–	–
Age (years)	23. 90 $\pm$ 2. 75	23. 7 $\pm$ 3. 26	0. 816	0. 235
Handedness (R/L)	32/0	29/0	–	–
MoCA score (mean $\pm$ SD)	15. 17 $\pm$ 1. 48	26. 79 $\pm$ 1. 11	–31. 455	0. 00

Demographic and neuropsychological characteristics of CI-TLE patients and healthy controls. The montreal cognitive assessment–MoCA– scores in patients and controls were based on the results of 32 and 29 participants, respectively. R: right sided; L: left sided;M:male;F:false;p<0.05–the difference was statistically significant.

3.2 ICA Results

Group statistical analysis was performed between the CI-TLE and healthy control groups for each resting-state VIS network and AN using ICA (see Figure 1). Figure 2 shows the results of the group ICA analysis for the resting-state VIS network and AN. Compared with the healthy control group, CI-TLE patients showed decreased FC in the right inferior occipital gyrus (IOG-R) and left lingual gyrus within VIS ($p<0.05$); decreased FC in the right TPJ within the VAN ($p<0.05$); decreased FC in the right SPG and right IPG within DAN($p<0.05$). CI-TLE patients showed significantly increased FC values in the right MFG and

the left PG within VAN ($p<0.05$). The brain regions with altered functional connections within the VIS networks are provided in Table 2, Figure 3, and Figure 4.

Table 2 Regions of interest showing significant functional connectivity within visual network and the visual networks in group independent component analysis in healthy controls as compared to CI-TLE patients.<

Brain network	Brain area	MNI coordinates			t-value	Cluster size
		x	y	z		
VIS	right inferior occipital gyrus	43	-70	-11	-4.23	49
	left lingual gyrus	-27	18	-38	-5.74	68
VAN	right middle frontal gyrus	35	52	19	9.16	123
	right temporal- parietal junction	-63	-48	42	-7.78	102
	right precuneus gyrus	-12	-69	30	7.32	94
DAN	right superior parietal gyrus	-22	-56	60	-8.14	117
	right inferior parietal gyrus	30	-49	52	-6.33	75

ICA=independent component analysis;VIS=visual network;VAN=ventral attention network ; DAN=dorsal attention network; MNI Montreal Institute of Neurology.

3.3 GCA Results

Compared with the HC group, the CI-TLE group showed significantly increased causal connectivity from the right SPG to the right IPG within DAN ($p<0.05$). Furthermore, compared to the healthy control group, the right IPG showed increased causal connectivity to the TPJ in patients with CI-TLE, which was extracted from the DAN to the VAN ($p <0.05$). The causal connectivity was increased from the TPJ to the left PG within VAN. However,compared with the HC group, the CI-TLE group showed a significant decrease from the left LG to the right IOG within VIS. The right TPJ showed a decreased causal connectivity to the left LG, which was extracted from the DAN to the VIS. The GCA value revealed the enhanced EC between ROIs, as shown in Table 3 and Figure 5.

Table 3

Significant differences in ROI-wise GCA results between default mode network and attention networks between patients and healthy controls.

Causal flow between brain networks	Inter-brain causal flow	t-value	p-value
VIS→VIS	LG-L →IOG-R	-5.36	0.00
DAN→DAN	SPG-R→IPG-R	4.25	0.00
DAN→VAN	IPG-R →R-TPJ	6.09	0.00
DAN→VIS	IPG-R→LG-L	-5.12	0.00
VAN→VAN	R-TPJ→PG-R	4.94	0.00

VIS=visual network;VAN=ventral attention network ; DAN=dorsal attention network; L=left; R= right; LG-L: left lingual gyrus;IOG-R:right inferior occipital gyrus;SPG-R:right superior parietal gyrus;IPG-R :right inferior parietal gyrus;R-TPJ:right temporal- parietal junction.GCA:granger causal analysis.

3.4 Voxel-wise GCA

Seed-to-whole-brain analysis.

The affected FC abnormal area was set as the seed zone for the analysis. The seed-to-whole-brain analysis identified many cortical areas and subcortical structures driven by the seed region in CI-TLE patients (Figure 2b). CI-TLE patients showed significantly increased EC from the left LG to the right SPG and statistically enhanced EC from the right TPJ to the right caudate, compared to healthy controls (Table 4), concurring with the existing VIS and VAN.

Table4 Significant group differences in voxel-wise GCA between patients and healthy control group

Brain region (ROI)	MNI coordinates			t-value	p-value
Effective connectivity	x	y	z		
from seed (L-LG) to whole brain					
the R-SPG	-20	-54	59	2.51	0.02
from seed(R-TPJ) to whole brain					
right the caudate	4	13	9	2.27	0.03

R-TPJ: right temporal- parietal junction; L-LG: left lingual gyrus; R-SPG : right superior parietal gyrus GCA: Granger causal analysis.

Whole-brain-to-seed analysis.

The whole-brain-to-seed analysis showed no negative/positive correlation of anomaly driving effect existed from the whole brain to seed in the CI-TLE patients.

4. Discussion

As a neuroimaging marker for CI-TLE patients, this paper studies abnormal functional and EC between the VIS network and AN via the combination of ICA and GCA. The results indicate that visual attention was derived into VIS, VAN, and DAN, i.e., the relationship between changes in networks and cognitive performances. Previous studies have described that CI-TLE may influence brain networks or the core brain regions [26]. However, little work was done for a complete description of functional and EC in VAN in CI-TLE. ICA was used to evaluate FC changes in the abnormal brain based on the resting-state visual network. In terms of visual network C, CI-TLE patients showed significantly decreased FC values of the right IOG and left LG within the VIS network, indicating that CI-TLE patients have most likely caused a restrained VIS network. This paper revealed no FC-enhanced brain region exists, which is consistent with previous studies [27]. Hwang et al. [28] conducted cognitive slowing and its underlying neurobiology in TLE, which reacted that cognitive impairment was related to decreased FC in the primary visual network. ALFF in the medial occipital gyrus reduced and related to cognitive scores, suggesting it may be caused by influencing the VIS network, which is related to the cognitive function [29]. In this study, abnormal FC in left LG with the VIS network in CI-TLE patients and abnormal cortical integrity demonstrate that patients exhibit visual space damage. Accordingly, the reduced FC in the visual cortex and visual pathways could be caused by visual information dysfunction.

In the VAN, the CI-TLE patients showed decreased FC values of the right TPJ and increased FC values of the signal at right MFG and left PG. Several studies have observed that the ventral network might be more lateralized to the right brain hemisphere, and functional imaging research has consistently discovered that the right hemisphere activated the temporoparietal brain regions. In recent studies, the subserve attentional functions and the activation of bilateral TPJ in the attentional reorienting task and rare abnormal stimulus were found [30]. The main regions of the VAN are consistent with the literature [31], suggesting that the abnormal FC in the TPJ of CI-TLE patients could be related to the recurrent seizures or duration of seizures. It can be an important pathophysiological mechanism based on the foundation for cognitive behavior impairment in CI-TLE patients.

The increased FC in the right MFG and right PG implies a compensatory role for the VAN during the initial stages of cerebral diseases, which is extensively supported by results of AN area recruitment during attention tasks in temporal epilepsy patients [32]. Furthermore, this study also noted that bilateral SPG in DAN. The DAN is consistently involved in verbal and visual working memory (WM) tasks, which is task-related. In the top-down control of attention, the DAN manipulates encoding load and memory control requirements during a short-term probe recognition task for sequences of auditory or visual stimuli [33]. Veldsman et al. [34] indicated that this prominent node, the SPG, would show hypoconnectivity to the rest of the network in CI-TLE and that hypoconnectivity would be associated with cognitive impairment [34]. The SPG is mainly related to attentional orientation, and the SPG of brain regions usually refers to the ability to select target information from the received sensory information. Orientation dysfunction leads to greater sensitivity. The results are consistent with previous studies that account for an attentional bias for epileptic seizure irritate in CI-TLE [35]. Our study demonstrated that the information flow abnormality between the visual attention functions and intrinsic brain networks is an underlying neural basis connected with cognitive impairment in CI-TLE patients.

The GCA is an efficient and straightforward analysis of the rs-fMRI data in the brain functional networks, providing a summary of casual information flow in the epileptic network [36]. This study reveals changes among the VIS, DAN, and VAN based on ROI-wise GCA in the direct causal flow in CI-TLE patients. A more complicated causal flow was drawn between internal networks that appeared in CI-TLE patients compared with the healthy controls group. GCA results showed the unidirectional connection between the DAN, VAN, and VIS networks. Also, SPG with DAN, TPJ within VAN, and left LG within VIS with regions have significant implications in developing specialized VAN. In patients, EC from the right SPG within the DAN to the TPJ within the VAN was increased compared with the healthy controls group. In contrast, EC decreased from the PG to the left LG within the VIS network. Previous literature showed a higher FC between the DAN and VAN and a lower FC between the DAN and VIS networks. Our causal analysis also supports this conclusion. Similarly, GCA showed EC flow from the right SPG to the right IPG within DAN and from the right TPJ to the right PG within VAN. For the DAN and VAN, the enhanced capacity to adjust the DAN in the case of frequent seizures or epileptic seizures is related to the compensation of DAN dysfunction. Recent rs-fMRI researches indicated the switching of information between the DAN and the VAN. We found that an enhanced interaction between the two brain network systems enables to compensate for the control of attentional dysfunction associated with top-down goals and stimulated bottom-up sensory [37]. Also, we observed a decrease from the left LG to the right IOG within the VIS network, indicating reduced EC can be connected with the disrupted network interactions in the VIS networks in patients. In summary, our results suggest that the attentional control system is potentially used to compensate for visual cortex deficits.

The voxel-wise GCA was adopted to investigate the causal information flow between the abnormal information flow of important brain areas and the entire brain areas, separately. A significant excitatory effect was shown from the left LG to the right SPG in CI-TLE patients compared to the healthy control group. Meanwhile, the DAN is composed of the important anatomical structure of the SPG, involved in controlling goal-oriented top-down attention deployment [38]. Previous fMRI research indicated that SPG plays an important role in transforming the VIS network and the DAN. Our results depicted abnormal EC with VIS or DAN, which can be related to cognitive dysfunction [39]. Another analysis showed that regions of the DAN are involved in establishing and maintaining preparatory signals for spatial attention—which causally modulates activity in the visual areas [40]. Those results imply that increased causal EC from the left LG to the right SPG can cause damage to visual attention function in CI-TLE patients. In addition, it was testified that the right TPG was positive feedback in CI-TLE patients, compared with the healthy control group. The TPG plays a key role in the VAN, which controls stimulus-driven bottom-up attention deployment [41]. In our previous study, evidence from neuroimaging studies suggests that the TPJ participates in a broad range of behaviors and functions, from bottom-up perception to cognitive capacities, uniquely human. The organization of the TPJ is challenging to study due to the complex anatomy and high inter-individual variability of this cortical region [42]. We deduced that such an enhanced EC from the right TPJ to the right caudate could be used as a potential adaptive mechanism to better express visual attention tasks. Further research is needed to confirm this speculation in the future.

Fortunately, the data suggest EC between the DAN and DAN can be used as a potential pathogenesis mechanism of recurrent seizure consumption induced cognitive dysfunction.

5. Conclusion

This paper explores FC and EC of the VIS network, VAN, and DAN between CI-TLE patients and the healthy control group. CI-TLE Patients showed abnormal FC enhancement and causal connectivity in the VIS network, VAN and DAN. It is supposed that recurrent seizures play the destruction of the aforementioned brain networks. Simultaneously, self-modulation takes to compensate for a decrease in cognitive function. Our research can provide a better neural imaging marker of CI-TLE. However, our study had some limitations. Statistical analysis was challenging due to the relatively small sample size and the disproportionate number of subjects. Future works will distinguish EC changes between TLE and CI-TLE patient groups and between right CI-TLE and left CI-TLE. Further, the causal relationship between CI-TLE and abnormal EC will be distinguished using cross-sectional in the sample size.

Declarations

Ethics approval and consent to participate

The First Affiliated Hospital of Guangxi Medical University Ethics Committee approved the study and written informed consent was obtained from all participants prior to this study [NO. (2018-KY-040)]. All the methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable

Availability of data and material

All data is available on request to the corresponding author.

Competing interests

The authors declare they have no competing interests.

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Authors' contributions

Yanchun Jiang conceived and Jinou Zheng designed the study. Yanbo Zhang, Nieliluo performed the research. Yanchun Jiang and HuihuaLiu contributed to data analysis. Yanchun Jiang and HuihuaLiu supervised the data analysis. Yanchun Jiang wrote the original article. All authors reviewed, edited the manuscript gave final approval of publication.

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Figures

Figure 1

Illustration of three independent components (ICs) identified in our study. There are three separated maps showing the brain regions included in each component (VIS, DAN and VAN), thresholded at $p < 0.05$ FDR corrected. DAN: dorsal attention network; VAN: ventral attention network; VIS network: visual network.

Figure 2

Brain regions showed the significantly different in functional connectivity between CI-TLE patients and healthy control group; Areas of the brain with altered functional connectivity with visual network.

Figure 3

Brain regions showed the significantly different in functional connectivity between CI-TLE patients and healthy control group; Areas of the brain with altered functional connectivity with ventral attention network.

Figure 4

Brain regions showed the significantly different in functional connectivity between CI-TLE patients and healthy control group; Areas of the brain with altered functional connectivity with dorsal attention network.

Figure 5

DAN:dorsal attention network;VAN:ventral attention network;VIS network:visual network;R:right;L:left;LG:lingual gyrus;IPG:inferior parietal gyrus;IOG:inferior occipital gyrus;SPG:superior parietal gyrus;TPG:right temporal- parietal junction;PG:precuneus gyrus.