

## Original Article

# An event-related potentials study on the attention function of posttraumatic stress disorder

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**Abstract:** Objective: In order to examine the functional defects and attentional bias in post-traumatic stress disorder (PTSD) patients, event-related potentials (ERP) of attention was investigated. Methods: Three groups of emotion pictures, positive, negative (or violent) and neutral, were viewed by 19 PTSD patients and 15 normal controls. Each picture had a frame, and participants reacted to the color of the frame by clicking buttons. Electroencephalogram (EEG) and behavior data were recorded. Peak latencies and amplitudes of P2 were measured. Results: For the three groups of pictures, PTSD patients had longer reaction time than the controls. Significant difference was found between PTSD patients and controls in response to violent, positive and neutral pictures.

**Keywords:** Post-traumatic stress disorder, attention dysfunction, event-related potentials, P2

## Introduction

Post-traumatic Stress Disorder (PTSD) is an anxiety disorder, a delayed-onset and long-term mental or psychological disturbance, which may develop within a few days or up to 6 months after sudden, threatening or catastrophic life events [1]. In short, PTSD is a post-traumatic psychological imbalance. The three "clusters" of symptoms associated with PTSD are re-experiencing the traumatic events (flashbacks), avoidance and hypervigilance. Generally, acute stress disorders (ASD) develops a few days after the traumatic events. If the symptoms persist over a month, it can be diagnosed as PTSD.

Attentional bias is the tendency of hypersensitivity towards certain specific stimulus, along with selective attention. Emotional stimuli attract more attention or occupy more attentional resources. When different stimuli exist in the environment, some people may prioritize negative stimuli, which is defined as "negativity bias". Many studies indicate that PTSD patients, and individuals who have been through traumatic events but do not have PTSD, tend to have attentional bias towards negative stimuli related to the trauma [2-5].

Due to the specificity and severity of PTSD, there is a growing number of studies focusing on the cognitive foundation and neurological mechanism for PTSD. Some studies suggest that PTSD patients are usually suffering from significant impairment in cognitive function [6]. For example, PTSD patients may have defects in sustained attention [7, 8] and executive function [9]. They tend to have more attentional bias, stress response and memory bias towards information related to the trauma. Vasteding et al used the method developed by Mirsky et al to demonstrate the impaired attentional function in PTSD patients [8, 10]. Attention function has been extensively studied as one of the basic cognitive functions. There have been studies focusing on different aspects of attentional function of PTSD patients. Study from Leskin and White indicates that PTSD patients have significantly delayed response under different conditions, compared to control group; however, there is no significant difference under the same condition between the two groups [9]. These results indicate that PTSD patients may have specific impairment in inhibiting irrelevant or interrupting information. Study from Shucard and colleagues suggests that, impaired attention in PTSD patients is due to delayed central

**Table 1.** Responses between PTSD patients and control

Type of pictures	PTSD (Mean $\pm$ SD)	Control (Mean $\pm$ SD)
Negative	796.22 $\pm$ 410.997*	667.65 $\pm$ 174.438
Positive	798.70 $\pm$ 451.875*	675.45 $\pm$ 390.880
Neutral	795.28 $\pm$ 707.017*	680.99 $\pm$ 214.722

\*P&lt;0.001.

neural processing, when inhibitory response is needed, so that irrelevant information cannot be filtered [11]. Their study also indicates the impaired attention in PTSD patients is not only limited to trauma related information. In psychopathological studies on PTSD patients, the theory of cognitive model purposes that PTSD is caused and maintained by attentional bias towards trauma related information. Some studies also indicate that, PTSD patients have attentional bias towards trauma related information. Study by Stanford et al in combat-related PTSD patients suggests that, compared to emotionally neutral information, PTSD patients have significant attentional bias towards threatening stimuli [12].

The studies mentioned above focus on behavior analysis. Moreover, imaging studies on PTSD have also made enormous progress. PTSD patients have significantly reduced hippocampus volume [13-17]. Study by Ruocco et al also shows reduced amygdala volume in PTSD patients [18]. El Khoury-Malhame et al focus on amygdala activity of PTSD patients, and report the correlation between the severity of the symptoms and attentional bias [19]. Emotion-face expression matching and attention target detection were performed in PTSD patients and control group, using functional magnetic resonance imaging (fMRI). Compared to the control group, amygdala activity in the PTSD patients was significantly increased, which was positively correlated with anxiety score, PTSD symptoms and disengagement index. Most importantly, these results provide initial support that amygdala plays a vital role in threat related attentional bias in PTSD patients. In recent decade, event-related potential (ERP) plays a significant role in studying abnormal neurophysiological events during information processing in PTSD patients. A widely used model is Stroop effect. A Stroop study shows that PTSD patients have delayed response and attentional bias towards threat relevant words

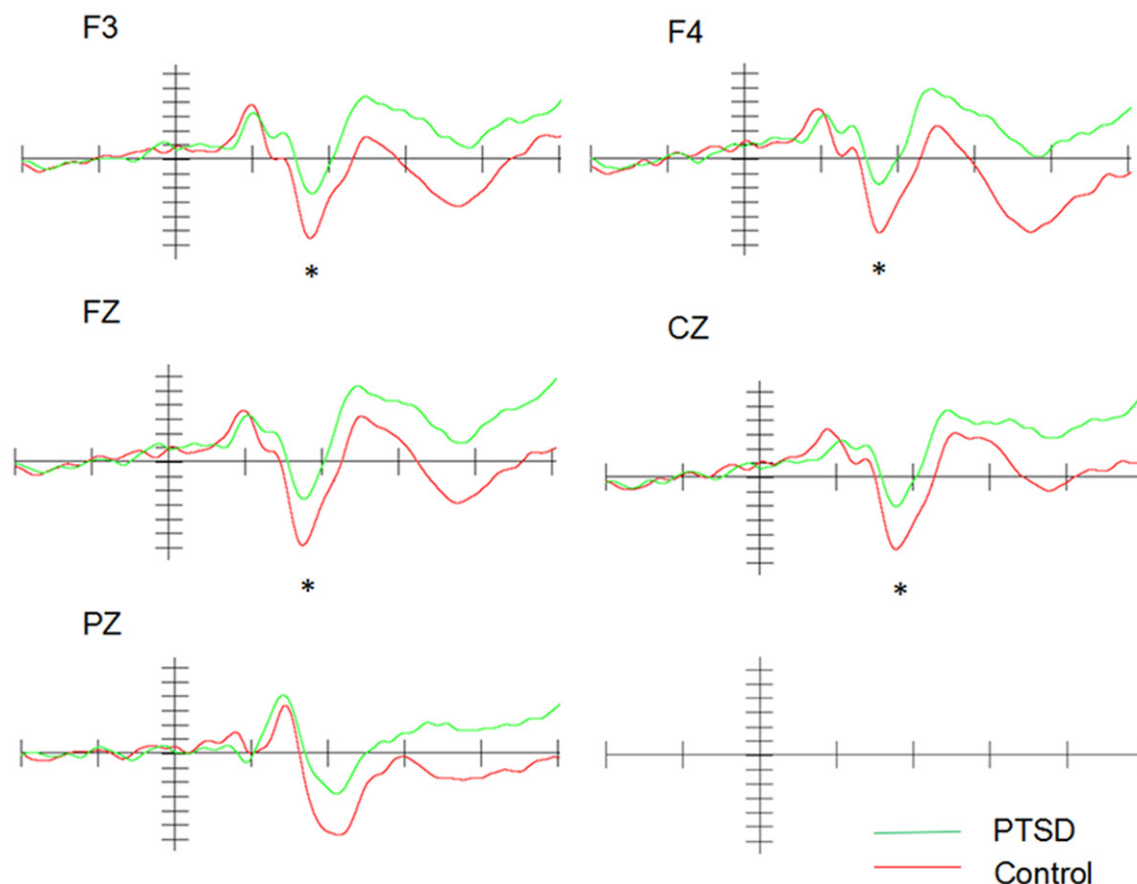
[20]. Some studies suggest that negative attentional bias induced by threatening stimuli shows earlier P2 peak latencies on ERP, compared to neutral or positive emotion [21-24]. Negative emotion attracts attention much faster. To our knowledge, Stroop interference effect related ERP parameters in PTSD patients are P2 and N280-380 [25]. P50 indicates the defect in sensory gating in PTSD patients [26, 27]. P2 and P3 are considered to reflect cognitive processing and closely related to attention. Study by Kimble et al shows that PTSD patients have negative expectation towards threatening stimuli [28]. Compared to normal individuals, PTSD patients produce smaller N400 wave, which is also supported by behavior analysis. The brain regions related to attention may be compromised in PTSD patients. These results are contributed by the advancement in imaging technology and functional imaging analysis, mainly MRI imaging. When processing and responding to threat and emotion-relevant information, amygdala and orbitofrontal cortex are not controlled by self-attention. However, other brain regions involved in threat information processing, e.g. upper surface of temporal lobe and anterior cingulate cortex, are regulated by self-attention. These brain regions are overlapping with the impaired regions in PTSD patients. With the inconsistent conclusions from previous studies, in order to further identify the difference in attention function and attentional bias between PTSD patients and normal people, we have used Stroop emotion test in our study.

## Methods and subjects

### Subjects

Patients who have suffered from violence and sought treatment in Chinese People's Liberation Army (PLA) General Hospital were selected in our study. The diagnostic criterion for PTSD is DSM-IV, along with PCL-C index for screening. Through diagnosis by physician specialists, 19 patients were identified as PTSD (age 33.8 $\pm$ 3.8) and 15 as healthy control (age 34.4 $\pm$ 3.9, *p*-value =0.632, Mann-Whitney test). Participants in both studied groups were all right-handed, normal or corrected visual acuity. There was no colorblind for red and green, no history for neurological or psychological diseases. They all had educational level above junior high school.

## ERP study of PTSD



**Figure 1.** ERP in PTSD and control in response to violent pictures. ERP was recorded when PTSD and control groups were viewing the violent pictures. Green lines represent the amplitude of each wave for PTSD patients and red lines for the control. \* $P < 0.05$ .

There was no statistical difference in age, occupation, marital status, educational background, medication or psychiatric condition between the two groups.

### Material

Experimental materials included negative (violence photos), neutral (cups) and positive pictures (mother love), with 20 pictures in each group. Every picture had a color frame, red, yellow or blue. The color of frame was randomly matched with the pictures. Pictures were selected from International Affective Picture System (IAPS). Negative pictures were assessed and screened by 50 participants, with average arousal  $5.34 \pm 0.73$  and average valence  $2.57 \pm 0.32$ . After being processed by Photoshop, each picture was adjusted to the same size, brightness and contrast. The eyes of each participant were one meter away from the computer screen. The room was quiet and dark.

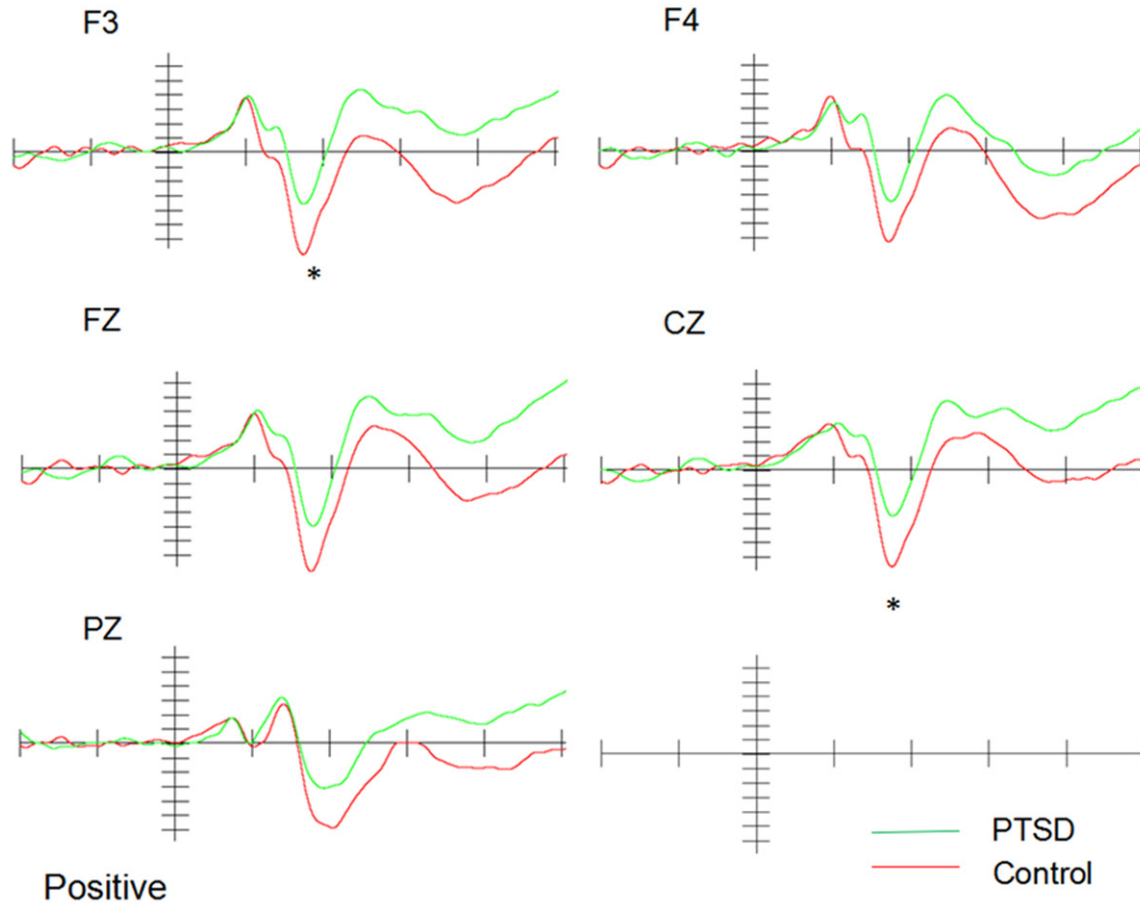
### Program

The experimental program was designed by E-Prime software. There was a practice experiment before the formal experiment started. The participants only responded to the color of the photo frame by clicking buttons, without noticing the content of the photos.

### Data collection

Experimental data was collected by a 32-channel Electroencephalograph (EEG) recording and analysis system (NeuroScan). Reference electrode was placed on the left mastoid. Horizontal electrooculogram (HEOG) and vertical electrooculogram (VEOG) were both double-electrode recording. The electrodes for HEOG were placed on the outer canthi of both eyes. The electrodes for VEOG were placed on 1.5 cm infra- or supra-orbital ridges of left eye. The electrical impedance for scalp was less than  $5 \text{ k}\Omega$ , with low-

## ERP study of PTSD



**Figure 2.** ERP in PTSD and control in response to positive pictures. ERP was recorded when PTSD and control groups were viewing the positive pictures. Green lines represent the amplitude of each wave for PTSD patients and red lines for the control. \* $P < 0.05$ .

pass filtering and sampling rate at 1000 Hz. There was a 400 ms interval before the first image appeared, and a 1000 ms interval between every two images. The artifacts from electrooculographic (EOG) and others were manually removed. The EEG activities for each picture was added up and averaged to generate ERP wave.

### Data analysis

The brain regions for attention function are mainly in the forehead and the top center of the head. Therefore, our study focused on these regions. F3, Fz, F4, Cz and Pz were selected as 5 electrode points. SPSS 19.0 was used to perform analysis of variance (ANOVA) with repeated measures for the peak latencies and average amplitude of P2 wave induced by the three groups of pictures. The internal factors were

the three groups of emotion pictures (positive, neutral and negative), and transverse position of the electrodes (Fz, Cz and Pz).

## Results

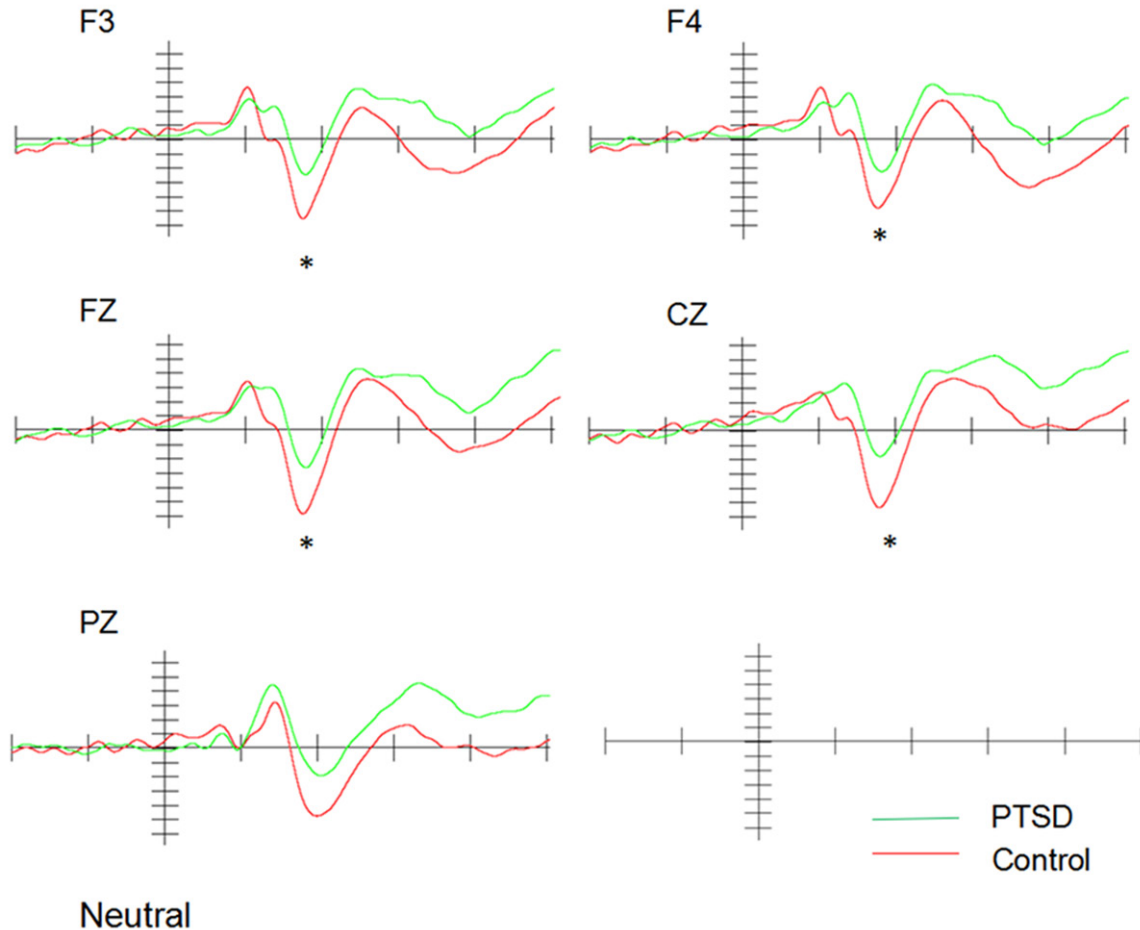
### Behavior analysis

As shown in **Table 1**, PTSD patients had significantly increased responses to all three groups of emotion pictures, compared to the control group.

### Basic characters of ERP

As shown in **Figure 1**, there was significant difference in F3 ( $F = 6.310$ ,  $P = 0.017$ ), Fz ( $F = 5.487$ ,  $P = 0.026$ ), F4 ( $F = 6.035$ ,  $P = 0.020$ ) and Cz ( $F = 4.481$ ,  $P = 0.042$ ) between the two groups in response to violent pictures. **Figure 2** indicates

## ERP study of PTSD



**Figure 3.** ERP in PTSD and control in response to neutral pictures. ERP was recorded when PTSD and control groups were viewing the neutral pictures. Green lines represent the amplitude of each wave for PTSD patients and red lines for the control. \* $P < 0.05$ .

significant difference in F3 ( $F=5.591$ ,  $P=0.020$ ) and Cz ( $F=5.090$ ,  $P=0.031$ ) between the two groups in response to positive pictures. **Figure 3** shows significant difference in F3 ( $F=6.150$ ,  $P=0.019$ ), Fz ( $F=6.001$ ,  $P=0.020$ ), F4 ( $F=5.211$ ,  $P=0.029$ ) and Cz ( $F=6.861$ ,  $P=0.013$ ) between the two groups in response to neutral pictures. For all the participants, there was no significant difference in P2 peak latencies among the three groups of emotion pictures ( $F=0.278$ ,  $P=0.759$ ), and no significant difference between the two groups of participants, based on ANOVA test. There was significant difference in Fz, Cz and Pz representative brain regions ( $F=8.687$ ,  $P=0.001$ ), which indicated the significant difference in latency phase in forebrain, midbrain and hindbrain, in response to the three groups of pictures. There was significant difference in average P2 amplitude induced by

the three groups of emotion pictures ( $F=9.891$ ,  $P=0.0001$ ), and also significant difference between PTSD and control group ( $F=5.761$ ,  $P=0.022$ ). There was no statistical interaction among Fz, Cz and Pz represented brain regions. Data were presented in **Tables 2** and **3**.

### Discussion

This study is a dynamic experiment, which focuses on the attention process for PTSD patients to view the pictures, instead of internal factors. The most studied component, P3, will be our future research direction. In this experiment, for the three groups of emotion pictures, we have observed significant difference in the average amplitude of P2 wave for the two groups of participants. The amplitude of P2 wave generated by the three groups of pictures is, neutral pictures < negative pictures < posi-



## ERP study of PTSD

**Table 2.** P2 latency between PTSD and control group

	Fz (Mean ± SD)	Cz (Mean ± SD)	Pz (Mean ± SD)
PTSD			
Negative	168.74±23.570	178.63±13.154	187.79±37.098
Positive	173.79±15.918	178.21±14.351	185.68±33.225
Neutral	174.37±17.544	181.26±13.353	185.32±22.246
Control			
Negative	175.87±16.698	184.40±11.673	188.80±50.519
Positive	174.40±19.194	179.40±12.721	177.73±43.649
Neutral	178.80±11.767	183.80±11.827	173.07±47.723

**Table 3.** Average P2 amplitude between PTSD patients and control (x±s)

	Fz (Mean ± SD)	Cz (Mean ± SD)	Pz (Mean ± SD)
PTSD			
Negative	1.0389±3.69881	0.6516±3.50233	0.6884±4.86580
Positive	2.5147±4.18575	1.9589±3.8824	1.6168±4.76933
Neutral	1.5379±3.44213	0.7221±3.89754	0.2763±5.21755
Control			
Negative	4.2660±4.333.3	3.5340±4.44413	3.0747±4.12119
Positive	5.3440±4.06699	4.9953±3.90726	3.3773±3.83606
Neutral	4.4353±3.40141	4.0473±3.36833	1.8953±3.75776

tive pictures. There was also significant difference between the two groups, with PTSD patients having smaller P2 wave than the control group. These results are slightly different from previous studies, but mostly consistent, which indicates significant difference between PTSD patients and normal individuals. PTSD patients have more negativity bias, which produce bigger amplitude in ERP. However, Chen et al show that PTSD patients have reduced amplitude of P2 and P3 wave [29]. Study by Araki et al shows that PTSD patients have smaller P300 wave, compared to individuals who have been through traumatic events but do not develop PTSD [30]. The P300 amplitude at Pz electrode is significantly correlated to the score of avoidance/numbness symptoms. He is also the first person to discover that the electrophysiological defect in the attention function of PTSD patients may be associated with potential changes in their brain structure. ERP study by Carretie et al also confirms that, in normal individuals, the negativity bias is closely correlated with the intensity of P200 [22]. Study by He et al focuses on the effect of positive emotion on extraverted individuals, and shows that positive stimuli with different intensity result in different P2 amplitude [31]. Higher effect is asso-

ciated with higher amplitude. There is statistical difference among Fz, Cz and Pz represented brain regions, with Fz>Cz>Pz. This suggests the difference between different regions of the brain, and prefrontal cortex generates bigger P2 wave. Since processing of attention is mostly in prefrontal cortex, Fz generates the biggest P2 wave. For peak latencies, there was no significant difference for the three groups of emotion pictures between the two groups of participants. This is consistent with the study by McNally et al [32]. His study shows no difference in response to positive pictures, which may be due to higher arousal by positive words than neutral words. There may also be difference in arousal effect between positive words and threatening words. Based on previous studies, the arousal effect of stimuli, rather than emotional effect, plays an important role in interrupting attention [33].

A major defect for PTSD is determined by the bias of cognition and information processing. A most commonly used examination method is Stroop emotion test, which was used in our study to test attention, a small part in cognition. Some studies have found that PTSD patients have attentional bias towards threat-relevant stimuli [34, 35]. With the inconsistent results from previous studies, in order to determine whether attentional bias is interrupted or enhanced in PTSD patients, Pineles et al conducted a study using visual search paradigm [36]. They show that PTSD group with high PCL rating have increased attention interruption by threatening words, and it is difficult for them to be disengaged from threatening words. Leskin and White show that the severity of PTSD symptoms, e.g. high arousal, flashbacks and avoidance, is correlated with defect in executive function [9]. Executive function is more complicated, which is closely associated with the three major symptoms of PTSD patients, and needs further characterization. A study by Shucard shows that the attention problem for PTSD patients is associated with delayed processing in their brain, when inhibition response

is needed [11]. The ability for PTSD patients to screen and filter irrelevant information is also compromised. He further concludes that PTSD patients may not necessarily have impaired attention for trauma related stimuli. High arousal symptoms may increase the irregularity of attention function of PTSD patients. These problems need further characterization in future studies.

### Conclusion

Based on these results, the attention related brain regions in PTSD patients may be damaged, which reduce their inhibition capacity for attention. PTSD patients cannot inhibit response to threat stimuli, which may induce attentional bias. Therefore, compared to normal people, PTSD patients generate smaller waves. A shortage of our current study is, the three "clusters" of symptoms for PTSD patients were not separately compared. According to previous studies, PTSD patients with different scores for various symptoms may have different behavior. Whether this is related to prognosis needs to be further characterized. To develop a training system for attention function of PTSD patient, and to improve their daily life by improving their attention and prognosis, will need to be our future research targets.

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### Disclosure of conflict of interest

None.

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