

# Traumatic Rescue Experiences and Post-Traumatic Stress Disorder in Firefighters: The Moderating Roles of Inhibitory Control and Cognitive Flexibility

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**Keywords:** Firefighters, PTSD, Traumatic Stress Exposure, Inhibitory Control, Cognitive Flexibility.

**Abstract:** **OBJECTIVES:** This study aimed to analyze the correlation between traumatic stress exposure and PTSD symptoms in Chinese firefighters using questionnaire and test methods, and to examine the moderating effects of inhibitory control and cognitive flexibility of executive functions.  
**METHODS:** A total of 263 frontline firefighters from China participated in this study. The self-developed "20-item Firefighter Stress Trauma Exposure Experience Inventory" was employed to investigate the subjects' experiences of traumatic events related to firefighting and rescue tasks since their recruitment. The Post-Traumatic Stress Disorder Scale (PCL-5) was used to assess the presence and severity of PTSD-related symptoms. Inhibitory control and cognitive flexibility were evaluated using the Stroop test and the number manipulation test, respectively. A moderating model was constructed through path analysis.  
**RESULTS:** Linear regression analysis revealed that traumatic stress exposure significantly and positively predicted the severity of PTSD symptoms in firefighters ( $p < 0.05$ ). The moderating effect of inhibitory control was significant ( $p < 0.05$ ), with simple slope analysis indicating that firefighters with strong inhibitory control were less adversely affected by traumatic stress exposure. Although the moderating effect of cognitive flexibility was not significant ( $p > 0.05$ ), the simple slope analysis exhibited a trend similar to that of inhibitory control.  
**CONCLUSION:** Inhibitory control and cognitive flexibility can moderate the development of PTSD in firefighters to some extent. The findings underscore the potential value of utilizing executive function and other cognitive training to enhance firefighters' resilience to PTSD.

## 1 INTRODUCTION

As an unique occupational group, firefighters are entrusted with the critical tasks of fire prevention, fire suppression, and emergency rescue, all of which entail significant danger, complexity, and uncertainty. Firefighters are frequently exposed to various hazards, intense auditory and visual stimuli, traumatic scenes, and the experience or witnessing of casualties among themselves and others during rescue missions. Such exposures can easily lead to traumatic experiences and, consequently, to various psychological disorders (Smith, Goldstein, & Grant, 2016). Post-Traumatic Stress Disorder (PTSD) is characterized by the delayed onset and persistence of intense fear, anxiety, helplessness, distress, and other mental disorders resulting from exceptionally threatening or catastrophic psychological trauma (Goldstein et al., 2016). PTSD is one of the most common mental disorders among firefighters,

significantly impairing their occupational health. Numerous studies have investigated the prevalence of PTSD in firefighters, with lifetime prevalence rates ranging from 1.9% to 57% across different countries, depending on sample sources and assessment methods (Obuobi-Donkor, Oluwasina, Nkire, & Agyapong, 2022). Overall, firefighters have a higher risk of developing PTSD and experience more severe symptoms than the general population.

Various traumatic task experiences are often considered the primary triggers of PTSD in firefighters (Serrano-Ibanez, Corras, Del Prado, Diz, & Varela, 2022). Due to the nature of their work, firefighters are more frequently exposed to traumatic events than the general population, including witnessing gruesome and bloody scenes, experiencing or witnessing severe injuries, facing death directly, and encountering various shocking disaster scenarios (Wagner et al., 2021). In addition to task experiences, numerous studies have identified other variables that influence the development of

PTSD, such as age (Chung, Lee, Jung, & Nam, 2015), marital status (Chen et al., 2007), level of burnout (Meyer et al., 2012), work climate (Jo et al., 2018), social support (Jin et al., 2022; Shi, Chen, Li, & An, 2021), history of psychological and psychiatric disorders (Kim, Park, & Kim, 2018; Noor, Pao, Dragomir-Davis, Tran, & Arbona, 2019), and cognitive factors (Wild & Gur, 2008). The development of PTSD is thus a multifactorial process, with traumatic experiences being one of the most critical causal factors.

Typical symptoms of PTSD include recurrent intrusive traumatic experiences (such as flashbacks and nightmares), persistent avoidance, negative alterations in cognition and mood, and heightened arousal (Pietrzak et al., 2015). These symptoms make it difficult for firefighters with PTSD to fully engage in rescue missions, potentially leading to mission hindrance or failure. PTSD has also been associated with cognitive impairments (Qureshi et al., 2011; Schuitevoerder et al., 2013). Patients with PTSD often exhibit varying degrees of cognitive deficits, such as impairments in memory and learning (Johnsen & Asbjornsen, 2008; Mattson, Nelson, Sponheim, & Disner, 2019), visuospatial processing (Kunimatsu, Yasaka, Akai, Kunimatsu, & Abe, 2020), and central executive functions (Jagger-Rickels et al., 2021; Li et al., 2019; Polak, Witteveen, Reitsma, & Olf, 2012), such as inhibitory control and cognitive flexibility. Inhibitory control refers to the mental process by which individuals regulate their attention, thoughts, behaviors, or emotions to overcome strong internal tendencies or external temptations, while cognitive flexibility refers to the ability to shift cognitive resources across multiple tasks (Diamond, 2012). Studies have shown that these executive functions are related to PTSD symptoms such as flashbacks, nightmares, persistent anxiety, depression, and heightened arousal (Fitzgerald, DiGangi, & Phan, 2018). Some researchers even suggest that deficits in executive functions, particularly inhibitory control, make it difficult for PTSD patients to suppress memories and thoughts related to traumatic experiences, leading to recurrent intrusive memories and persistent negative emotions (Cavicchioli et al., 2020; Philippot & Agrigoroaei, 2017).

Therefore, researchers have explored the application of systematic cognitive training in the treatment and rehabilitation of PTSD, achieving positive results with interventions such as Eye Movement Desensitization and Reprocessing (EMDR) (Jeffries & Davis, 2013) and Cognitive Processing Therapy (CPT) (Asmundson et al., 2019; Resick, Suvak, Johnides, Mitchell, & Iverson, 2012). Based on these findings, it is reasonable to hypothesize that the chain of PTSD triggered by

traumatic events is moderated by individual cognitive abilities, such as executive functions.

In this study, frontline firefighters from eastern and central China were selected to investigate the pathways by which traumatic task experiences affect PTSD symptoms and to examine the moderating effect of higher cognitive abilities, particularly central executive functions, on this relationship.

## 2 MATERIALS AND METHODS

### 2.1 Research Design

This retrospective study involved frontline firefighters (defined as those serving in basic fire rescue stations) from Anhui and Shanghai province, China. We assessed their exposure to traumatic events related to firefighting and rescue duties since their recruitment and evaluated their current PTSD symptoms using questionnaires. Additionally, we measured the participants' inhibitory control and cognitive flexibility using a set of executive function tests administered on handheld PDA devices. All assessments were conducted at the fire rescue stations where the subjects were employed, with participants gathered in a conference room to complete the tests and questionnaires. Informed consent was obtained from all station officers (station chiefs or instructors) prior to the study.

The specific procedures for administering the tests were as follows: First, permission was obtained from the chief officers of each fire station to conduct the study. Before administering the tests, these officers collected demographic information on all station members, including gender, age, length of service, marital status, and educational background. The fire station officers then organized the subjects to take the tests in the conference room, ensuring they were seated at intervals to avoid interruptions. Once all subjects were ready, the researcher guided them through the completion of the questionnaires and tests.

### 2.2 Tools

#### 2.2.1 Traumatic Rescue Experiences

The "20-item Firefighters' Stress Trauma Exposure Experience Inventory," a self-compiled tool, was used to investigate subjects' exposure to traumatic events related to firefighting and rescue missions since their recruitment. The questionnaire includes 20 items representing typical stress trauma experiences, such as life-threatening situations for oneself and comrades, witnessing brutal scenes,

handling dead bodies or severely injured individuals, and being present at disaster scenes. Each item is scored on a 3-point scale: 0 (never), 1 (once), and 2 (twice or more). Higher scores indicate more extensive exposure to stress trauma. The Cronbach's alpha coefficient of the scale was 0.914, indicating good reliability. Specific inventory items are presented in Appendix.

## 2.2.2 PTSD Symptoms

The Post-Traumatic Stress Disorder Scale (PCL-5) was used to assess the presence and severity of PTSD-related symptoms. The scale consists of 20 items that meet the diagnostic criteria for PTSD according to the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) (Blevins, Weathers, Davis, Witte, & Domino, 2015). Although the PCL-5 is not a stand-alone diagnostic tool for PTSD, it can be used for initial assessment and monitoring of potential PTSD-related symptoms (Wortmann et al., 2016). The Cronbach's alpha coefficient of the scale was above 0.9, indicating good reliability (Cheng et al., 2020). Specific inventory items are presented in Appendix.

## 2.2.3 Inhibitory Control and Cognitive Flexibility

A classic Stroop test was used to assess subjects' inhibitory control, where color words were presented randomly, and the task was to respond to the font color of the word with a keystroke. The test included two conditions: congruent (the word meaning matches the font color, e.g., "red" in red) and incongruent (the word meaning does not match the font color, e.g., "yellow" in red). The test comprised 36 trials, with half in the congruent condition and half in the incongruent condition. Higher accuracy and shorter response times indicate better inhibitory control.

A number manipulation test was designed to assess cognitive flexibility. In this test, a pair of numbers (both within 10) was presented randomly, and the task was to quickly determine the size relationship between the two numbers. If the left number was greater, subtraction was performed (left minus right); if the right number was greater, addition was performed. Results were entered via a numeric keyboard. The test consisted of 20 trials, requiring 10 conversion processes (switching from subtraction to addition or vice versa). All subjects completed a general numerical ability test before this test to control for differences in mathematical ability. Higher accuracy and shorter completion times indicated better cognitive flexibility, assuming consistent general numerical ability among subjects.

## 2.3 Subjects

The study involved administering scales and tests in 20 fire rescue stations (the most basic firefighting units) in Anhui and Shanghai province, China. All subjects met the following criteria: (1) informed consent and voluntary participation; (2) completion of all induction training and formal enrollment in service; (3) participation in at least one rescue mission. Subjects were excluded if they: (1) were absent or left midway through the test due to vacation, duty, or rescue tasks; (2) had a history of mental illness or a family history of hereditary mental illness; (3) had never participated in a fire rescue mission since recruitment; (4) did not wish to participate for other reasons.

## 2.4 Data Analysis

All scale and test data were analyzed using IBM SPSS 22.0 and IBM SPSS AMOS 22.0. Demographic data were described using frequency, percentage, mean, and standard deviation. Linear regression was employed to model the pathway linking traumatic rescue experiences to PTSD symptom severity. Pathway analysis was conducted to examine the moderating effects of inhibitory control and cognitive flexibility on this relationship.

## 3 RESULTS

### 3.1 Sociodemographic Characteristics

Table 1 presents the sociodemographic information of all subjects. Data from 263 valid subjects were collected, all male. Ages ranged from 20 to 44 years,

Table 1: Sociodemographic characteristics(n=263).

items	frequency (%)
age	
≤25	123 (46.8)
26~30	104 (39.5)
>30	36 (13.7)
Enlistment duration	
≤3	142 (54)
4~8	76 (28.8)
>8	45 (17.2)
Marital status	
married	72 (27.4)
unmarried	191 (72.6)
Educational background	
Below university degree	210 (79.9)
University degree or above	53 (20.1)

Table 2: Linear regression model of PTSD symptoms on TRAUMA scores.

	Unstandardized coefficients		Standardized coefficients	t	P value
	B	Standard error	Beta		
Constant	7.095	1.032	-	6.872	0.000**
TRAUMA scores	0.260	0.071	0.221	3.655	0.000**
R <sup>2</sup>			0.049		
Adjusted R <sup>2</sup>			0.045		
F			F (1, 261) =13.356, p=0.000		
D-W			1.710		

Table 3: Mediating model of Stroop test scores.

Model summary					
	Unstandardized coefficients		Standardized coefficients	t	P value
	B	Standard error	Beta		
constant	0.048	0.059	-	0.802	0.423
TRAUMA scores	0.209	0.060	0.209	3.494	0.001**
Stroop scores	-0.115	0.060	-0.115	-1.929	0.055
TRAUMA*Stroop	-0.097	0.042	-0.140	-2.341	0.020*
R <sup>2</sup>			0.084		
R <sup>2</sup> changes			0.019		
F value			F (3,259)=7.882,p=0.000		
F value changes			F (1,259) =5.482, p=0.020		
simple slope analysis					
Levels of moderating variable	Regression coefficients	Standard error	t	P value	95% CI
average	0.209	0.060	3.494	0.001	[0.092,0.327]
High level (+1SD)	0.112	0.076	1.465	0.144	[-0.038,0.262]
Low level (-1SD)	0.307	0.069	4.435	0.000	[0.171,0.442]

with a mean age of  $26.51 \pm 4.18$  years ( $M \pm SD$ ). The shortest length of service was less than 1 year, and the longest was 25 years, with a mean of  $4.44 \pm 4.29$  years ( $M \pm SD$ ). There were 191 unmarried subjects (72.6%) and 72 married subjects (27.4%). Educational levels were as follows: 1 junior high school graduate (0.4%), 86 high school graduates (32.7%), 123 college degree holders (46.8%), 48 university degree holders (18.3%), and 5 with a bachelor's degree or higher (1.9%).

### 3.2 The Effect of Traumatic Rescue Experiences on PTSD Symptoms

A linear regression model was constructed with the subjects' scores on the PCL-5 as the dependent variable and their scores on the '20-item Firefighters' Stress Trauma Exposure Experience Inventory' (hereafter referred to as the TRAUMA Inventory) as the independent variable. Table 2 presents the model fit with  $R^2=0.049$ , indicating that this independent variable explains 4.9% of the variance in the dependent variable. The model passed the F-test

( $F=13.356$ ,  $p=0.000<0.05$ ). The regression coefficient for the independent variable was 0.260 ( $p=0.000<0.05$ ), indicating that the independent variable had a significant positive effect on the dependent variable. This result suggests that firefighters who scored high on the TRAUMA Inventory may exhibit a higher propensity for PTSD symptoms.

### 3.3 Moderating Effects of Inhibitory Control and Cognitive Flexibility

To explore the moderating effects of subjects' inhibitory control and cognitive flexibility on PTSD symptoms, all variables involved in the analysis were converted to standard Z scores. The subjects' scores on the Stroop test and the number manipulation test (hereafter referred to as the NT) were added to the model constructed in section 3.2. Table 3 presents the model with Stroop test scores as a moderating variable. In this model, the number of correct responses (ranging from 0 to 36) was used as

Table 4: Mediating model of NT time taken.

Model summary					
	Unstandardized coefficients		Standardized coefficients	t	P value
	B	Standard error	Beta		
constant	0.254	0.418	-	0.608	0.544
TRAUMA scores	0.222	0.061	0.222	3.626	0.000**
NT time taken	0.038	0.065	0.038	0.581	0.562
TRAUMA*NT	0.053	0.067	0.048	0.793	0.429
R <sup>2</sup>	0.057				
R <sup>2</sup> changes	0.002				
F value	F (3, 257) = 3.110, p=0.010				
F value changes	F (1,257) = 0.628, p=0.429				
simple slope analysis					
Levels of moderating variable	Regression coefficients	Standard error	t	P value	95% CI
average	0.222	0.061	3.626	0.000	[0.102,0.342]
High level (+1SD)	0.275	0.093	2.941	0.004	[0.092,0.458]
Low level (-1SD)	0.169	0.087	1.931	0.055	[-0.002,0.340]

an indicator of test performance. The interaction regression coefficient for TRAUMA scores and Stroop scores was  $-0.097(p=0.020<0.05)$ , indicating a significant moderating effect. Further simple slope analysis showed that when the moderating variable (Stroop scores) was at a low or average level, there was a significant positive effect of TRAUMA scores on PTSD symptoms ( $B=0.307, p=0.000<0.05$ ;  $B=0.209, p=0.001<0.05$ ), while at a high level, this effect was not significant ( $B=0.112, p=0.144>0.05$ ), as shown in Figure 1 and Table 3. This suggests that subjects with greater inhibitory control are somewhat able to withstand the impact of traumatic rescue experiences, as evidenced by the lesser effect on PTSD symptoms.

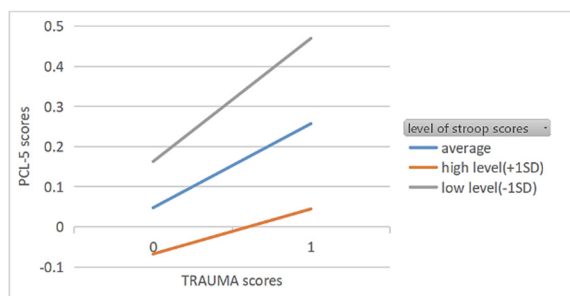


Figure 1: Simple slope diagram for different Stroop scores levels.

Table 4 presents the model with NT scores as a moderating variable. Due to the low difficulty of the test items (addition and subtraction within 10), the

vast majority of subjects achieved nearly 100% accuracy. Therefore, the time taken by subjects to complete the test was used as an indicator of performance, with longer times indicating worse cognitive flexibility. To avoid confounding general numerical ability with cognitive flexibility, subjects' time on the General Numerical Ability Test (completed before the formal test) was added as a covariate. The model fit indicated that the interaction term's regression coefficient was  $0.053(p=0.429>0.05)$ , suggesting that the moderating effect of NT was not significant. Despite the poor model fit, simple slope analysis was performed, as shown in Figure 2. Results indicated that TRAUMA scores had a significant positive effect on PTSD symptoms when NT time was at average or high levels ( $B=0.222, p=0.000<0.05$ ;  $B=0.275, p=0.004<0.05$ ), but not at low levels ( $B=0.169, p=0.055>0.05$ ).

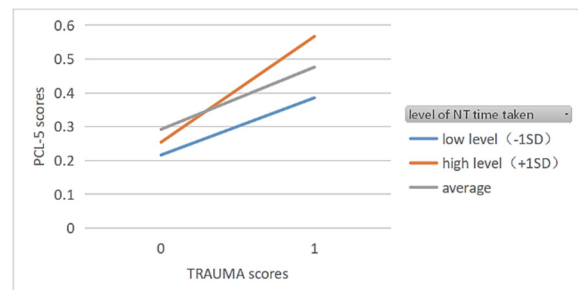


Figure 2: Simple slope diagram for different NT levels.



## 4 DISCUSSION

This study constructed a pathway model to examine the effect of stress trauma exposure on the development of PTSD symptoms in firefighters. Findings indicate that the extent of stress trauma exposure significantly positively affects the severity of PTSD symptoms in firefighters, meaning those who experience more traumatic rescue events tend to exhibit more PTSD symptoms. Traumatic events and scenarios are inevitable for firefighters. The majority of firefighters face shocking events including injury, illness, death, heat, noise, and explosions, making them more susceptible to PTSD compared to the general population. Studies in the United States, Canada, and the United Kingdom show that firefighters have a much higher prevalence of PTSD than the general population, as well as military personnel and first responders (Obuobi-Donkor et al., 2022). Additionally, PTSD can coexist with other psychological disorders, and firefighters are often at risk for other mental health problems such as anxiety and depression due to their work environment (Alghamdi, Hunt, & Thomas, 2015), complicating the screening, diagnosis, and intervention processes for PTSD.

For PTSD prevention, avoiding stressors is an effective option (Kyron, Rikkers, LaMontagne, Bartlett, & Lawrence, 2022). However, for firefighters, this is difficult to achieve since exposure to various stressors is inherent to their job. Even retired firefighters may have a high prevalence of PTSD (McFarlane & Bryant, 2007). Thus, preemptive approaches to reduce PTSD incidence in firefighters are challenging.

In recent years, cognitive therapy has been widely used for treating various psychological disorders, such as autism (Wass & Porayska-Pomsta, 2014), Alzheimer's disease (Vecchio et al., 2022), and PTSD (Ehlers & Clark, 2000). Executive function, a core aspect of higher cognitive abilities, has been linked to PTSD development and recovery (Olff, Polak, Witteveen, & Denys, 2014; Smits, Geuze, Schutter, van Honk, & Gladwin, 2021). This study tested the moderating effects of inhibitory control and cognitive flexibility. Results indicated that inhibitory control significantly moderates PTSD symptoms, with stronger inhibitory control associated with fewer PTSD symptoms. Although the moderating effect of cognitive flexibility was not significant, slope analysis suggested a potential effect. Inhibitory control allows individuals to suppress dominant responses detrimental to current activities (Ullsperger & Danielmeier, 2022), helping control intrusive traumatic experiences and negative thinking in PTSD. Cognitive flexibility enables

individuals to transfer cognitive resources between tasks, potentially reducing hypervigilance, a common PTSD symptom, by shifting attention and adjusting mental states.

Firefighters' occupational characteristics make them vulnerable to various hazards and traumatic events, and their management practices may increase susceptibility to anxiety, depression, and stress disorders, impacting performance and increasing separation and suicide risks (Davidson, Stein, Shalev, & Yehuda, 2004). Effective treatment or alleviation of PTSD symptoms is crucial for maintaining firefighters' occupational health. However, many PTSD treatments are not suitable for firefighters due to the long duration and systematic interventions required, often necessitating time away from duty, which is not feasible. Moreover, the fire department's militaristic and masculine culture can stigmatize mental health treatment, leading to condition concealment or negative treatment. Given these factors, enhancing firefighters' resilience to traumatic stress through cognitive training to reduce PTSD probability or alleviate symptoms appears to be a prudent intervention.

## 5 CONCLUSION

In conclusion, this study verified the moderating effects of inhibitory control and cognitive flexibility on PTSD morbidity and symptom severity in firefighters. Firefighters with greater inhibitory control and cognitive flexibility under the influence of traumatic rescue experiences are less likely to develop PTSD symptoms. Enhancing executive functioning in firefighters to prevent PTSD onset or reduce symptom severity is a viable strategy for improving their occupational mental health.

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## APPENDIX

the 20-item Firefighters' Stress Trauma Exposure Experience Inventory				
Instructions: Please select the number of times you have experienced the following events since your enlistment based on your actual situation.				
	items	0	1 time	2 times or more
1	Minor injuries sustained during training or missions (requiring medical treatment but not hospitalization)			
2	Seriously injured in training or missions (requiring hospitalization)			
3	Witnessing a comrade slightly injured during training or mission (requiring medical treatment but not hospitalization)			
4	Witnessing a comrade seriously injured during training or mission (requiring hospitalization for treatment)			
5	Witnessing the death of a comrade in training or during a mission			
6	Hearing the death of a comrade in training or during a mission			
7	Participate in fire extinguishing with injuries or fatalities			
8	Participate in flood, typhoon and other weather disaster rescues			
9	Participate in earthquake, mudslide and other geological disaster rescues			
10	Participate in traffic accident rescues			
11	Rescue of suicides			
12	Participate in the building (structure) and facilities and equipment collapse accident disposals			
13	Participate in the disposals of hazardous materials leaks, explosions and poisoning			
14	Participate in the disposals of pressure vessels, pipelines and other equipment leaks and explosions			
15	Rescues of burned or mutilated people			
16	Rescues of seriously injured people			
17	Rescues of minors			
18	Witnessing the death of a minor during a mission			
19	Witness/search/contact/carry bodies during the mission			
20	Witness the fragmented bodies during the mission			

The Post-traumatic Stress Disorder Scale (PCL-5)						
Instructions: below is a list of problems that people sometimes have in response to a very stressful experience. Keeping your worst event in mind, please read each problem carefully and then circle one of the numbers to the right to indicate how much you have been bothered by that problem in the past month.						
	In the past month, how much were you bothered by:	Not at all	A little bit	Moderately	Quite a bit	extremely
1	Repeated, disturbing, and unwanted memories of the stressful experience?	0	1	2	3	4
2	Repeated, disturbing dreams of the stressful experience?	0	1	2	3	4
3	Suddenly feeling or acting as if the stressful experience were actually happening again (as if you were actually back there reliving it)?	0	1	2	3	4
4	Feeling very upset when something reminded you of the stressful experience?	0	1	2	3	4
5	Having strong physical reactions when something reminded you of the stressful experience (for example, heart pounding, trouble breathing, sweating)?	0	1	2	3	4
6	Avoiding memories, thoughts, or feelings related to the stressful experience?	0	1	2	3	4
7	Avoiding external reminders of the stressful experience (for example, people, places, conversations, activities, objects, or situations)?	0	1	2	3	4
8	Trouble remembering important parts of the stressful experience?	0	1	2	3	4
9	Having strong negative beliefs about yourself, other people, or the world (for example, having thoughts such as: I am bad, there is something seriously wrong with me, no one can be trusted, the world is completely dangerous)?	0	1	2	3	4
10	Blaming yourself or someone else for the stressful experience or what happened after it?	0	1	2	3	4
11	Having strong negative feelings such as fear, horror, anger, guilt, or shame?	0	1	2	3	4
12	Loss of interest in activities that you used to enjoy?	0	1	2	3	4
13	Feeling distant or cut off from other people?	0	1	2	3	4
14	Trouble experiencing positive feelings (for example, being unable to feel happiness or have loving feelings for people close to you)?	0	1	2	3	4
15	Irritable behavior, angry outbursts, or acting aggressively?	0	1	2	3	4
16	Taking too many risks or doing things that could cause you harm?	0	1	2	3	4
17	Being "superalert" or watchful or on guard?	0	1	2	3	4
18	Feeling jumpy or easily startled?	0	1	2	3	4
19	Having difficulty concentrating?	0	1	2	3	4
20	Trouble falling or staying asleep?	0	1	2	3	4