Long-Term Psychosocial Stress Attenuates Attention Resource of Post-Error

Yiran Yuan[1,2], Jianhui Wu[1], and Kan Zhang[1]

[1] Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, China
[2] University of Chinese Academy of Sciences, Beijing, China
{yuanyr,wujh,zhangk}@psych.ac.cn

Abstract. This study examined both the behavioral performance and the brain mechanisms of post-error adjustments under long-term psychological stress by using ERP technique. Forty two participants who had been exposed to long-term exam preparation (versus 21 controls who were not exposed to such exam) performed a Go/NoGo task while electroencephalograms were recorded. We used Cohen's Perceived Stress Scale to assess their chronic stress level, and results suggested that participants in the exam group had higher levels of perceived stress. Although the behavioral performance of post-error trials had no difference between two groups, the exam group elicited significantly decreased P3 amplitude than the non-exam group in the post-error condition. Furthermore, the P3 amplitude in the post-error condition was negatively correlated with the perceived stress scores, suggesting that long-term psychosocial stress may lead to the decrease of the attention resource after committing an error.

Keywords: Long-term psychosocial stress, Post-error adjustments, Event-related potentials, Go/NoGo, P3, Attention resource.

1 Introduction

Human brain not only has the ability to detect errors but also to adjust behavioral performance after committing an error. One study has showed that stress can impair processes involved in error detection [1]. But how effect of stress on post-error behavior?

The common observed post-error adjustments reflected on change of reaction time and accuracy rate [2]. Usually we observed a prolonged reaction time responded after an error trial compared to a correct trial (so called post-error slowing) [3, 4]. The literatures have showed the mix results of accuracy rate in post-error. Some studies found that the accuracy increased after committing an error [5, 6], while some other studies found decreased or no affect [7, 8]. There are some theories to explain for post-error adjustments. One explanation is orienting account, which has received much attention nowadays. It refers to an orienting response elicited by error (infrequent events) and leads to prolonged reacting time in post-error trials, sometimes in combination with decreased accuracy [7, 9]. The previous ERP result that the P3 amplitude of error

D. Harris (Ed.): EPCE 2014, LNAI 8532, pp. 114–122, 2014.

trials was positively correlated with the post-error reaction time also supported the orienting account [10].

It is well known that stress not only lead to an increased activity of the hypothalamic-pituitary-adrenocortical axis (HPA axis), but also impacts the cognitive function and emotion [11]. But how cognition and behavior are modulated after committing an error under the stressful situation? One behavioral study reported that baseline cortisol was independently positively associated with post-error slowing [12], suggesting that more stressed state before the task as indexed by the cortisol level could increase post-error slowing. However, little is known whether and how long-term stress affects the post-error adjustments.

The aim of this study is to examine both the behavioral performance and the neural dynamics of post-error adjustments under long-term psychological stress by using the ERP technique. We used a major, highly competitive Chinese National Postgraduate Entrance Exam (NPEE) as long-term psychological stressor. The participants performed a Go/NoGo task while EEG data was recorded. Perceived stress scale was obtained to assess the effect of long-term stressor exposure. According to the orienting account of post-error adjustments and the P3 component was associated with the attention resource allocation [13], we expect long-term psychosocial stress to decrease attention resource of post-error trials, reflected by the decreased behavioral performance and/or attenuated P3 amplitude of post-error (false-alarm of the NoGo trials) Go trials.

2 Material and Methods

2.1 Participant

Forty two young healthy participants who had exposed to a major, high-competitive Chinese National Postgraduate Entrance Exam (NPEE) for 6 months and 21 non-exam as controls were recruited for this study. Considering gender differences in the effects of stress [14, 15], only male participants were recruited in this study. All participants were assessed by the Chinese version of the Life Events Scale (LES) [16, 17] to exclude other major life stressors during the past month. This experiment was approved by the Ethics Committee of Human Experimentation at the Institute of Psychology, Chinese Academy of Sciences. All participants provided written informed consent and were compensated for their participation.

2.2 General Procedure

Between 11-25 days before the national NPEE, all qualified participants came to the laboratory, completed questionnaires and several psychological tests including Go/NoGo task while EEG data was collected (the other tests didn't report here).

2.3 Psychological Measurements

To assess chronic stress level, all qualified participants completed the Perceived Stress Scale (PSS 10-item version) [18], which were widely used as an index of the perception of chronic stress [19, 20]. In addition, the participants completed the Chinese version of the Mini International Personality Item Pool (the Mini-IPIP) to measure the Big Five factors of personality (neuroticism, extraversion, conscientiousness, openness, and agreeableness) [21].

2.4 Go/NoGo Task

During each trial, participants were asked to respond as soon as possible to letter “O” (Go trial) by pressing the button with the index finger of one of their hands, while didn’t respond to the letter “X” (NoGo trial). The buttons were counterbalanced for the left/right hand across the participants. The probability of Go trial and NoGo trial was 80%: 20%. The consecutive presentation of two NoGo trials was avoided. Before the experiment session, participants received a practice session of 20 stimuli. During the experiment session, all participants received two blocks each consisting of 240 stimuli with 1-2 min breaks between blocks. The stimuli were displayed for 500 ms with a random interstimulus interval of 1200–1500ms.

2.5 ERP Recordings

During the experiment session, electroencephalograms (EEG) were continuously recorded from 64 scalp sites using Ag/AgCl electrodes mounted in an elastic cap (Neuroscan Inc., USA). The ground electrode was placed on the forehead, with an online reference to the left mastoid and an off-line algebraic re-reference to the average of the left and right mastoids. The vertical (VEOG) and horizontal electrooculograms (HEOG) were recorded from two pairs of electrodes, one pair placed above and below the left eye, and another pair placed at 1 cm from the outer canthi of each eye. All interelectrode impedances were kept below 5 kΩ. The signals were amplified by a Neuroscan SynAmps^2 amplifier (Neuroscan Inc., USA) with a 0.05-100 Hz bandpass filter and digitized at 1000 Hz.

The EEG data were digitally filtered with a 30 Hz lowpass filter and epoched into periods of 1000 ms (including a 200 ms prestimulus baseline) that were time-locked to the onset of the presented digit. The EEG signal was corrected by removing ocular artifacts through a regression procedure implemented in the Neuroscan software [22]. Trials with various artifacts were rejected, with a criterion of ± 100 μV.

2.6 Data Analyses

We used independent sample t-tests to compare the differences of exam and non-exam group on PSS and the Mini-IPIP.

There were two conditions for analyses of both behavioral performance and ERP measures. Post-correct condition referred to the Go trial after the hit trial. Post-error condition referred to the Go trial after the false alarm trial. For the behavioral performance, the percentage of correct responses (correct rate) and reaction time of correct responses (RT) were calculated separately for post-error and post-correct condition. For the ERP data, the mean amplitude of P3 was measured in each condition during the time interval from 250 to 310 ms after stimulus onset at Pz site.

Repeated-measures ANOVAs with condition (post-correct vs. post-error) as the within-subjects factor and group (exam group vs. non-exam group) as the between-subjects factor were calculated separately for both behavioral performance and ERP data.

Participants who had less than 10 false alarm trials were excluded before data analyses. Finally, 35 participants in the exam group and 18 participants in the non-exam group remained when analyzing the behavioral performance. In addition, participants who had less than 10 accepted trials of ERP data were also excluded, so there were 27 participants in the exam group and 12 participants in the non-exam group remained when analyzing the ERP data.

Correlation analyses using Pearson's r were conducted between perceived stress and the behavioral performance and ERP data of post-error adjustments for all the participants.

The Greenhouse-Geisser correction was used to compensate for sphericity violations. Measures of effect size are reported using eta square (partial η^2). All p values $\leq$ .05 were considered statistically significant (two-tailed).

3 Results

3.1 Psychological Measurements of Long-Term Psychosocial Stress

The exam group and non-exam group were matched with respect to age (M ± SD: exam group 22.4 ± 1.0 years vs. non-exam group 22.7 ± 1.1 years). Perceived stress scores was significantly higher in the exam group than in the non-exam group (t = 2.197, df = 22, p = 0.039; see Fig 1). There was no significant difference between the exam group and the non-exam group on big five factors of personality ($p_s > 0.1$).

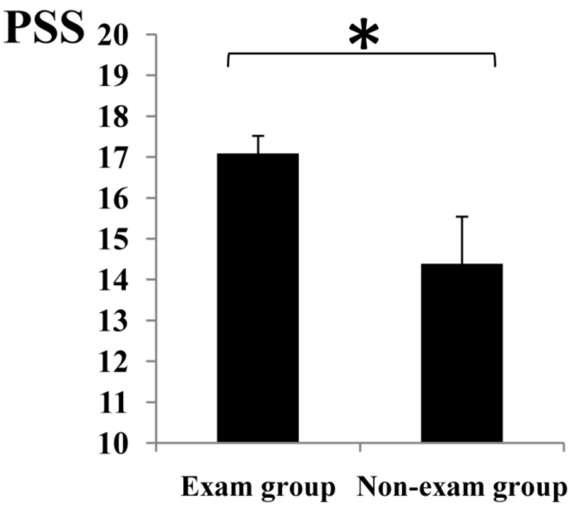

Fig. 1. Average Perceived stress scores (PSS) in the exam and non-exam groups. Error bars represent standard error of the mean. Notes: *: $p < 0.05$.

3.2 Effects of Long-Term Psychosocial Stress on Behavioral Performance

Analysis of correct rate revealed a significant main effect for condition (post-correct vs. post-error). In comparison with the post-correct condition, participants in both groups had significantly lower correct rates in the post-error condition ($F_{(1,51)}$ = 15.269, $p < 0.001$, partial $\eta^2 = 0.230$). Neither the main effect for group nor the interaction between the two factors was significant ($p_s > 0.1$). Analysis of RT showed that neither the main effects nor the interaction was significant ($p_s > 0.1$) (see Fig 2).

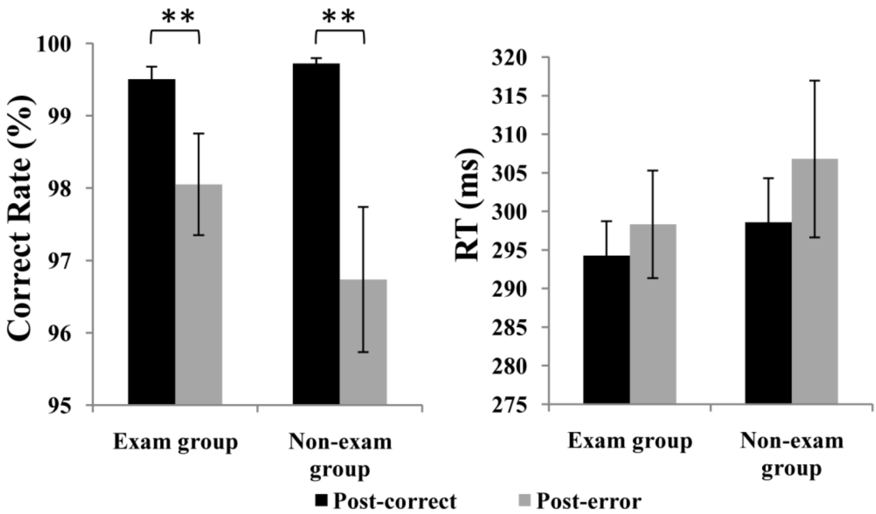

Fig. 2. Correct rate and RT for the post-correct and post-error conditions in the exam and non-exam groups. Error bars represent the standard error of the mean. Notes: **: $p < 0.01$.

3.3 Effects of Long-Term Psychosocial Stress on P3 Amplitude

The ANOVA revealed a significant main effect for condition and group (condition: $F_{(1,37)} = 7.307$, $p = 0.010$, partial $\eta^2 = 0.165$; group: $F_{(1,37)} = 4.424$, $p = 0.042$, partial $\eta^2 = 0.107$). The type × group interaction also reached significance ($F_{(1,37)} = 4.394$, $p = 0.043$, partial $\eta^2 = 0.106$). For further analysis of the interaction, there was no difference between the exam group and the non-exam group in the post-correct condition ($p > 0.1$). But in the post-error condition, the P3 amplitude of the exam group was significantly smaller than the non-exam group ($p = 0.015$) (see Fig 3).

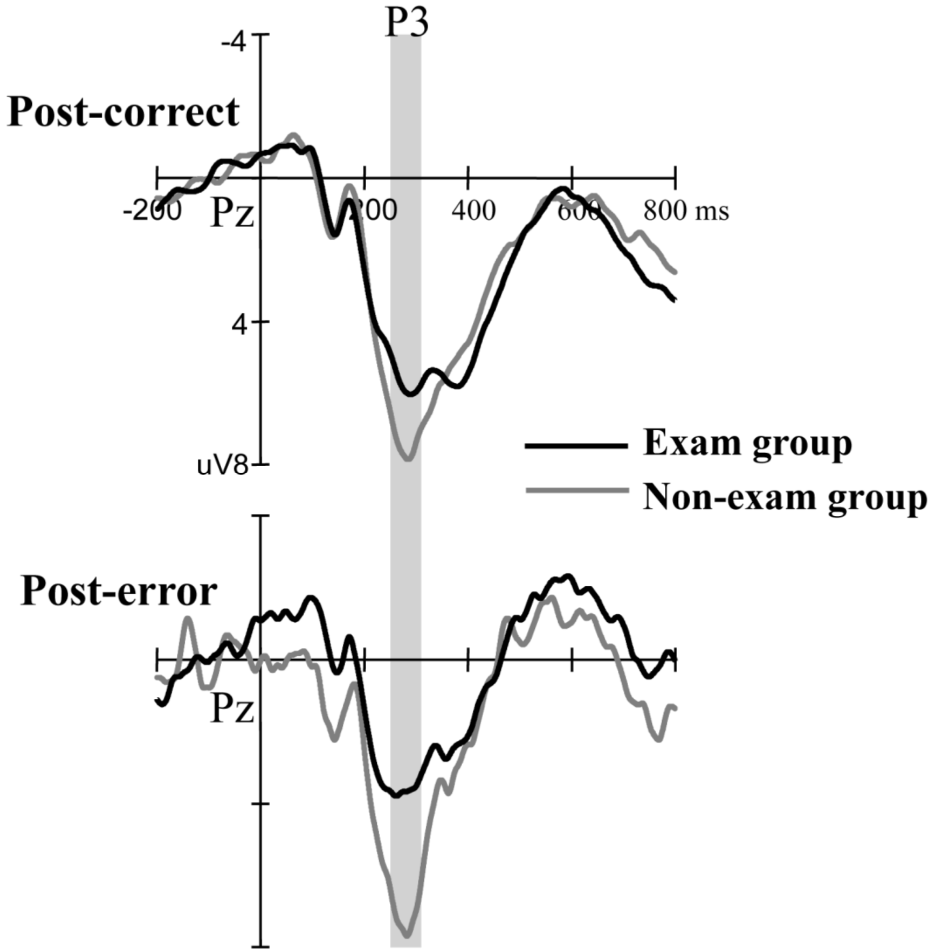

Fig. 3. Grand average ERPs elicited by performing post-correct and post-error conditions in the exam group and non-exam group at Pz electrode site. The gray areas highlight the time windows for P3 (250–310 ms) that was used for the statistical analysis.

3.4 Relationship between Perceived Stress and P3 Amplitude

For the whole participant sample, the perceived stress scores was negatively correlated with P3 amplitude in the post-error condition (r = -0.318, $p = 0.048$). There were no significant relationships between perceived stress and behavioral performance of post-error adjustments ($p_s > 0.1$).

4 Discussion

The present study investigated effects of long-term psychosocial stress on both the behavioral performance and the neural dynamics of post-error adjustments.

Psychological assessments confirmed that participants in the exam group were exposed to high levels of perceived stress. In comparison with the non-exam group, the exam group elicited a decrease in the P3 amplitude in the post-error condition when performing a Go/NoGo task, whereas behavioral performance remained no change between two groups. Furthermore, the P3 amplitude in the post-error condition was negatively correlated with the perceived stress scores.

Our behavioral results only showed that participants in both groups had significantly lower correct rates in the post-error condition of Go trials than in the post-correct condition. RT in the post-error condition was longer than in the post-correct condition, but it didn't reach significant level. These results were consistent with previous finding indicating that post-error slowing and correct rates of post-error were not always co-occur [2]. No change was found between two groups on behavioral performance, maybe the output of behavioral performance was not sensitive to stress.

Importantly, our ERP result showed significantly decreased P3 amplitude of the exam group compare with the non-exam group in the post-error condition. Literature has suggested that the P3 component was associated with the attention resource allocation [13]. Our results was consistent with the explanation of orienting account [9], suggesting that the exam group have less attention resource allocated to the post-error trials. Furthermore, the P3 amplitude in the post-error condition was negatively correlated with the perceived stress scores. It suggested that long-term psychosocial stress may lead to decreased attention resource in the post-error condition. The previous studies also have showed that stress can result in some cognitive consequences, such as attentional tunneling and impaired attention shifting [19, 23].

Although there was no group difference in behavioral performance of post-error behavior, the ERP result showed significantly difference between two groups. This might implicate that we cannot only depend on the final behavioral output when we examine the effects of stress on cognitive function. The event-related potentials (ERPs) technique is a widely used method to examine alterations in the dynamic time course, known as its high temporal resolution in millisecond. The current results suggest that chronic stress modulated the step of attention resource allocation for the post-error behavior. According to our knowledge, this is the first ERP evidence suggesting the stress may modulate the post-error behavior.

There are a few limitations in our study. First, small sample size were analyzed in this study partially due to the fact that we excluded some participants because they committed small number of errors. Second, we used only male undergraduate students as participants, which might limit the generalizability of our results. Third, we did not evaluate whether the two groups differed before they started preparing for the NPEE, so we cannot directly conclude that long-term psychosocial stress leads to a difference between the two groups on post-error adjustments. But we assessed the big five factors of personality on two groups and the results showed that no difference between two groups. A future study may add a test during a non-exam period to obtain a baseline to study the effects of the exam.

To summarize, our results provide electrophysiological evidence that long-term psychosocial stress may lead to the decrease of the attention resource after committing an error, which reflecting on significantly decreased P3 amplitude in the post-error condition of the exam group than the non-exam group.

Acknowledgements. This work was supported by the National Natural Science Foundation of China (91124003, 81371203, 31100750 and 31100734).

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