Brain and Cognition 94 (2015) 60–67

Contents lists available at ScienceDirect

Brain and Cognition

journal homepage: www.elsevier.com/locate/b&c

Anticipatory processes under academic stress: An ERP study

Duan Hongxia [a,b], Yuan Yiran [a,b], Yang Can [a,b], Zhang Liang [a], Zhang Kan [b], Wu Jianhui [a,*]

[a] Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, China
[b] University of Chinese Academy of Sciences, Beijing, China

ARTICLE INFO

Article history:
Accepted 10 January 2015
Available online 5 February 2015

Keywords:
Long-term academic stress
Anticipation
State anxiety
ERP
CNV

ABSTRACT

It is well known that preparing for and taking high-stakes exams has a significant influence on the emotional and physiological wellbeing of exam-takers, but few studies have investigated the resulting cognitive changes. The current study examined the effect of examination-induced academic stress on anticipation in information processing. Anticipation was indexed using the contingent negative variation (CNV). Electroencephalograms (EEG) were collected from 42 participants using the classic S1–S2 paradigm. These participants were preparing for the Chinese National Postgraduate Entrance Exam (NPEE). EEGs were also collected from 21 age-matched, non-exam comparison participants. The levels of perceived stress and state anxiety were higher and both the initial CNV (iCNV) and the late CNV (lCNV) were more negative in the exam group than in the non-exam group. These results suggest that participants under academic stress experienced greater anticipation of upcoming events. More important, for the non-exam group, state anxiety was positively related to both the iCNV and lCNV amplitude, and this correlation existed when trait anxiety was controlled; however, there was no such relationship in the exam group. These results suggested that the cortical anticipatory activity in the high-stressed exam group reached the maximum ceiling, leaving little room for transient increases in state anxiety.

1. Introduction

Academic examinations have long been used to study how real-life stressors lead to psychological and physiological changes. Studies have shown that academic examinations can elicit both psychological responses, such as stress (Backovic, Zivojinovic, Maksimovic, & Maksimovic, 2012; Halamandaris & Power, 1999), anxiety (Borella et al., 1999; Conley & Lehman, 2012; Herbert, Moore, de la Riva, & Watts, 1986; Spangler, 1997) or depression (Kurokawa et al., 2011; Liu & Lu, 2012), and physiological responses, including changes in cardiovascular activity (Conley & Lehman, 2012; Papousek et al., 2010), hypothalamic–pituitary–adrenal axis activity (Bardi, Koone, Mewaldt, & O'Connor, 2011; Verschoor & Markus, 2011) and the immune system (Kamezaki, Katsuura, Kuwano, Tanahashi, & Rokutan, 2012; Koh et al., 2012). Studies exploring cognitive changes that occur during an examination period have found facilitatory and detrimental effects on higher cognitive functions, such as attention, working memory and executive function (Kofman, Meiran, Greenberg, Balas, & Cohen, 2006; Mogg, Bradley, & Hallowell, 1994; Vedhara, Hyde, Gilchrist, Tytherleigh, & Plummer, 2000). Liston, McEwen, and Casey (2009) examined the effect of long-term stress elicited by exam preparation on the attentional neural network. Their results suggested that exposure to one month of exam-related stress disrupts attention shifts and functional connectivity within the frontoparietal network. The predominant focus of these studies has been on neurocognitive response and behavioral output after stimulus presentation. Before a stimulus is presented, however, the brain has begun to anticipate and prepare for upcoming events. It is therefore possible that the anticipatory cognitive processes are also influenced by examination-induced academic stress.

The anticipation of future events is an important adaption in human beings. "These anticipatory processes enable us to prepare for and consider the potential consequences of forthcoming events rather than respond to such events in a purely reactive manner" (Wynn, Horan, Kring, Simons, & Green, 2010). Contingent negative variation (CNV) is the most extensively studied anticipatory event-related potential (ERP). It is recorded from the scalp after a warning stimulus (S1) has been presented while the participant is waiting for an imperative stimulus (S2) and preparing to respond (Walter, 1967). According to Birbaumer, Elbert, Canavan, and Rockstroh (1990), CNV represents the activity of the dendritic trees of cortical pyramidal neurons and its amplitudes manifest the availability of resources of related neural systems. From the per-

* Corresponding author at: Institute of Psychology, Chinese Academy of Sciences, 16 Lincui Road, Chaoyang District, Beijing 100101, China. Fax: +86 10 64836047.
E-mail address: wujh@psych.ac.cn (J. Wu).

http://dx.doi.org/10.1016/j.bandc.2015.01.002
0278-2626/

spective of psychological processes, CNV amplitude is related to anticipation, attention, motivation and motor preparation (for reviews, see Brunia & van Boxtel, 2001; van Boxtel & Böcker, 2004). When the interstimulus intervals are extended to 3 s, two CNV components can be distinguished: the initial wave (iCNV) and the late wave (lCNV) (Kropp, Kiewitt, Göbel, Vetter, & Gerber, 2000; Loveless, 1973). The iCNV amplitude is thought to be modulated by physiological arousal and anticipation of S2 (McCallum, 1988; Simons, Macmillan Iii, & Ireland, 1982). The lCNV is thought to reflect neural activities that prepare for goal-directed movement (McCallum, 1988; Sanquist, Beatty, & Lindsley, 1981). Both iCNV and lCNV have a scalp distribution over the front-central areas, with lCNV distributed relatively more posterior and broader than iCNV (Cui et al., 2000; Fischer, Langner, Diers, Brocke, & Birbaumer, 2010; Gaillard, 1976; Hamano et al., 1997; van den Bosch, 1983).

The CNVs have a potential significance in clinical application, i.e., to evaluate the changes in cognitive functions occurring in various diseases and mental states. Previous CNV studies examined clinical samples with anticipatory deficits, such as schizophrenia (Wynn et al., 2010); posttraumatic stress disorder (Kimble, Ruddy, Deldin, & Kaufman, 2004) and migraine (Siniatchkin, Averkina, & Gerber, 2006; Siniatchkin, Gerber-von, Darabaneanu, Stephani, et al., 2011; Siniatchkin, Sandor, Schoenen, & Gerber, 2003); motor disorders, such as Parkinsonism (Oishi, Mochizuki, Du, & Takasu, 1995); or attention deficits, such as attention deficit hyperactivity disorder (Banaschewski et al., 2003). Electrophysiological studies also revealed that CNV can be modulated by stress and anxiety in otherwise healthy samples. Previous studies found that higher CNV was associated with relatively higher stress and arousal levels (Brown, Fenwick, & Howard, 1989; Nagai et al., 2004; Tecce, 1972). The results of a study by Siniatchkin et al. (2006) also showed that healthy women under experimental achievement stress had increased iCNV amplitude compared with those under control conditions. More interestingly, studies found that high-trait anxious individuals had a greater CNV than low-trait anxious individuals who performed at comparable levels (Ansari & Derakshan, 2011; Glanzmann & Froehlich, 1984). They explained that anxious individuals use more processing resources to prevent decrements in performance at the expense of processing efficiency (Ansari & Derakshan, 2011). These studies utilized laboratory-induced acute stress/anxiety (Glanzmann & Froehlich, 1984; Siniatchkin et al., 2006) or specific anxiety population samples (Ansari & Derakshan, 2011), and relatively little is known about how natural, long-term psychosocial stressors modulate the anticipation step of information processing, as indexed by CNV.

Some studies focused on the individual difference of trait anxiety in the relationship between CNV amplitude and stress/state anxiety. In a series experiments (Knott & Irwin, 1967; Knott & Irwin, 1968; Knott & Irwin, 1973; Van Veen, Peters, Knott, Miller, & Cohen, 1973), a larger CNV was found in low-trait anxiety subjects when the S2 was an electrical shock compared with the neutral stimulus; in high anxiety subjects, however, CNV was reduced. Similarly, McCallum and Papakostopoulos (1973) found that as a function of increasing task complexity, CNV increases in low-anxiety subjects and decreases in high-anxiety subjects. Glanzmann and Froehlich (1984) also suggested that the reduction of CNV is associated with an increase of state anxiety in high-anxiety subjects; no such relationship is found in low anxiety subjects. There have been two interpretations suggested for these results. Knott and Irwin (1967) suggested a "ceiling hypothesis," meaning high-anxiety persons operate this anticipation cognition from a higher baseline than low-anxiety persons, leaving little room for additional negativity. The "distraction hypothesis" proposed by Tecce (1971), Tecce (1972), however, suggest that high-anxiety persons might be more distracted by worry and preoccupation with current task-irrelevant, self-focused thoughts when S2 is anticipated. These studies have usually differentiated participants by self-report scales. It is still unclear how a natural, specific type and long-term stressor (e.g., academic stress) modulates the relationship between CNV amplitude and state anxiety.

Therefore, the aim of our study was to improve the field's understanding of the mechanisms involved in CNV under the conditions produced by real-life stressors. For this purpose, CNV was used within the classic S1–S2 paradigm to measure anticipatory processing in a homogeneous sample composed of 42 male students who had been preparing for an exam for a long time and 21 age- and education-matched non-exam male students. We collected electroencephalograms (EEG) 11–25 days before the examination from graduating male students who were preparing to participate in the National Postgraduate Entrance Exam (NPEE), which is a highly competitive and time-consuming event. According to the results of previous studies, we predicted that: (1) the exam group will produce iCNV and/or lCNV of greater amplitude than those of the non-exam group; (2) the relationship between state anxiety and CNV amplitude would be different between the groups, for example, there will be a positive correlation between CNV amplitude and state anxiety and/or stress level in the non-exam group, while there might be a negative or no correlation for the exam group, based on both the ceiling hypothesis and the distraction hypothesis.

2. Methods

2.1. Participants

Because of the effects of gender on stress and electrophysiological activity (Crasson, Lembreghts, el Ahmadi, Legros, & Timsit-Berthier, 2001; Knott & Peters, 1974), we recruited only male graduating participants. Sixty-three right-handed, healthy, male college students were recruited through advertisements posted at Wannan Medical College. All participants were medical students from the same university, and all of them had passed the same entrance requirements (e.g., the university entrance exam), which minimized the possibility that the observed group differences can be explained by major or intelligence related factors. Forty-two of these participants were planning to take the NPEE, while the remaining students did not plan to participate in any academic examinations or interviews one month before or after the experiment. None of the participants had a history of neurological or psychiatric disorders. All participants were screened using the Life Events Scale (LES) (Tennant & Andrews, 1976; Zhang et al., 1987) to exclude students who had experienced any other major stressor during the past month. Since there are evidences that the different personality characteristics have different CNV patterns (Brown et al., 1989; Werre, Mattie, & Berretty, 2001), we also measured their personality scores, as described in the questionnaires section, to ensure the homogeny of the two groups in personality characteristics. All of the students reported normal hearing and normal or corrected-to-normal vision, and all of them right-handed based on self-report.

Three participants in the exam group were excluded from the analyses due to that the number of acceptable EEG trials was no less than five (Kropp et al., 2000). The final sample consisted of 39 exam-group participants and 21 non-exam group participants. The exam group and non-exam control group were matched for age (mean age of exam-group: 22.5 ± 1.0; non-exam group: 22.6 ± 1.1) and education level (17 years of education for all participants). All participants gave written informed consent and were paid for their participation. This experiment was approved by the Ethics Committee of Human Experimentation at the Institute of Psychology, Chinese Academy of Sciences.