International Journal of Psychophysiology 76 (2010) 107–117

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

The influence of negative affect on the neural correlates of cognitive control

Robert West [a,*], Peter Choi [a], Stephanie Travers [b]

[a] Department of Psychology, Iowa State University, Ames, USA
[b] Luther College, Department of Psychology, Luther College, Decorah, USA

ARTICLE INFO

Article history:
Received 27 August 2009
Received in revised form 25 February 2010
Accepted 2 March 2010
Available online 10 March 2010

Keywords:
Negative affect
Cognitive control
ERPs
Counting Stroop task

ABSTRACT

Negative affect can be associated with the disruption of processes supporting cognitive control. The current study investigated the hypothesis that chronic negative affect is associated with a decrease in the utilization of proactive control and an increase in reliance on reactive control. Individuals performed the counting Stroop task while event-related brain potentials were recorded. Negative affect, as measured with the Beck Depression Inventory II, was associated with a decrease in the amplitude of a pre-stimulus slow wave and an increase in the amplitude of the medial frontal negativity, and was weakly related to the amplitude of the conflict sustained potential. These findings lead to the suggestion that negative affect may attenuate the engagement of processes associated with both proactive and reactive cognitive control.

Cognitive control serves to bias the information processing architecture in support of goal-directed action (Botvinick et al., 2001; Kerns et al., 2004; Ridderinkhof et al., 2004). The engagement of cognitive control is particularly important in situations where distracting information related to competing goals is present in the environment or where competing response tendencies are activated (Braver and Ruge, 2006; Miller and Cohen, 2001; Shallice, 1982). A classic example of such a situation is embodied in the Stroop task (Stroop, 1935). In this task individuals encounter incongruent color-words (e.g., the word RED presented in green) and must overcome the prepotent tendency to read the word in order to name the color of the stimulus (MacLeod, 1991). Considerable evidence indicates that the ability to overcome this prepotent response is supported by a neural network that includes structures within the anterior cingulate cortex (ACC) and lateral prefrontal cortex (LPFC; Botvinick et al., 2001, 2004; Braver and Ruge, 2006; Cole and Schneider, 2007). The current study was designed to examine the relationship between chronic negative affect and neurophysiological indices of proactive and reactive cognitive control.

The influence of negative affect on cognitive, or executive, control has been the focus of a substantial body of research that has examined the influence of normative variation in trait negative emotion (Luu et al., 2000), elevated levels of depressive symptoms in non-clinical samples (Holmes and Pizzagalli, 2007), and clinical depression (Liotti and Mayberg, 2001; Rogers et al., 2004). Behavioral data indicates that the presence of negative affect in both non-clinical samples and major depressive disorder (MDD) can be associated with poor performance on neuropsychological measures of executive control (Moritz et al., 2002), that may result from a disruption of the moment-to-moment tuning of control settings (Holmes and Pizzagalli, 2007; Pizzagalli et al., 2006; but see Chiu and Deldin, 2007). Studies using functional neuroimaging methods (i.e., EEG, fMRI, and PET) reveal that neural structures commonly associated with cognitive control (i.e., ACC and LPFC) often demonstrate hypoactivity in the resting state in depressed individuals relative to non-depressed individuals (Liotti and Mayberg, 2001; Pizzagalli et al., 2006). Additionally, during cognitive challenges that tax selective attention, error-monitoring, and working memory some studies reveal hyperactivity in these structures in individuals with elevated levels of negative affect or depressive symptoms (Chiu and Deldin, 2007; Harvey et al., 2005; Holmes and Pizzagalli, 2008a; Luu et al., 2000) and other studies reveal hypoactivity in these structures in the same types of individuals (Holmes and Pizzagalli, 2008b; Vanderhasselt and De Raedt, 2009).

The reason for the variation observed across studies is unclear, and does not appear to necessarily be driven by the sample that is tested or the task that is performed. For instance, in a study using the Stroop task with ERPs, Holmes and Pizzagalli (2008a,b) found that the amplitude of the error-related negativity (ERN) was enhanced in depressed individuals relative to controls and that the amplitude of the medial frontal negativity (MFN or N450) related to conflict detection in the Stroop task was attenuated in the depressed individuals relative to controls. These findings are curious as the ACC is thought to contribute to the generation of both of these components of the ERPs that are related to processes underpinning cognitive control (Dehaene et al., 1994; Liotti et al., 2000).

The interaction between negative affect and cognitive control represents the basis of one prominent theory wherein the dysregulation of top down cortical-limbic pathways is thought to result in the cognitive and emotional disturbances associated with depression

* Corresponding author. W112 Lagomarcino Hall, Iowa State University, Ames, IA 50011, USA. Tel.: +1 515 294 3950.
E-mail address: rwest@iastate.edu (R. West).

0167-8760/$ – see front matter
doi:10.1016/j.ijpsycho.2010.03.002

(Mayberg, 1997). This model is supported by a variety of evidence. At a general level there is a fair degree of overlap in the core neural structures that contribute to the cognitive control network (i.e., ACC and LPFC; Braver and Ruge, 2006) and the emotion regulation network (i.e., ACC, medial and lateral PFC, and orbital frontal cortex; Davidson et al., 2000; Ochsner and Gross, 2005). Although, there is some degree of separation observed between cognitive and affective processing in these brain networks (Bush et al., 2000). For instance, cognitive or response conflict is more commonly associated with the recruitment of dorsal ACC while conflict related to emotion is more commonly associated with the recruitment of rostral ACC (Whalen et al., 1998; Bush et al., 2000).

The idea that negative affect is associated with the disruption of cortical-limbic interactions is interesting within the context of the Dual Mechanisms of Cognitive Control Theory (Braver et al., 2007). In this theory, cognitive control can be implemented in one of two modes (i.e., proactive or reactive). Proactive control represents a prospective mode of control that serves to bias the information processing system toward the realization of a desired goal before the onset of an imperative stimulus and is thought to arise from interactions between ACC and anterior prefrontal cortex (DePisapia and Braver, 2006). In contrast, reactive control represents a just-in-time form of control that is engaged when conflict or ambiguity arises within the information processing system and is thought to result from interactions between ACC and LPFC (Braver et al., 2007; DePisapia and Braver, 2006). The Dual Mechanisms Theory is conceptually similar to a theory of motivated learning described by Tucker and Luu (2007). In this theory, motor control arises from either a feed forward (proactive) system that involves a mediodorsal pathway through the frontal cortex or a feedback (reactive) system that involves a ventrolateral pathway through the frontal cortex (Tucker and Luu, 2007). The feed forward system is thought to be sensitive to a positive motivational bias while the feedback system is thought be sensitive to a negative motivational bias.

Foundational work related to the Dual Mechanisms Theory revealed that variation in positive and negative affect associated with mood induction can result in differential recruitment of LPFC during the maintenance of verbal or non-verbal information in working memory (Gray et al., 2002). More recent evidence indicates that individual differences in affective style, as related to the behavioral approach and inhibition systems, may covary with the mode of control that is engaged during task performance (Braver et al., 2007). Specifically, a negative affective style may be associated with the adoption of a reactive control strategy while a positive affective style may be associated with the use of a proactive control strategy (Braver et al., 2007). The differential influence of affective style on the engagement of proactive or reactive control strategies served as one motivation for the current study examining the relationship between negative affect and neurophysiological correlates of processes associated with proactive and reactive cognitive control.

The current study sought to extend work related to the Dual Mechanisms Theory by examining the relationship between individual differences in negative affect and the neural correlates of proactive and reactive cognitive control. Based on the Dual Mechanisms Theory, negative affect should be negatively related to the engagement of proactive control, and positively related to the engagement of reactive control. These predictions are based on evidence indicating that task conditions promoting proactive control are associated with a decrease in the recruitment of the neural structures supporting reactive control, and that task conditions promoting reactive control are associated with a decrease in the recruitment of neural structures supporting proactive control (Braver et al., 2007). To test these hypotheses event-related brain potentials (ERPs) were recorded while individuals performed a counting Stroop task that permitted the examination of distinct components of the ERPs associated with different control processes (West and Schwarb, 2006). Participants were selected for the study based on their reported level of chronic negative affect as measured on the Beck Depression Inventory II (BDI; Beck et al., 1996). The final sample included individuals who reported minimal to moderate levels of negative affect, and none reported being diagnosed with a mood disorder or taking antidepressant medications at the time of testing.

The study was modeled after an investigation examining the effects of aging on the neural correlates of proactive and reactive cognitive control (West and Schwarb, 2006). Proactive control was operationalized in the amplitude of pre-stimulus slow wave activity that was measured during the response-to-stimulus interval (West and Schwarb, 2006). This slow wave activity reflects a sustained modulation of the ERPs that reverses polarity from the frontal-polar region to the parietal region of the scalp. The association between proactive control and the pre-stimulus slow wave is supported by evidence indicating that the amplitude of the slow wave is positively related to individual differences in measures of executive control and response time in younger adults, and that this relationship is altered in older adults (West and Schwarb, 2006) who may have difficultly utilizing proactive control (Braver and West, 2008).

Reactive control was operationalized in the amplitude of the MFN and conflict sustained potential (SP). The MFN or N450 reflects a negativity between 300 and 500 ms after stimulus onset that extends from the frontal to the parietal region of the scalp over the midline (Liotti et al., 2000; West, 2003; West and Alain, 2000). The label “MFN” may be more appropriate for this component of the ERPs than the “N450” used in other studies (West, 2003; West and Alain, 2000) as the timing of the component can vary somewhat with the information processing demands of the task. For instance, in a study using the counting Stroop task the MFN was observed in younger adults beginning around 300 ms after stimulus onset (West and Schwarb, 2006). In contrast, in more demanding Stroop tasks that involved task switching the MFN may not emerge until around 400–500 ms after stimulus onset (West, 2003; West and Alain, 1999). The MFN may reflect processes that are similar to those associated with the N2 in the flanker task (van Veen and Carter, 2002), with the primary difference between the two components reflecting a variation in the time course of information processing across the two tasks (i.e., response time in the flanker task tends to be significantly faster than response time in the Stroop task). The MFN is associated with conflict detection in the Stroop and similar tasks (West et al., 2005) and may reflect the activity of neural generators in ACC or medial frontal cortex and related frontal structures (Liotti et al., 2000; West, 2003; West et al., 2004).

The conflict SP reflects a sustained parietal positivity/lateral frontal negativity that typically emerges between 500 and 600 ms after stimulus onset and persists until 800–1200 ms after stimulus onset (West, 2003; West et al., 2005). The timing and amplitude of the conflict SP is correlated with response time for incongruent trials (West and Alain, 2000; West et al., 2005) leading to the idea that it is associated with conflict resolution or response selection in the Stroop task (West et al., 2005). Like the MFN, the conflict SP is elicited in other tasks that are similar in structure to the Stroop task (West et al., 2005) indicating that this component is generally related to conflict processing. Spatiotemporal dipole modeling reveals that the conflict SP may reflect the activity of neural generators in the lateral frontal and posterior cortices (West, 2003). The amplitude of MFN and conflict SP is attenuated in groups that are thought to experience deficits in cognitive control (e.g., older adults [West, 2004; West and Schwarb, 2006] and individuals with schizophrenia [McNeely et al., 2003]) relative to appropriate controls. These findings indicate that both of these components of the ERPs are sensitive to individual differences in cognitive control.

Based on the Dual Mechanisms Theory, the amplitude of the pre-stimulus slow wave should be negatively correlated with negative affect and the amplitude of the MFN and conflict SP should be