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Trait anxiety and the dynamics of attentional control

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ABSTRACT

According to recent theoretical approaches dispositional anxiety is fundamentally linked to neural mechanisms of cognitive control (Braver et al., 2007; Eysenck et al., 2007). The present study was conducted to further investigate this topic by focusing on the relation between trait anxiety, conflict-processing and dynamic adjustments in attentional allocation. Participants completed a modified version of the face–word Stroop task while an electroencephalogram was recorded. We analyzed behavioral and electrophysiological correlates of conflict processing and conflict-driven modulations in target and distractor processing. Anxiety was not related to general conflict-sensitivity but to individual differences in conflict-driven adjustments in attentional allocation: following a high level of stimulus–response conflict, highly anxious participants allocated more attentional resources to the processing of predominantly task-relevant information and withdrew attention from the processing of predominantly task-irrelevant information. Thus, trait anxiety appears to be closely related to individual differences in dynamic adjustments of attentional control.

1. Introduction

In their influential *attentional control theory* (ACT), Eysenck and colleagues (Derakshan and Eysenck, 2009; Eysenck et al., 2007) have recently claimed that anxiety as personality trait is closely related to individual differences in higher-order functions of cognitive control. Specifically, high trait anxiety is thought to bias the balance between a goal-directed attention system and a stimulus-driven attention system in favor of the latter (also see, Corbetta and Shulman, 2002). Consequently, task-irrelevant information should be more intrusive in highly anxious compared to low anxious individuals. Moreover, Eysenck et al. hypothesize that the deficit in attentional control should affect processing efficiency (as typically indexed by reaction times [RTs]) rather than effectiveness (as typically indexed by error-rates), especially in tasks requiring inhibitory control (i.e., inhibiting the distracting influence of task-irrelevant information) and/or attentional set shifting (i.e., shifting attention between multiple task rules). A further postulate of the ACT is that anxious subjects can compensate for the deficiencies in attentional control by recruiting additional cognitive resources. On the neuronal level this should lead to an enhanced activity of brain circuits involved in cognitive control.

By now these theoretical assumptions have received considerable empirical support by studies using behavioral indices of attentional processing. For instance, there is a large body of research, demonstrating that emotionally arousing but task-irrelevant stimuli are more intrusive in highly compared to low anxious subjects (Bar-Haim et al., 2007). Other findings indicate that high anxiety is indeed associated with a general deficit in inhibitory control and attentional set-shifting (e.g., Ansari et al., 2008; Derakshan et al., 2009b; Fox, 1993, 1994; Wieser et al., 2009; Wood et al., 2001) and that these deficits affect processing efficiency rather than processing effectiveness (Derakshan et al., 2009a).

In contrast to this rather homogeneous picture of behavioral findings, prior studies investigating the link between anxiety and neural correlates of attention and cognitive control have yielded more inconsistent results. While some authors report an increased recruitment of neural control mechanisms in highly trait anxious subjects (e.g., Ansari and Derakshan, 2011; Basten et al., 2011; Gray and Braver, 2002; Telzer et al., 2008) others report the opposite (e.g., Bishop, 2009; Bishop et al., 2004; Klumpp et al., 2011). Recent theoretical and empirical works suggest that these inconsistencies are partly caused by disregarding the temporal dynamics of cognitive control. For instance, Braver et al. (2007) postulated that low and highly anxious individuals generally differ in the

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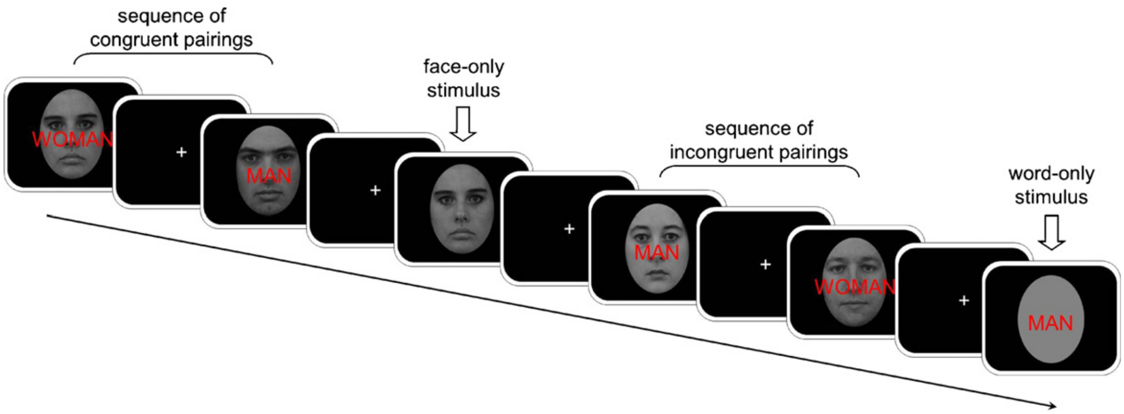

Fig. 1. Schematic depiction of the facial Stroop task showing the three stimulus types (face–word stimuli, face-only stimuli and word-only stimuli).

way they exert top–down control. Specifically, highly anxious subjects are proposed to recruit neurocognitive control resources in a transient and reactive manner (i.e., only when control is needed) whereas low anxious subjects are thought to engage control in a rather sustained and proactive way (also see, Fales et al., 2008). The assumption of a reactive recruitment of cognitive-control in highly anxious subjects is also supported by data from our group (Osinsky et al., 2010). In this study, we investigated dynamic adjustments in conflict-processing, measuring event-related potentials (ERP) of the electroencephalogram (EEG) while subjects performed a face–word version of the Stroop task. Results of this study indicate that highly anxious subjects only more strongly engage neural mechanisms of conflict-monitoring when previously exposed to a high level of stimulus–response conflict. Similarly, findings from two other recent studies suggest that highly anxious subjects more strongly recruit mechanisms of conflict-monitoring (Dennis and Chen, 2009) and inhibitory control (Hardin et al., 2009) after seeing fearful faces. In sum these studies indicate that highly anxious subjects especially show a reactive and compensatory recruitment of control resources and goal-directed attention when previously exposed to a highly cognitive demanding or distracting event.

The present study was conducted to further investigate the link between anxiety and cognitive control by focusing on behavioral and neurophysiological indices of conflict-processing and attentional allocation. Our main purposes were (1) to investigate the potential relation between anxiety and sensitivity for distracting and task-irrelevant information and (2) to examine how a potential reactive recruitment of cognitive control in highly anxious individuals affects dynamic adjustments in attentional processing. We recorded EEG while subjects performed a modified version of the face–word Stroop task (see Fig. 1). In most trials of this task, a single female or male face was combined with the word man or woman written across the face, resulting in a congruent or incongruent face–word pairing (hereafter 'face–word stimuli'). In these trials, subjects were asked to discriminate the gender of the face by button-press. In the remaining infrequent trials only a single face (hereafter 'face-only stimuli') or word (hereafter 'word-only stimuli') was presented, requiring the same discrimination as in the frequent face–word trials. This task allows for testing several predictions of the ACT.

First, highly anxious subjects should be more sensitive to distracting and task-irrelevant information, resulting in higher behavioral interference effects in the face–word trials. This should especially be seen in RTs as an index of processing efficiency but not in hit rates (HRs) as an index of processing effectiveness. Moreover, conflict-related brain potentials should increase with the level of anxiety. We therefore analyzed the so-called conflict-N450 and the conflict-SP (sustained potential) which are typically observed in the Stroop task. The conflict-N450 is a negative-going ERP deflection, typically observed at central scalp sites. It occurs about 450 ms after the onset of an incongruent stimulus and probably reflects processes of conflict-monitoring in the anterior cingulate cortex (Badzakova-Trajkov et al., 2009; Bruchmann et al., 2010; Hanslmayr et al., 2008; Liotti et al., 2000; Rebai et al., 1997; West, 2003; West et al., 2005). It is directly followed by the more parietal positive going conflict-SP which has also been linked to conflict-monitoring and to the execution of top–down control (Liotti et al., 2000; West, 2003; West et al., 2005).

To investigate the link between anxiety and dynamic adjustments in attentional processing we analyzed behavioral indices and ERPs in the face-only and word-only trials. Using similar conflict-evoking tasks, previous studies have demonstrated that, following a high level of conflict between task-relevant and task-irrelevant stimuli, attention is more strongly oriented toward target stimuli and/or away from distractor stimuli (e.g., Egner and Hirsch, 2005; Scerif et al., 2006). According to the ACT (Eysenck et al., 2007) and prior findings from our group (Osinsky et al., 2010), such reactive recruitment of attentional resources should be increased in highly trait anxious subjects. In our task, this should result in a facilitated processing of the predominantly task-relevant face dimension and/or a suppressed processing of the predominantly task-irrelevant word-dimension. We therefore analyzed two frequently studied ERP deflections related to face- and word-processing, namely the N170 and the N400, respectively. The N170 is a negative-going deflection which peaks about 170 ms after stimulus onset and is especially pronounced for face stimuli (Bentin et al., 1996). It probably reflects processes of structural face encoding in temporo-occipital brain areas and is sensitive to attentional processes (Hole and Bourne, 2010; Holmes et al., 2003; Mohamed et al., 2009). After a high level of conflict, a top–down attentional amplification in processing of the predominantly task-relevant face dimension should therefore lead to an elevated N170 and this effect should be increased in highly anxious subjects. The N400 has been classically observed in sentence reading tasks as a relative negative-going deflection about 400 ms after the onset of a word that does not match its preceding semantic context (Kutas and Hillyard, 1980). This ERP component is inversely related to the ease of accessing semantic memory representations and, consequently, to the ease of processing a word's meaning (Federmeier, 2007; Kutas and Federmeier, 2000). Accordingly, the N400 can be used as an index for the depth of word processing (i.e., the smaller the N400 amplitude the easier word processing; see, e.g., Stewart et al., 2010). In our task, a reactive suppression of the predominantly task-irrelevant word dimension may therefore lead to an N400 effect, that is, more negative amplitudes when words are