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Reprint of "Effortful control, depression, and anxiety correlate with the influence of emotion on executive attentional control"

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ABSTRACT

Recent evidence confirms that emotion can trigger executive attentional control. Participants resolve conflict faster when encountering emotionally negative or positive stimuli. This effect is accompanied by an enlarged conflict negativity in event-related brain potentials (ERPs) and activation of the ventral anterior cingulate cortex (ACC) in fMRI. Here, we tested whether temperament (the trait effortful control) and subclinical factors (anxiety, depression) can influence the emotional modulation of executive attention. These factors correlated with conflict processing in six experiments that utilized different conflict tasks (flanker, Simon) and different types of emotional stimuli (visual, auditory). Participants high in effortful control and low in anxiety and depression responded faster to conflict processing in emotional stimuli, showed an enhanced ERP conflict negativity, and additional activation in the ventral ACC. The data show that temperamental effortful control, depression, and anxiety are related to the influence of emotion on executive attention and its underlying neural correlates.

1. Introduction

It has long been hypothesized that emotion may influence executive control of attention. For example, Norman and Shallice (1986) argued that a number of different situations trigger attentional control, including errors, novelty and also danger is signaled by emotional stimuli. Several recent studies show that emotion can indeed speed up attentional control processes. Using different conflict tasks as a measure of attentional control, we reported faster resolution of conflict when target stimuli were emotional compared to neutral stimuli (Kanske and Kotz, 2010b, 2011a,c,d,e). This adaptive mechanism reduces the time that conflicting action tendencies yield an organism unable to react in highly salient situations such as those signaled by emotion. This mechanism is subserved by a neural network comprising the ventral and dorsal portions of the anterior cingulate cortex (ACC), as well as the amygdala (Kanske and Kotz, 2011c,d). While the dorsal ACC is involved in conflict processing irrespective of emotion, the ventral ACC is recruited for conflict processing only when target stimuli are emotional, potentially via input from the amygdala as indicated by increased functional connectivity. Recordings from the electroencephalogram indicate the rapid speed of this mechanism, as emotion already modulates the first stages of conflict processing in event-related brain potentials (ERP; Kanske and Kotz, 2010b, 2011a,e).

Temperament-related differences in effortful control have been shown to relate to attentional control (Rueda et al., 2005), and individuals' emotional states modulate the perception of emotional stimuli (Li et al., 2008). Therefore, they may also relate to the influence of emotion on attentional control. This is a critical question, which could yield insight into the factors that influence this relation and explain interindividual variability. To probe this question, we applied a correlational approach and tested whether individual differences in effortful control and subclinical depression and anxiety correlate with the speeding up of conflict processing and its underlying neural mechanisms.

Temperamental effortful control describes an individual's capacity for self-regulation (Rothbart, 2007). More specifically, it has been defined as the "ability to choose a course of action under conditions of conflict, to plan for the future, and to detect errors" (Rothbart, 2007, p. 207). The concept has mainly been applied in developmental research involving psychometric and laboratory studies (Rothbart and Bates, 2006). Nevertheless, effortful control can also be reliably measured in adults using the adult temperament questionnaire, which was used in the present study (ATQ, Evans and Rothbart, 2007; Rothbart et al., 2000).

The relation of effortful control and executive attention has been extensively studied in children. Children high in effortful control commonly exhibit better performance in conflict tasks

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(Gerardi-Caulton, 2000; Rothbart et al., 2003). Evidence of such a relation also comes from biopsychological data. Both effortful control (Goldsmith et al., 1999) and executive attention (Fan et al., 2001) have been shown to be heritable. For example, Rueda et al. (2005) investigated the dopamine-related DAT1 gene which is, among other dopamine genes, related to executive attention (Blasi et al., 2005; Diamond et al., 2004; Fan et al., 2003; Fossella et al., 2002). They found that the long form of the DAT1 gene was associated with higher effortful control, better conflict scores, and a reliable ERP conflict negativity, which children with the mixed allele did not show.[1] This strong evidence suggests that temperamental effortful control can explain inter-individual differences in executive attention. However, it is unclear whether this relation is also present in adults. Furthermore, it is unknown whether effortful control affects the influence of emotion on executive attentional control.

Interestingly, there is some data that hint at a potential role of effortful control in emotion processing. Kochanska et al. (2000) found that effortful control measured with a battery of simple tasks at 22 months of age was associated with the ability to regulate anger, and predicted anger and joy regulation at 33 months of age. A positive relation of effortful control to emotion regulation has also been reported by several other groups (Carlson and Wang, 2007; Salmon and Pereira, 2002; Valiente et al., 2007, for a review, see Spinrad et al., 2007). In addition, effortful control is related to several other measures including delay of gratification, the development of conscience, the development of empathy, and lower levels of psychopathology and maladjustment (Eisenberg, 2000; Kochanska, 1997; Kochanska et al., 2000; Krueger et al., 1996; White et al., 1994). Effortful control has even been found to negatively correlate with subclinical depression and anxiety (Moriya and Tanno, 2008).

Emotional states such as depression and anxiety strongly modulate the perception of emotional stimuli. This has been observed in patients with specific phobias. Spider phobics, for example, detect and will be distracted by spiders much faster and stronger than non-phobic participants (Gerdes et al., 2008; Mühlberger et al., 2006). Furthermore, generalized anxiety disorder (Bradley et al., 1999) and depression (Mitterschiffthaler et al., 2008) mainly affect the processing of negative emotional stimuli. Interestingly, these effects can be observed not only in clinical, but also in subclinical anxiety and depression, i.e., different anxiety levels in healthy participants can explain differences in processing of emotional stimuli (Li et al., 2008; Mercado et al., 2006; Scott et al., 2001). The neural basis of the heightened sensitivity to emotional stimuli in anxiety and depression includes altered processing in emotion-relevant brain regions such as the amygdala and the ventral ACC. In depression, amygdala activation to negative emotional stimuli is increased for pictures (Lee et al., 2007) and words (Siegle et al., 2007). This effect is even present when the presentation of negative but not positive emotional stimuli is anticipated, but no stimulus is presented (Abler et al., 2007). In contrast, activation of the ventral ACC can be reduced in depression (Drevets et al., 1997). Volume changes in the amygdala and ventral ACC in depression have also been observed (Pezawas et al., 2005; for reviews about the neural basis of depression, see Drevets, 2001; Kalia, 2005). Similar effects have been reported in anxiety, also regarding the amygdala response (Bishop et al., 2004; Most et al., 2006; for a review, see Bishop, 2007). This influence of depression and anxiety on emotion processing occurs already very early after stimulus onset as documented in early ERP effects (e.g., P1) and reactions to subliminally presented pictures (Mercado et al., 2006), faces (Bar-Haim et al., 2005) and words (Li et al., 2007, 2008; Weinstein, 1995). There are also several studies yielding insight into the nature of these differences. Participants scoring high in anxiety and depression seem to be faster to detect negative emotional stimuli, orient attention to stimuli, and experience difficulties in disengaging from them (Bradley et al., 1999; Fox et al., 2001, 2002; Garner et al., 2006; Mogg and Bradley, 1999; Mogg et al., 2000, 2004, 2007; for a meta-analysis, see Bar-Haim et al., 2007).

In summary, temperamental effortful control is associated with efficient conflict processing, but also the regulation of emotion. Altered processing of emotional stimuli in anxiety and depression indicates that the relevance of a stimulus in a given situation may not be appropriately detected. This fits well with the pattern of hyper- and hypoactivation in amygdala and ACC.

Thus, heightened sensitivity to negative stimuli in anxiety and depression, and the negative correlation of regulatory processing (effortful control) and depression and anxiety suggest less appropriate evaluation of emotional stimuli. Consequently, the supportive role of emotion in guiding executive control of attention could be affected by inter-individual differences in effortful control, depression, and anxiety. Therefore, we assessed effortful control, depression, and anxiety through questionnaires and correlated them to the speed of conflict processing in emotional trials. We analyzed this potential impact in six previously published experiments based on different conflict tasks (flanker and Simon type of conflict) and stimuli in different sensory modalities (visual and auditory). We hypothesized that participants high on depression and anxiety, but low on effortful control scores would show a reduced benefit from emotion in conflict resolution response times. Furthermore, we expected to find a relation to the underlying neural mechanisms measured with ERPs and functional magnetic resonance imaging (fMRI). As the ERP conflict negativity is increased in emotional trials with better behavioral conflict resolution, the amplitude increase should be smaller in high depression, anxiety and low effortful control. Similarly, activation increase of the ventral ACC has been related to enhanced conflict resolution and should, therefore, be reduced in high depression, anxiety and low effortful control.

2. Materials and methods

2.1. Participants

A total of 142 participants (70 females) were included in the analysis. They were distributed across six separate experiments (see Table 1 for details). Five participants were excluded because of excessive EEG artifacts. The mean age was 24.2 (SD 2.3), there were no significant age differences between the six subgroups ($p > 30$). All participants were native speakers of German, right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971), with a mean laterality quotient of 95.7 (SD 6.9). Participants reported normal or corrected-to-normal vision and normal hearing and no history of neurological or psychiatric disorders as assessed in a screening questionnaire that asked for previous diagnoses and treatments. The study was approved by the Ethics Committee of the University of Leipzig. All participants gave written informed consent prior to participation.

2.2. Questionnaires

2.2.1. Depression Anxiety Stress Scales (DASS)

To assess the subclinical range of depression and anxiety, the DASS (Lovibond and Lovibond, 1995b) were administered. In addition to depression and anxiety, this questionnaire also measures stress levels, each scale consists of 14 items. In the instruction, participants are asked to evaluate whether an item applied to them during the last week. There were four response options ranging from "did not apply to me at all" to "applied to me very much, or most of the time. Scores of 0–3 were assigned to each response option and mean scores for each participant and scale were calculated. Reliability (Cronbach's alpha) in nonclinical samples is for the depression scale .91, the anxiety scale .84, for the stress scale .90 (Lovibond and Lovibond, 1995b). Cronbach's alpha for the present samples is reported in Table 2.

[1] An ERP negativity has consistently been observed in conflict tasks. The timing of this negativity, however, has varied in different conflict tasks. Accordingly, the component has been labeled differently (Folstein and Van Petten, 2008). As we applied two different conflict tasks in the experiments reported here, we use the term "ERP conflict negativity" throughout the manuscript to avoid confusion.