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Early frontal responses elicited by physical threat words in an emotional Stroop task: Modulation by anxiety sensitivity

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ABSTRACT

High-density brain electrical activity elicited by physical threat, positive and neutral words were recorded in 33 healthy individuals screened for high or low anxiety sensitivity (AS) during a modified emotional Stroop task. The paradigm allowed the separate assessment of block and mixed-trial effects. In the block analysis, a significant emotional RT slowing was observed along with the modulation of a frontocentral negativity (350–400 ms) in the high AS group only. In contrast, the mixed-trial analysis revealed a positive enhancement of the ERP to threat words peaking earlier (200–300 ms) over anterior frontal scalp in the absence of RT slowing. This component was preceded by a very early positive modulation (peaking 50 ms) in the high AS group only. It is concluded that frontal ERPs to physical threat words can distinguish the contribution of emotional conflict and emotional salience, particularly in individuals with high trait-anxiety.

1. Introduction

People with clinical anxiety disorders display cognitive biases in the domain of attention to threat, which appear to be largely content-specific to the particular symptoms of the various anxiety disorders (e.g., MacLeod et al., 1986; Asmundson et al., 1992). A commonly used laboratory measure revealing such attentional biases is the emotional Stroop (eStroop) task, where emotional and neutral words are presented in different ink colours, and participants are instructed to respond to the *colour* of the word, while ignoring the word meaning. Anxiety disorder patients and healthy individuals with high trait or state anxiety have been found to have slower reaction times to content-specific threat words relative to positive or neutral words (e.g., Becker et al., 2001; Williams et al., 1996; Hope et al., 1990). Unlike the classic colour Stroop Task (cStroop), in which interference is thought to originate from the need to override competing and incompatible biases at the stage of response selection, the relevant factors contributing to emotional interference in the eStroop are still under considerable debate. Unlike the cStroop, emotional interference has been more consistently found in *block* designs than in mixed-trials designs (see meta-analysis in Phaf and Kan, 2007). The prevalence of sizeable emotional interference in block versions of the eStroop has been recently explained by the fact that RT slowing may not be originating from the current word (“fast effect”), but rather be caused by the influence of the *previous* threat stimulus (so called “*slow* effect”). In mixed-trial designs, the emotional interference would simply dilute and cancel out (McKenna and Sharma, 2004; Waters et al., 2005).

Another aspect which may distinguish the cStroop from the eStroop task concerns the neuroanatomical substrates associated with the two tasks. Functional neuroimaging studies with PET and fMRI in healthy volunteers have consistently identified a central role of the dorsal anterior cingulate cortex (dACC) in the cognitive control and conflict monitoring operations involved in the cStroop (e.g., Botvinick et al., 2001; Bush et al., 2000; Roberts and Hah, 2008). Furthermore, event-related potential (ERP) studies of the cStroop have added timing information by revealing a correlate of the interference effect (incongruent versus congruent words) as a negative deflection peaking around 400 ms from word onset (the N450), with midline frontocentral scalp distribution, which has been source-localized to dACC (e.g., Liotti et al., 2000; West & Alain, 1999; Markela-Lerenc et al., 2004). More recent ERP studies using the Eriksen Flanker Task and Go-no-Go task have reported similar conflict-related negativities with the same scalp distribution, but at earlier latency (the ‘conflict N2’, e.g., Van Veen and Carter, 2002; Mathalon et al., 2003).

Although substantially less evidence is available, neuroimaging studies of the eStroop task have been associated with activation of more *ventral* sectors of the ACC (the so called ‘rostral’ anterior cingulate cortex or rACC; Bush et al., 2000; Mohanty et al., 2007). This ACC subdivision has been characterized as ‘affective’,

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based on differential connectivity to limbic and subcortical areas involved in emotion and autonomic/vegetative functions (Devinsky et al., 1995). A question left open by the Bush et al. (2000) study is whether the rACC activation is indeed related to conflict generated by the emotional word. Note that no emotional RT difference was found in their study that only included healthy participants. Haas et al. (2006) used a modified version of the eStroop task, which employed overlapping emotional or neutral faces and words of congruent and incongruent content. In that paradigm, they independently evaluated brain activity associated with *conflict* and correlated with emotional RT interference (incongruent emotional face/word stimuli), and brain activity associated with a more general response to *emotional salience* (congruent emotional stimuli versus neutral stimuli). Emotionally incongruent pairs yielded significant RT slowing, and were associated with increased activation in dorsal ACC, consistent with the conflict-monitoring model of dACC function. In contrast, no effects in rACC were found in response to emotional saliency (Haas et al., 2006). The latter discrepancy may be explained by methodological differences between the classic eStroop task and the face eStroop task they employed.

In contrast to investigations of the cStroop, only a few studies have addressed timing issues in the eStroop paradigm using ERPs. In a first study, ERPs to threat relative to neutral words (in a mixed-trial design) were distinguished by larger amplitude of a late positive potential (LPP) with posterior scalp distribution, as well as by larger amplitude of an earlier, parietally distributed P2 component over the right hemisphere, in the absence of significant RT interference for emotional words (Thomas et al., 2007). Note, however, that no differences were reported over frontal scalp sites, reflecting possible involvement of ACC. A second study utilized *blocks* of threat and neutral words that were presented to individuals varying in trait-anxiety. The authors reported greater amplitude occipital P1 waves in response to threat than neutral words for the high anxiety subjects only. Unlike the previous study, threat words gave rise to greater amplitude of a *frontal* positivity (300–500 ms) independent of anxiety group (Li et al., 2007). Finally, a third study employed *blocks* of negative and neutral words. As in the previous study, threat stimuli elicited larger occipital P1 amplitudes. While there was no overall frontal ERP modulation for threat vs. neutral blocks, those threat words that on a subject to subject basis produced RT interference evoked greater amplitude of a *negative* slow wave with frontal topography (300–700 ms). This study did not find effects of trait-anxiety on the ERP measures (Van Hoff et al., 2008).

In summary, current ERP studies of the eStroop task fail to report a consistent association with RT interference effects (see Van Hoff et al., 2008, for an exception), and therefore cannot adequately address the question of which electrophysiological changes are functional correlates of slower RT to emotional words. Furthermore, while those studies that do not report RT differences show ERP modulations as a function of emotion, they do not provide consistent findings in relation to which components are affected (P1, P2, LPP, frontal slow wave), or whether the frontal ERP modulation is a positive wave (Li et al., 2007), or a negative wave (Van Hoff et al., 2008). Finally, studies diverge on whether ERPs to threat words are enhanced as a function of levels of trait-anxiety. Differences in timing, particularly of early stages of information processing of threat stimuli can be expected in anxious participants, according to the model of hypervigilance to threat, and earlier ERP findings employing emotional faces (Williams et al., 1996, 2007b).

In order to address such limitations, the present study employed a variation of the classic eStroop task allowing to independently assess the effects of emotional conflict and emotional salience (as in Haas et al., 2006). Such paradigm allowed separate measurements of *block* effects and *mixed-trial* effects. Threat Blocks were composed of equally occurring physical threat and neutral words; Positive Blocks were a random mixture of equally occurring positive and neutral words. It was reasoned that the contrast of Threat and Positive Blocks would yield emotional RT slowing, consistent with a recent meta-analysis of the eStroop literature showing more robust RT effects in block designs (‘slow’ effect, Phaf and Kan, 2007). Furthermore, to determine the impact of trait-anxiety on both behavioural and electrophysiological measures of the eStroop, two groups were included, with high and low Anxiety Sensitivity (AS). AS describes the extent to which people fear a future situation in which they may experience symptoms of physical anxiety (e.g., palpitations, sweating, choking; McNally, 2002). A recent analysis of the psychometric properties suggested that this construct ‘‘is broadly applicable to a range of anxiety-related phenomena’’ (Deacon and Abramowitz, 2007, p. 852). Hence, AS can be considered a subtype of trait-anxiety where the concerns are centred on the experience of the physical manifestations of anxiety. Furthermore, AS has been recognized as a risk factor for the development of panic disorder, in which such symptoms are prevalent (Schmidt and Lerew, 1997). A few behavioural studies have reported eStroop interference for physical threat words in healthy individuals with high AS (e.g., Koven et al., 2003; Teachman, 2005). The prediction was made that emotional RT slowing would be only present in response to Threat Blocks in individuals with high AS.

The following hypotheses were formulated with regard to the electrophysiological correlates of the eStroop task. First, an ERP correlate of the RT effect was expected only for the contrast between Threat and Positive *Blocks* (associated to a emotional RT slowing). Such effect would be an ERP *negative* modulation over frontocentral scalp present only in the high AS group (as in Li et al., 2007) and similar to the N450 indexing cognitive conflict in the cStroop task (Liotti et al., 2000).

The mixed-trial analysis of the ERP data allowed to additionally test whether the evoked response to threat vs. neutral words would reveal ERP modulations even in the absence of RT slowing (emotional salience, Haas et al., 2006). The main goal was to ascertain whether trial-by-trial emotion-specific modulations, particularly over frontal scalp, would be detectable; and if so, whether they would display the same timing, scalp topography and polarity as those observed in the block analysis where RT differences were expected.

It was anticipated that within-block ERP responses to threat words (mixed-trial analysis) would be detectable over frontal scalp, and that they would occur earlier than those observed in the block analysis, and possibly be more robust and/or would manifest even *earlier* in the high anxiety group, consistent with the idea that anxiety results in an exaggeration of mechanisms of *early* vigilance to threat stimuli (Williams and Gordon, 2007a).

Finally, consistent with previous ERP studies employing blocks of threat vs. non-threat stimuli, it was predicted that Threat Blocks would elicit greater occipital P1 and parietal LPP waves (Li et al., 2007; Van Hoff et al., 2008), and it was further hypothesized that the P1 modulation would be greater for the high AS group.

2. Methods

2.1. Screening session

933 undergraduate students took part in a screening session in which they completed the Anxiety Sensitivity Inventory (ASI) and a demographic questionnaire. The ASI is a 16-item scale used to reveal the fear of anxiety related sensations (Reiss et al., 1986). Scores were distributed as such: Mean = 21.3 ± 9.6, range 2–53. Cut-off points were made at ± 1 standard deviation; those with ASI scores ≥ 30 were classified as high AS, while those with ASI scores ≤ 11 were labeled as low AS. Subjects in the two subgroups, who reported in the demographic questionnaire being native English speakers, were contacted by email and invited to participate in the second study session.