

## Event-related potentials during an emotional Stroop task

Susan J. Thomas<sup>\*</sup>, Stuart J. Johnstone, Craig J. Gonsalvez

*Brain & Behaviour Research Institute, School of Psychology, University of Wollongong, Australia*

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### Abstract

Emotional Stroop tasks have gained wide interest in scientific literature in the last two decades. Although no direct measure of attention is employed, these studies infer the presence of preferential processing of threatening information based on reaction time (RT) impairment in a competing task. Because event-related potential (ERP) measures are sensitive to both the extent (amplitude) and speed (latency) of cerebral processing, they are valuable tools with which to examine more directly the claim that threatening stimuli are associated with enhanced attention. Twenty-two students rated a pool of words to identify those that were personally disturbing. Two word types (threat and neutral) were then compared in two tasks (color relevant, in which the color ink of words was identified, and word relevant in which words were classified as threatening or not). No emotional Stroop effect was observed in terms of longer RTs to identify the colors of threat words. ERP results provided valuable information about threat processing which was not observed with behavioral measures. Threat content was associated with larger P2 amplitude in the right than left hemisphere, and larger P3 amplitude, across tasks. The results indicate strong evidence for enhanced processing of threat-related stimuli in healthy individuals. It is concluded that ERPs are a sensitive measure of processes underlying emotional Stroop performance, which can be used to elucidate attentional biases in healthy and clinical populations.

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### 1. Introduction

Emotional Stroop tasks are the principal research tool for demonstrating attentional biases (Wells and Mathews, 1996). Interpretations of emotional Stroop studies, however, usually infer the presence of attentional biases towards threatening words based on impaired reaction time (RT) performance in a competing (color-naming) task, without direct measures of attention towards threatening material. Emotional Stroop RT studies can therefore only equivocally establish the presence of an attention bias or determine whether such a bias takes the form of more elaborate, or faster, processing of threat stimuli. Event-related potentials (ERPs) provide more direct measures of attention-related cerebral processing (Mangun and Hillyard, 1995), and are therefore an excellent means of directly examining attention to stimuli during emotional Stroop tasks. Amplitudes of ERP components are generally assumed to signify the degree or intensity of the

engagement of cognitive processes, and latencies are thought to measure the time course of stages of processing (Luck et al., 2000). ERPs allow a finer examination than RTs of the amount of time and resources allocated to stimulus evaluation during sensory and cognitive stages of information processing, in order to examine the stage and precise temporal loci of experimental phenomena (Hillyard and Kutas, 1983). Also, several studies have shown that ERPs are sensitive to emotional aspects of stimuli, with larger amplitude ERP components to emotional relative to neutral stimuli, and emotionally negative relative to emotionally positive stimuli, interpreted as indicating enhanced attention towards more salient stimuli (Bernat et al., 2001; Carretie et al., 2001a; Ito et al., 1998; Johnston et al., 1986; Lang et al., 1990). ERPs also allow the study of attentional biases that are not accompanied by reliable impairments in task performance at a behavioral level (e.g., Perez-Edgar and Fox, 2003; Weinstein, 1995).

#### 1.1. Emotional versus traditional Stroop tasks

Traditionally, Stroop tasks investigated interference caused when naming the ink color of incongruent compound stimuli (e.g., the word *red* printed in green ink), relative to the time

<sup>\*</sup> Corresponding author. School of Psychology, University of Wollongong, NSW, 2522, Australia. Tel.: +61 2 4221 3660; fax: +61 2 4221 4163.

E-mail address: [sue.thomas@psyc.uow.edu.au](mailto:sue.thomas@psyc.uow.edu.au) (S.J. Thomas).

taken to color name congruent or neutral stimuli (Stroop, 1935). Emotionally modified Stroop tasks emerged in the 1980s, investigating the effect of emotional words, rather than color words, as embedded distracters during information processing. Individuals are typically asked to name the color ink of words varying in emotional value (e.g., neutral versus anxiety-related words), and RTs between word types are compared. Emotional Stroop tasks have been applied to the study of information processing in a wide range of clinical and subclinical psychological conditions, particularly anxiety (see Williams et al., 1996 for a review). Individuals with psychological disorders often show longer RTs during emotional Stroop tasks when color-naming words related to their clinical concerns, compared to neutral words. It is assumed that these effects are due to attentional biases which lead to facilitated detection of threatening stimuli, which “captures” attentional resources at the expense of processing neutral material, hence interfering with the competing color-naming task (Williams et al., 1997). Despite two decades of research using emotional Stroop tasks in clinical and non-clinical populations, however, fundamental questions about the locus and nature of emotional Stroop effects remain inadequately examined. The current study addresses aspects of these questions by employing ERP methodologies.

### 1.2. ERPs during Stroop tasks

There is a well established literature examining ERPs in *traditional* color–word Stroop tasks (e.g. Duncan-Johnson and Kopell, 1981; Ilan and Polich, 1999; Liotti et al., 2000; Rebai et al., 1996; West, 2003; West and Alain, 1999, 2000), however very few ERP studies of *emotional* Stroop tasks (Metzger et al., 1997; Perez-Edgar and Fox, 2003) have been reported. In a study in the clinical domain, Metzger and colleagues (1997) used ERPs to investigate the emotional Stroop effect in individuals with post-traumatic stress disorder (PTSD). They found slower RTs for those with PTSD to name word colors, especially for traumatic words, suggesting a processing bias towards trauma-related information in PTSD. This was accompanied, however, by significantly reduced and delayed P3 components across all word types, suggesting that Stroop interference was not related to discernable differences in attention-related cerebral processing of trauma versus non-trauma related words. These results were unexpected and seem contrary to cognitive models of anxiety (Williams et al., 1988, 1997). Metzger and colleagues, however, did not report on ERP components other than the P3, raising the possibility that relevant, earlier, attentional effects were overlooked. Another possibility is that emotional Stroop interference was due to effort taken to avoid processing emotional information, rather than enhanced processing, interfering with the ongoing color-naming task (de Ruyter and Brosschot, 1994; Kyrios and Iob, 1998). Traditional Stroop studies often include a word relevant comparison condition where task requirements maintain the association between the words and their meanings (Duncan-Johnson and Kopell, 1981; Stroop, 1935), in anticipation that participants may develop strategies (such as blurring the focus of their eyes) to avoid processing interfering word content

during the color task (see MacLeod, 1991 for a discussion). Emotional Stroop studies, however, have yet to address this issue. As it may be possible for participants to avoid attending to unpleasant word meaning during the color categorization task, it is important to compare implicit attention to threatening words during the typical emotional Stroop color-naming task with explicit, task relevant attention to threat words in order to avoid the above interpretive difficulties, and to fully explore attention towards threatening stimuli.

In a non-clinical study, Perez-Edgar and Fox (2003) investigated ERPs in an emotional Stroop task with normal children. They found smaller N1 and N2 components to emotionally negative words (e.g., *afraid*, *alone*) relative to positive and control words, indicating differential processing during both sensory and cognitive stages. Slow waves were more pronounced for negative words, indicating the likely involvement of additional processing resources, even though there were no discernable differences between words at the RT level, supporting the utility of using ERPs to examine the subtleties of attentional biases in healthy individuals.

### 1.3. ERPs and emotion

There are suggestions in the literature that ERPs are a more sensitive measure of attentional biases than RT measures. RT studies of emotional Stroop tasks (e.g., Becker et al., 2001; Cox et al., 2002; Kampman et al., 2002; Lavy et al., 1994; MacLeod and Dunbar, 1988; Martin et al., 1991; Mathews and MacLeod, 1985; McNally et al., 1994; Mogg et al., 1989; Yovel and Mineka, 2004) have generally found no delayed latencies to color name general threat words for non-clinical participants (although there are some exceptions: McKenna and Sharma, 1995; Pratto and John, 1991). A number of ERP studies of healthy individuals, however, have found larger amplitude ERPs in response to emotional relative to neutral stimuli, and in emotionally negative relative to emotionally positive stimuli, suggesting that preferential processing is apparent when examining ERP rather than RT measures. Carretie et al. (2001a), for example, measured ERPs in normal participants to arousing positive, arousing negative, relaxing and neutral pictorial stimuli in a cue/target paradigm. The P200 and P340 post-target components had their highest amplitudes to negative stimuli. Ito et al. (1998) found larger late positive potentials (LPPs) for positive and negative relative to neutral pictures, and for negative relative to positive pictures, during tasks in which undergraduates pressed computer keys to evaluate stimuli as positive, neutral or negative. Bernat et al. (2001) had undergraduates merely watch words that appeared on a computer screen, and found that unpleasant words elicited more positive amplitudes than pleasant words across all components (P1, N1, P2, P3 and LPP) in both supraliminal and subliminal conditions. Weinstein (1995) found no RT differences between high and low anxious normals' performance in deciding whether visually presented words (positive, neutral or threat) matched semantically with priming sentences (threat or positive). ERPs, however, showed larger amplitude N100 and P400 in the high anxious group in the threat priming condition. Larger amplitude ERPs to

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