Available online at www.sciencedirect.com
ScienceDirect
Brain and Cognition 65 (2007) 22–35
Brain and Cognition
www.elsevier.com/locate/b&c

Temperamental contributions to children's performance in an emotion-word processing task: A behavioral and electrophysiological study

Koraly Pérez-Edgar [a,*], Nathan A. Fox [b]

[a] Department of Psychology, George Mason University, Fairfax, VA, USA
[b] Institute for Child Study, University of Maryland, 3304 Benjamin Building, College Park, MD 20742, USA

Accepted 15 October 2006
Available online 16 July 2007

Abstract

Seven-year-old children ($N = 65$) participating in a study of the influence of infant temperament on socioemotional development performed an auditory selective attention task involving words that varied in both affective (positive vs. negative) and social (social vs. non-social) content. Parent report of contemporaneous child temperament was also collected, and individual differences in self-regulation in the affective (soothability) and cognitive (attentional control) domains were noted. Overall, children showed slower responses to stimuli that were either social or negative in content, with the largest effect elicited by words that possessed both traits. Children rated high in soothability and attentional control showed slower responses to social negative words. The other children showed little to no differential response patterns across the word categories. ERPs collected during the task indicated that processing differences were evident in the later more cognitive components of the ERP, especially in children low in attentional control. These findings indicate that performance on an auditory selective attention task can assist in identifying underlying patterns of affective processing.

Keywords: Attention; Temperament; Emotion Processing; ERPs

1. Introduction

Individuals show an attentional bias for information congruent with or relevant to their current concerns (McNally, 1996). This bias allows an individual to sort through a cluttered environment and identify environmental cues that either further one's goals or best match his or her current interests or emotional state. An attentional bias may become maladaptive if an individual is unable to disengage from particular aspects of his environment, thus creating a rigid and less flexible cognitive or behavioral response (Fox, Russo, Bowles, & Dutton, 2001; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). A growing literature has shown that many clinical populations, particularly those within the class of anxiety disorders, display disturbances in attention bias, including the selection and interpretation of affective stimuli (Ehrenreich & Gross, 2002; Fox, Russo, & Dutton, 2002; Pauli et al., 1997). For example, individuals with panic disorder are prone to detecting body-related stimuli, particularly threat cues, at lower thresholds than their peers (Foa & McNally, 1986) and then misinterpreting these sensations as signs of impending catastrophe (Clark, 1988).

In examining individual differences in selective attention, researchers have found it difficult to tap into the underlying psychological mechanisms using explicit measures of affective processing. As a result, there are a growing number of measures designed to implicitly test individual affect biases and selective processing patterns. Prominent among these tasks are the affective priming task (Fazio, Sanbonmatsu,

* Corresponding author.
E-mail address: kperezed@gmu.edu (K. Pérez-Edgar).

0278-2626/$ - see front matter © 2007 Elsevier Inc. All rights reserved.
doi:10.1016/j.bandc.2006.10.010

Powell, & Kardes, 1986), the emotional Stroop task (Norman & Shallice, 1986), the implicit association test (Greenwald, McGhee, & Schwartz, 1998), and the affective Simon task (De Houwer & Eelen, 1998).

These tasks are designed to examine the bi-directional influences of affective and cognitive processes. Emotions may be thought of as the driving energy observed in arousal levels and behavioral movement toward or away from environmental stimuli, while cognitive structures serve as the rule-bound organization and content of the behavioral scheme (Crick & Dodge, 1994). As such, emotions can alternately strengthen or disrupt the efficiency of information processing (Vasey & Daleiden, 1996).

Each of these tasks has examined different parameters of the affect-cognition balance such as cognitive load (Keinan, Friedland, Kahneman, & Roth, 1999), the affective content of the stimuli to be processed (Pollak & Tolley-Schell, 2003), the affective context of testing (Chajut & Algom, 2003), and individual differences in cognitive ability (Gainotti, Marra, & Villa, 2001) or affective characteristics (Ehrenreich & Gross, 2002). Taken together, the data indicate that the functional balance between cognitive processes (e.g., attention) and emotional processes is dynamic, reflecting the particular characteristics of the task at hand and the individuals called upon to carry out the task.

The literature on the implicit testing of affect processing is of great theoretical interest in psychology in general. It is also of great practical use in developmental studies since children often have difficulty with more complex tasks that require extensive verbal skills or the retention of complex rule sets. Along these lines, developmental studies have demonstrated that children show differential patterns of processing with affective stimuli that are early appearing, potentially enduring, and possibly linked to the formation of higher-order socioemotional functioning. Generally, children appear sensitive to the affective context of the task before them, as seen in a recent study by Lewis and Steiben (2004) using a traditional and affective version of the Go/No-Go task. They found that the electrophysiological measures of anxiety rose and fell as an affective threat was added and then removed from blocks of trials. Similarly, Martin and Cole (2000) found that children who ranked low in popularity and social acceptance by their peers preferentially attended to socially negative words relative to popular children. Pérez-Edgar and Fox (2005) found that shy or anxious children showed differential attention to spatial cues linked to threatening stimuli (see also Pine et al., 2005; Vasey, Daleiden, Williams, & Brown, 1995). In addition, selective attention patterns to emotion words have been linked to patterns of maladjustment that persist from pre-school to middle childhood (Pérez-Edgar & Fox, 2003a).

One factor that may potentially impact the functional balance between cognitive and affective processing is individual variation in temperamental reactivity and regulation. Kagan (1994) refers to temperament as any moderately stable, emotional or behavioral quality whose appearance in childhood is influenced by an inherited biology. Research has found that individual differences in behavior can be seen within the first 3 months of life. For example, infants vary in their likelihood to cry to maternal separation (Davidson & Fox, 1989), fret and fuss to novel stimuli (Kagan et al., 1994), show vigorous motor activity (Kagan & Snidman, 1991), and express spontaneous smiles (Rothbart, 1991). Many of these early behaviors are viewed as markers for the infant's temperamental reactivity.

Individual differences in the tendency to experience and express negative affect are early appearing and often enduring. At 4 months, some infants are prone to vigorous displays of negative affect when confronted with novel sensory stimuli (Fox, Schmidt, Calkins, Rubin, & Coplan, 1996). These infants often develop into behaviorally inhibited toddlers and socially withdrawn or shy pre-schoolers (Fox, Henderson, Rubin, Calkins, & Schmidt, 2001; Rimm-Kauffman, 1996). There also appears to be a core psychophysiological profile that accompanies this pattern of behavioral and emotional reactivity. Infants who show negative emotional reactivity display high heart rate and low heart period variability (Calkins, Fox, & Marshall, 1996; Fox, 1989; Marshall & Stevenson-Hinde, 1998), elevated cortisol levels (Schmidt et al., 1997), heightened startle response (Schmidt & Fox, 1998, but not Schmidt et al., 1997), and right frontal EEG asymmetry (Bell & Fox, 1994; Calkins et al., 1996; Davidson, 1994; Fox, Henderson et al., 2001; McManis, Kagan, Snidman, & Woodward, 2002).

As with most constructs shaped by developmental processes, the behavioral manifestation of temperamental reactivity changes over time, shifting from motoric displays of negative affect in infancy to withdrawn and subdued behavior in middle childhood. This shift may be attributable to the emergence of higher order cognitive mechanisms that can interact with and co-regulate affective tendencies.

Rothbart (Derryberry & Rothbart, 1988) has outlined three main constructs that shape temperamental variations in affect and behavior. The first construct, arousal, is thought to reflect central reactivity—the cortical arousal of perceptual and cognitive processing. The second construct, emotionality, focuses on affective states that are of particular interest to current temperament theory. These affective states include discomfort, fear, sadness, and pleasure. The third construct is self-regulation, as illustrated in studies of attention focusing, attention shifting, and inhibitory control (Derryberry & Rothbart, 1988).

Self-regulation allows the child to suppress motivational tendencies, both negative and positive, in order to program behavior in conflict situations. As such, the child is somewhat freed from automatic affective drives and can respond more strategically to the context at hand. In this way, the young child begins to shape inborn behavioral tendencies through the effortful control of regulatory mechanisms (Posner & Rothbart, 2000).

The ability to sooth and control attention may arise from repeated guided interactions with the larger environment, usually with the parent. Once these mechanisms are internalized, the child has a ready system for regulating affective processes when novel cognitive challenges arise (Posner & Rothbart, 2000). Indeed, strategic deployment of self-regulatory mechanisms can be seen as early as 36 months of age (Kopp, 1982), just as children begin to display more controlled behaviors and are about to enter into the "age of reason" (White, 1996).

One central question in current temperament research attempts to isolate and examine the core processes that bridge temperamental differences in effortful control and socioemotional outcomes. Rothbart and colleagues have shown that individuals better equipped to regulate initial reactivity are less likely to show prolonged periods of negative affect. For example, their data suggest that infants prone to distress are less adept at shifting attention away from a distressing stimulus and have difficulty engaging in self-soothing activity (Rothbart, Posner, & Rosicky, 1994; Ruddy, 1993). In addition, infants whose mothers rate them as showing poor attentional control are also prone to distress and less likely to show spontaneous smiles (Pérez-Edgar & Fox, 2003b). At age four, these children show greater signs of social reticence.

The ability to self-regulate via selective attention may play an important role in observed patterns of socioemotional behavior. For example, Rothbart (Rothbart, Ellis, Rueda, & Posner, 2003) found less interference during a Stroop-like localization task among children rated high in effortful control. The current study examines children's patterns of attentional biases in response to the social, and emotional characteristics of word stimuli. To do so, the study utilizes a simple auditory identification task analogous to the emotion Stroop paradigm. It also investigates whether these patterns are shaped by individual differences in self-regulation profiles. Maternal ratings of soothability and attentional control were collected as part of a temperament questionnaire. Each measure is thought to reflect the child's ability to regulate within a cognitive or affective domain.

The emotional Stroop task is one of the most prominent implicit attention tasks (Williams, Mathews, & MacLeod, 1996). The traditional Stroop task (Stroop, 1935) presents individuals with a series of words and asks them to name the color in which the word is written, while disregarding the actual meaning of the word. Individuals are faster to respond when presented with congruent stimuli (e.g., the word RED in red ink) than when the stimuli are incongruent (e.g., the word RED in blue ink). The emotional Stroop substitutes emotionally charged words for the color words normally used.

In his extensive review of the emotional Stroop literature, Williams et al. (1996) found that across a wide range of clinical populations individuals are slow in responding to stimuli idiosyncratic to their disorder. These individual differences appear to track the participant's degree of impairment (McNally, 1995) and amenability to treatment (Mattia, Heimberg, & Hope, 1993). The emotional Stroop task has also been used successfully with nonclinical populations when stimuli are derived from individual interviews (Logan & Goetsch, 1993; Riemann & McNally, 1995) or when stimuli match experimentally induced moods (Gilboa-Schechtman, Revelle, & Gotlib, 2000; Richards, French, Johnson, Naparstek, & Williams, 1992; but not Gotlib & McCann, 1984; Riemann & McNally, 1995). The data from the Stroop task are in line with recent studies that find distinct patterns of neural responsivity to subjectively significant emotional stimuli (e.g., Ofek & Pratt, 2005).

In examining the task, De Houwer (2003) has noted "what is structurally unique about the emotional Stroop task is that it examines the effects of the task-irrelevant valence of stimuli in a situation where S–S and S–R compatibility are not manipulated" (p. 229). In the traditional Stroop, the target response (i.e., ink color) is in direct perceptual conflict with the irrelevant distractor (i.e., color word). However, in the emotional Stroop, there is no longer a direct coupling within the S–R pattern. The task is now, despite its pedigree and name, more akin to measures of selective attention than to the specific perceptual conflict seen in the original task. As such, De Houwer (2003) concluded that once the direct S–R coupling is broken, "the other aspects of the task should not be crucial" (p. 229).

Indeed, a number of "Stroop-like analogs" have been used in the last 2 decades to great effect. These analogs include (using the individual authors' terminology) a counting Stroop (Whalen et al., 1998), a pictorial Stroop (Gherstadt, Hong, & Diamond, 1994), a pictorial emotional Stroop (Kagan, Snidman, & Arcus, 1995), a Stroop-like crossmodal spatial cueing task (Mayer & Kosson, 2004), a Stroop-like spatial identification task (Rothbart et al., 2003), a face-word Stroop analog (Anes & Kruer, 2004; Kavcic & Clarke, 2000), and both tone- (McClain, 1983; Morgan & Brandt, 1989) and gender-based (Green & Barber, 1983; Jerger, Martin, & Pirozzolo, 1988; Most, 1999) auditory Stroop analogs.

Given the variable reading levels often seen in young children, an auditory analog of the emotional Stroop task was used in the current study. Children listened to words presented by either male or female speakers and were asked to identify the gender of the speaker. While it is unlikely that simply hearing a word triggers a deep semantic analysis (Heinrichs & Hofmann, 2004), single words do trigger some processing, as can be seen in priming (Plaut & Booth, 2000) and semantic incongruity tasks (McCallum, Farmer, & Pocock, 1984). The words presented in this study varied in social and emotional content in hopes of targeting the issue of peer relationships and friendships. This theme was specifically targeted since some of the children in this study were previously identified as exhibiting temperamental fearfulness/behavioral inhibition. These children had just started elementary school, and the issue of peer relationships is often extremely important for children at this time. The children in this study are navigating an ever-expanding social world of school and neighborhood, which would require a strong self-regulatory system for adaptive functioning (Kopp, 2002). Children with a temperamental bias towards fear and social avoidance may find this transition particularly difficult. They may have had fewer experiences in social situations, which may impede their ability to develop skills necessary to meet these new developmental challenges. It may be that early temperamental biases in attention and affect set in motion a self-reinforcing cognitive and behavioral loop involving few or poor social relationships and high levels of anxiety that continues on into early childhood.

In order to supplement the behavioral reaction time (RT) data generated by the task, event-related potentials (ERPs) were also collected during the task. The psychophysiological research literature has focused on determining the link between individual ERP components and discrete neural or psychological processes. For example, the N400 is thought to reflect the detection of linguistic discrepancies (Connolly, Phillips, Stewart, & Brake, 1992). Researchers interested in the neural underpinnings of affect have, in contrast, failed to uncover a dedicated "affective" component. Instead, perturbations in affect or motivation appear to moderate the ERP components normally generated by the particular task at hand (Lewis & Steiben, 2004; Ofek & Pratt, 2005).

For example, late components of the ERP appear to reflect the discrepant nature of stimuli undergoing cognitive or affective processing (Pauli et al., 1997). In particular, affective stimuli elicit more positive P300s and late positive slow waves than neutral stimuli in selective attention tasks (Ito, Larsen, Smith, & Cacioppo, 1998; Kostandov & Azumanov, 1977; Williamson, Harpur, & Hare, 1991). This effect is even more pronounced when the stimuli are tailored to individual participant concerns. For example, Pauli et al. (1997) found that panic patients showed larger P300s and positive slow waves to somatic vs. nonsomatic stimuli.

As a result, the current study chose for analysis ERP components that have previously been linked to processes elicited by similar selective attention tasks. The data analyses focused on three ERP components thought to reflect different aspects of early word processing: N2 (initial orienting and resource allocation), P3 (stimulus evaluation time and attentional requirements needed to generate a behavioral response), and the slow wave (attention allocation in the response selection phase).

Based on previous work (e.g., Ehrenreich & Gross, 2002; Fox et al., 2002; Lewis & Steiben, 2004; Martin & Cole, 2000; Pérez-Edgar & Fox, 2003a; Rothbart et al., 2003), a number of predictions were made concerning the current study. First, although the word categories are equivalent in their level of S–R incompatibility (Ragot & Fiori, 1994), we expected to see differential responses linked to the context (social vs. nonsocial) and valence (positive vs. negative) of the stimulus word. The general presumption in the literature is that attentional effects are driven by biases toward threat, particularly among individuals with affective concerns (e.g., anxiety). As such, we should see the greatest behavioral (slowed RTs) and psychophysiological (enhanced ERP amplitudes) effects for social negative words, particularly among children rated less adept in self-regulation at either the affective or cognitive domain.

2. Method

2.1. Participants

Participants were recruited from a large metropolitan area for a longitudinal study of the behavioral and physiological correlates of temperament. A subset of participants ($N = 58$) was recruited from the longitudinal cohort for the current study. An additional seven children were recruited from the community at the time of the study. A total of 65 children (36 male, 29 female) participated in the study at age seven.

Data from one child (a male) were not included in the analyses due to the diagnosis of a serious psychological disorder. Mechanical error disrupted data collection for two children (both girls). Three of the children (all boys) were unable to participate in the behavioral task. However, they each completed temperament questionnaires. In total, there were questionnaire data on 64 children and behavioral data for 61 children.

2.2. Temperament classification

Children were grouped along two dimensions based on maternal report on the Colorado Child Temperament Inventory (CCTI; Buss & Plomin, 1984). This 30-item measure asked mothers to rate their child with a 5-point Likert scale on six factors pertaining to different dimensions of child temperament: emotionality, activity, attentional control, soothability, shyness, and sociability. Data on the reliability and validity of the CCTI can be found in Rowe and Plomin (1977).

The data presented here focus on ratings from the attentional control and soothability scales. For each scale, the children were median split into two groups. Attention scores ranged from 2.2 to 5.0, with a mean rating of 3.77 [$SD = 0.54$]. There were 34 children in the low control group [$x = 3.42$, $SD = 0.42$] and 27 children in the high control group [$x = 4.21$, $SD = 0.29$]. On the soothability scale, scores ranged from 2.4 to 4.6, with a mean score of 3.45 [$SD = 0.53$], with 29 children in the low soothability group [$x = 2.98$, $SD = 0.28$] and 32 children in the high soothability group [$x = 3.88$, $SD = 0.27$]. There were no relations between attentional control and soothability in raw score [$r(61) = .23$, $p = .08$], and group membership [$\chi^2(1) = 0.89$, $p = .34$].

2.3. Measures of behavioral adjustment

Mothers also rated their children's behavior using the Child Behavior Checklist (CBCL; Achenbach, 1991). The CBCL is a 113-item checklist in which parents use a 3-point scale to rate behavior problems in their child. The CBCL yields eight narrow-band factors: social withdrawal, somatic problems, anxiety/depression, social problems, thought problems, attention problems, delinquency, and aggressive behavior. These factors can be further reduced to two broadband factors: internalizing and externalizing behavior problems. None of the children in the current sample were rated in the clinical range for either internalizing or externalizing behavior problems.

2.4. Auditory selective attention task

In this study, children were presented with a series of 60 words via headphones (see Appendix A). The list of words was repeated three times, for a total of 180 trials. A 1-min break followed each list. Half of the words in each list were spoken by a male, the other half by a female. Two male and two female voices (recruited from the community) were used in order to discourage feature-based processing. Order of presentation, speaker gender, and speaker identity were counterbalanced across the three lists.

A large pool of potential word stimuli were rated on separate 7-point Likert scales on emotional valence and social content (e.g., peer relationships, friendship). The included words form five categories: nonsocial positive (high positive rating, low social rating), nonsocial negative (low positive, low social), social positive (high positive, high social), social negative (low positive, high social), and control (neutral on both positive and social). There were 12 words selected for each category. Stimuli were matched across the five categories for frequency [nonsocial positive: $x = 54.0$, $SD = 66.5$; nonsocial negative: $x = 53.8$, $SD = 60.2$; social positive: $x = 53.2$, $SD = 63.5$; social negative: $x = 52.2$, $SD = 61.8$; control: $x = 52.7$, $SD = 62.4$] and number of syllables (Francis & Kucera, 1982).

Word presentation (ITI = 4000 ms; time-out latency = 3500 ms) was controlled by the STIM stimulus presentation system from the James Long Company (Caroga Lake, NY). The children were asked to identify the gender of the speaker by stating "girl" or "boy" into a microphone. RTs were collected for each trial through a voice triggered data collection system, and response errors were noted manually.

2.5. Physiological data collection

EEG signals were recorded with an electrode cap from frontal (Fz, F3, F4, F7, F8), parietal (Pz, P3, P4), and occipital (O1, O2) sites, referenced to vertex (Cz) using the international 10/20 system (Jasper, 1958).[1] Impedances were kept below 5 kΩ. The data from each channel were digitized at a 512 Hz sampling rate and calibrated to a 0.477 V rms 10 Hz signal that was input into each channel before testing. Vertical eye movements were recorded from electrodes placed above and below the right eye, while horizontal eye movements were monitored with electrodes placed at the external canthi of each eye. The digitized EEG data were manually edited for eye-blink (rise-time: 100 ms, fall-time: 150 ms, peak: 125 μV) or movement-related (100 μV cutoff or visually discrepant signal) artifact. Eye blinks were regressed out using software provided by James Long Company (Caroga Lake, NY). All other artifact was expunged from the files.

For 28 of the children, signals were amplified by individual Grass AC bioamplifiers (Model 78D) using high- and low-pass filters of 0.10 and 100 Hz and a 60 Hz notch filter. The signal was digitized using Snapshot–Snapstream acquisition software (HEM Data Corp.). The data from the remaining 36 children were collected with SA Instruments isolated bioelectric amplifiers (San Diego, CA) using high- and low-pass filters of 0.10 and 100 Hz. The signal was digitized with the Snapmaster Data Acquisition System (HEM Data Corp.). A repeated measures ANOVA of EEG power using testing group as a between-subjects factor found no significant differences between children tested with the Grass AC amplifiers and the amplifiers by SA Instruments [$F(1, 56) = 0.01$, $p = .93$].

ERPs were collected for each word, referenced to a baseline from −100 ms to stimulus onset. Included trials were artifact free for the 1000 ms following word presentation. In order to minimize the number of analyses and increase the stability of the ERP measures, we only examined issues of valence and group effects in this paper.

ERPs generated by the positive, negative, and control words were separated into three individual files to create mean ERPs for each child. ERP components were chosen for analysis (see results section) based on a review of the grand ERPs, which were created by averaging together the ERPs from all of the participating children.

On average, there were 36.1, 37.0, and 17.6 artifact free trials per child for positive, negative, and control words, respectively. The disparity in number of useable trials was due to the fact that the ERPs for the emotional words were created by aggregating across the social and nonsocial subcategories. There was no significant difference in the number of useable trials between positive and negative words [$t(58) = -1.30$, $p = .20$]. In addition, the groups did not differ across the three word categories in the number of valid trials available [ts < 1.13, ps $> .27$; Fs < 0.68, ps $> .57$].

As in other studies involving the relations of EEG to emotional and cognitive development (Marshall, Drummey, Newcombe, & Fox, 2002; Pérez-Edgar & Fox, 2003a, 2005; Pérez-Edgar, Fox, Cohn, & Kovacs, 2006), this study used average referencing in analyzing the EEG and ERP data. Although large sensor arrays are ideal when relying on average reference, (Davidson, Jackson, & Larson, 2000; Dien, 1998; Hagemann, Naumann, & Thayer, 2001), the scalp distribution of the electrodes in the present study was extensive enough to justify use of this reference configuration (Marshall et al., 2002, Marshall, Bar-Haim, & Fox, 2002).

[1] The data from F7 and F8 will not be presented here due to excessive artifact levels.

In plotting ERPs produced via average referencing, the ERP waves from the posterior sites (i.e., parietal and occipital) are inverted relative to the anterior sites. The components presented here were labeled based on their appearance in the ERPs produced by the frontal electrodes (Dien, 1998).

2.6. Statistical analyses

Before the analyses, RT data were edited for each child to remove error trials as well as any trials more than two standard deviations from his or her grand mean. Mean RTs were then calculated for each of the word categories. Children whose overall RTs were more than two standard deviations from the study mean were removed from further analyses. Error trials were then removed from the ERPs before processing. Children performed very well in this task, with accuracy rates of 97%.

The analyses presented below employ repeated measures ANOVAs. In order to minimize the risk for Type 1 error, the Greenhouse–Geisser (G–G) procedure was applied when appropriate (Geisser & Greenhouse, 1958). The degrees of freedom indicated in the text are those before the G–G correction. However, epsilon ($\in$) was noted when less than 1.0. Subsequent post hoc comparisons employed the Tukey test.

3. Results

3.1. Behavioral adjustment

Higher attentional control ratings on the CCTI were associated with fewer social problems [$r(61) = -.43$, $p = .001$], attention problems [$r(61) = -.41$, $p = .001$], delinquency [$r(61) = -.35$, $p = .01$], and aggressive behavior [$r(61) = -.35$, $p = .01$], on the CBCL. This pattern was seen in the overall negative relation with externalizing behaviors [$r(61) = -.40$, $p = .001$]. Independent-sample t-tests found group differences in delinquency, aggressive behavior, and overall externalizing levels, [ts > 2.11, ps $< .04$].

High soothability scores on the CCTI were linked to less social withdrawal [$r(61) = -.30$, $p = .02$], less anxiety and depression [$r(61) = -.32$, $p = .01$], fewer social problems [$r(61) = -.30$, $p = .02$], fewer attention problems [$r(61) = -.25$, $p = .05$], and less aggressive behavior [$r(61) = -.46$, $p = .001$] on the CBCL. As a result, there was also an negative relation between soothability and both externalizing [$r(61) = -.43$, $p = .001$] and internalizing behaviors [$r(61) = -.36$, $p = .004$]. On the other factors of the CCTI, soothability was associated with less emotionality [$r(61) = -.42$, $p = .001$] and impulsivity [$r(61) = -.37$, $p = .003$]. Independent t-tests also found significant group differences in aggression and externalizing behavior problems [ts > 2.11, ps $< .04$].

A multivariate ANOVA was used to examine potential relations between the two temperament variables and behavioral adjustment. Children high in attentional control showed fewer externalizing behavior problems [$F(1,57) = 4.96$, $p = .03$]. A similar trend was evident for soothability, [$F(1,57) = 3.65$, $p = .06$]. In addition, children low in attentional control and soothability had the highest levels of internalizing problems [$F(1,57) = 8.76$, $p = .01$]. A similar trend was noted for externalizing problems [$F(1,57) = 3.73$, $p = .06$].

3.2. Behavioral data

Preliminary paired-sample t-tests indicated that the children were significantly slower in responding to social negative [$t(57) = 5.38$, $p < .01$], social positive [$t(57) = 2.78$, $p = .01$], and nonsocial negative [$t(57) = 2.60$, $p = .01$] words relative to the control words (see Table 1).

In addition, responses to the negative social words were significantly slower than to the other three social-emotional word categories [ts > 2.36, ps $< .02$]. The data indicate that each of the word categories, except for nonsocial positive, significantly slowed processing rates. In addition, the greatest effect was found for the negative social words. The social negative words may hold the most meaning or attract the greatest attention for the children in the study, thus producing greater processing competition during the task.

A 2 (Social) × 2 (Emotion) ANOVA was then used to examine RTs across the affective word categories. Negative words elicited significantly slower RTs than positive words [$F(1,57) = 8.05$, $p = .01$]. In addition, social words elicited significantly slower RTs than nonsocial words [$F(1,57) = 11.65$, $p = .001$]. The interaction between emotion and social content was not significant [$F(1,57) = 0.47$, $p = .50$].

3.2.1. Temperament

Attentional control and soothability were added as between-subjects factors to create a 2 × 2 × 2 × 2 ANOVA. Fig. 1 shows difference scores between negative and positive words for the social and nonsocial categories across the four groups.

As in the original 2 × 2 ANOVA noted above, the main effects of social content and valence were again significant [Fs > 10.02, ps $< .003$] while the interaction was not significant. There were no two-way interactions involving valence and temperament. However, there was an interaction between social content and soothability. Specifically, children low in soothability did not differentiate between social and nonsocial words [$t(26) = 0.92$, $p = .37$]. Children high in soothability were significantly slower in responding to the social words vs. nonsocial words [$t(29) = 3.37$, $p = .002$].

There were also two significant three-way interactions. The first interaction involved social content, valence, and attentional control [$F(1,53) = 4.50$, $p = .04$]. Children low in attentional control showed no significant differences across the word categories [F's < 2.16, ps $> .15$]. In contrast, the children high in attentional control showed

Table 1
Mean reaction times (ms) and standard deviations in the auditory processing task by participant group

Participants	Word category				
	Nonsocial positive	Nonsocial negative	Social positive	Social negative	Controls
All children	1426.8 (200.3)	1444.7 (181.0)	1449.7 (198.2)	1479.5 (176.6)	1417.1 (179.8)
Low Soothability	1390.1 (188.7)	1429.0 (169.7)	1413.2 (171.1)	1423.2 (159.5)	1390.1 (177.9)
High Soothability	1463.6 (209.5)	1466.3 (190.2)	1489.8 (215.4)	1533.5 (179.3)	1446.1 (181.6)
Low Attention	1462.0 (209.0)	1489.6 (185.5)	1493.7 (205.8)	1492.9 (189.2)	1444.7 (197.5)
High Attention	1386.2 (187.2)	1396.2 (161.9)	1402.1 (177.9)	1466.2 (164.4)	1387.4 (153.9)

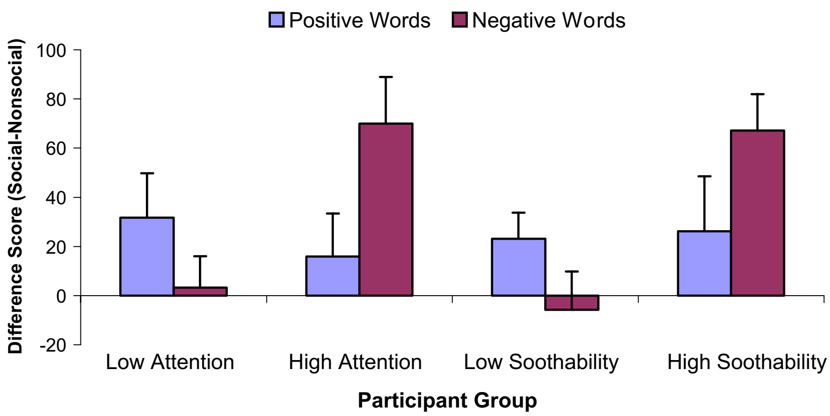

Fig. 1. Differential response to social content in emotion words as a function of Soothability and Attentional Control ratings.

significant main effects for valence and social content [F's > 9.03, $ps < .01$], and a trend toward an interaction between the two word categories [$F(1,24) = 3.84$, $p = .06$]. These results reflected the significantly slower RTs for the social negative words [$ts > 3.67$, $ps > .001$].

The second three-way interaction involved social content, valence, and soothability group [$F(1,53) = 4.38$, $p = .04$]. Children low in soothability showed a main effect of valence [$F(1,26) = 4.77$, $p = .04$], but not social content. In contrast, the children high in soothability showed a main effect of social content [$F(1,29) = 12.28$, $p = .002$] and a trend for valence [$F(1,29) = 3.21$, $p = .08$]. These data again reflect the slow RTs for the social negative words [$ts > 2.20$, $ps > .04$]. The four-way interaction was not significant.

3.3. Event-related potentials

3.3.1. General morphology

This study is among the first of its kind to employ ERP techniques. As such, an initial qualitative review was made of the resulting waveforms. The ERPs generated by the auditory processing task produced a number of distinct wave components (see Figs. 2 and 3). Early in the waveform, there is a distinct P1–N1–P2–N2 complex, which closely mirrors the N1–P2–N2 complex seen in visual conflict tasks such as the traditional Stroop task (Atkinson, Drysdale, & Fulham, 2003; Bauer & Hesselbrock, 1999; Ilan & Polich, 1999; Liotti, Woldroff, Pérez, & Mayberg, 2000; West & Alain, 1999, 2000a; but not West & Alain, 2000b).

This study found an attenuated P3 component and a marked negative slow wave late in the ERP. A similar auditory processing task in adults also mirrored these findings (Pérez-Edgar, Bhuiya, Marshall, & Fox, 2000). West and Alain (2000a) have speculated that late slow waves in visual tasks may mark the additional processing time needed to (a) counteract the ongoing cognitive processing of word meaning and then (b) respond to the task demands. A similar mechanism may be at play in this auditory task.

3.3.2. Quantitative analyses

ERPs were analyzed for the components N2 (230–330 ms) and P3 (280–380 ms; see Table 2). In addition, mean amplitudes for the negative slow wave were computed across 2 time windows: 400–700 ms and 700–1000 ms. The wave was split into two segments in order to avoid distorting the mean measure.

For each component analysis, an initial $3 \times 3 \times 2 \times 2 \times 2$ ANOVA was calculated. Word Category, Electrode Scalp Location, and Hemisphere were within-subject factors (see Table 2). Soothability and attentional control group served as the between-subjects measures. Analyses were then conducted separately for each electrode scalp location (i.e., frontal, parietal, occipital).

3.3.3. N2

There were no differences due to valence [$F(2,100) = 1.81$, $p = .17$, $\in = 0.98$] in the early N2 component. However, the effect of hemisphere was significant with larger

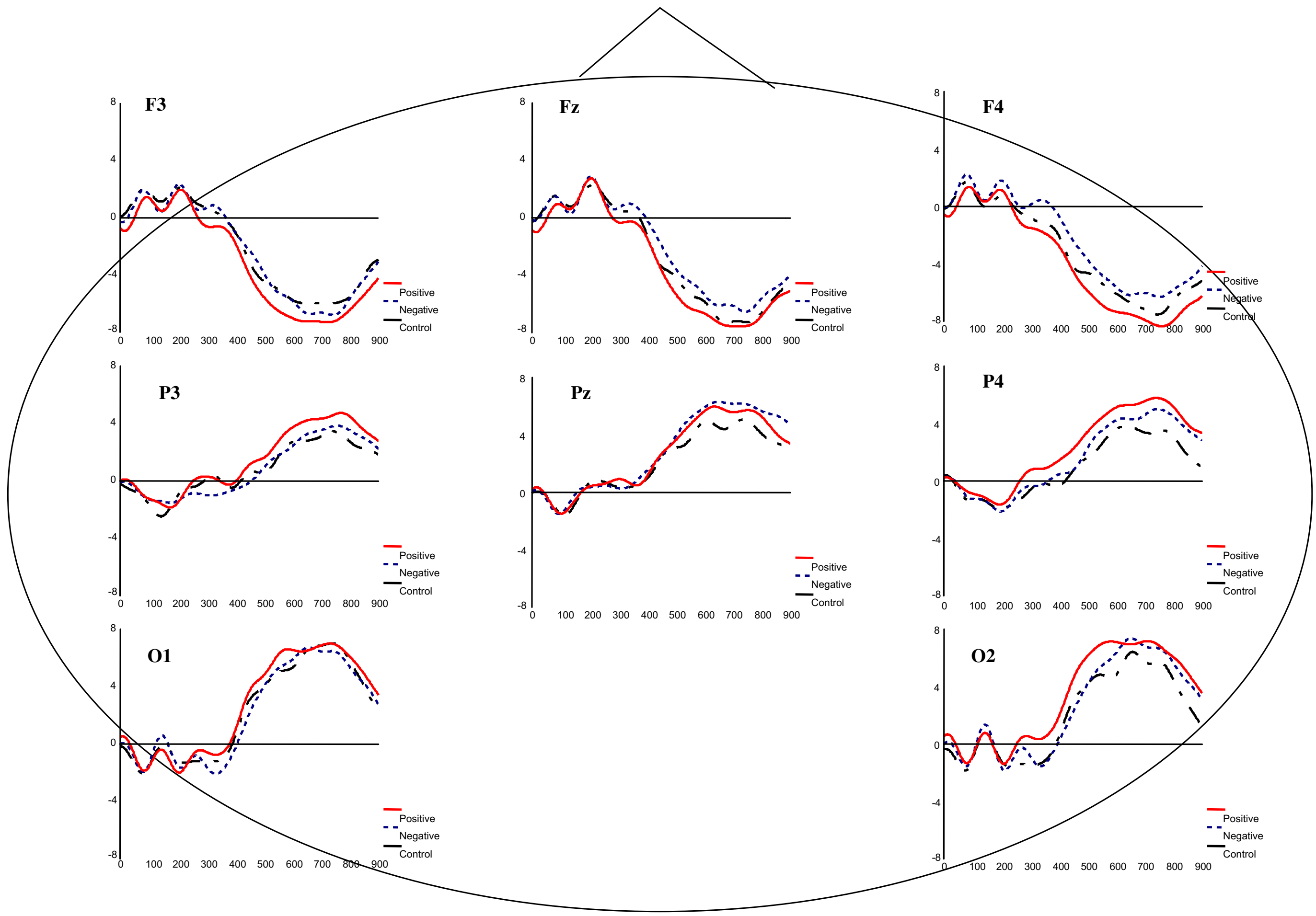

Fig. 2. Grand ERPs for the positive, negative, and control words presented in the study. ERPs are presented for the following sites: F3, F4, Fz, P3, P4, Pz, O1, and O2. Amplitude differences across word category and participant group were found for N2, P3, and the negative slow wave.

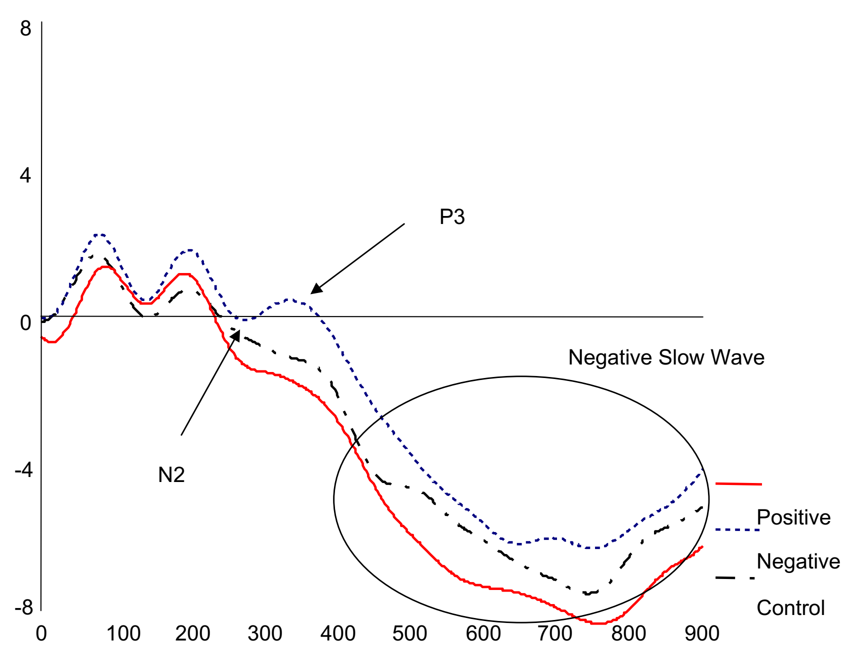

Fig. 3. ERP from F4. Noted are the main components of interest: N2, P3, and the negative slow wave.

Table 2
Mean amplitudes and standard errors in the auditory processing task by word category and ERP location

	N2		P3		SW1		SW2	
	LH	RH	LH	RH	LH	RH	LH	RH
Positive								
Frontal	−1.40 (.60)	−2.50 (.64)	1.63 (.66)	0.58 (.69)	−5.69 (.65)	−6.22 (.72)	−5.43 (.68)	−6.95 (.70)
Parietal	−1.82 (.58)	−1.76 (.57)	1.89 (.60)	1.03 (.56)	−2.11 (.67)	−4.15 (.64)	−3.36 (.64)	−4.29 (.53)
Occipital	−0.81 (.77)	−2.02 (.71)	2.81 (.74)	1.72 (.81)	−5.24 (.76)	−6.36 (.82)	−4.79 (.74)	−5.01 (.68)
Negative								
Frontal	−0.18 (.61)	−1.24 (.55)	2.75 (.73)	1.92 (.62)	−4.46 (.63)	−4.32 (.63)	−4.51 (.79)	−4.89 (.58)
Parietal	−0.57 (.58)	−0.56 (.53)	2.56 (.56)	2.45 (.60)	−1.56 (.61)	−2.73 (.65)	−2.77 (.62)	−3.36 (.57)
Occipital	−0.39 (.63)	−1.27 (.60)	3.84 (.72)	3.17 (.67)	−4.37 (.78)	−4.85 (.78)	−3.92 (.76)	−4.46 (.79)
Control								
Frontal	−0.50 (.51)	−2.71 (.69)	3.10 (.62)	1.46 (.72)	−4.22 (.87)	−5.25 (.84)	−3.70 (1.00)	−6.00 (.87)
Parietal	−1.60 (.56)	−1.37 (.61)	2.73 (.62)	2.88 (.68)	−0.93 (.70)	−2.32 (.82)	−1.84 (.70)	−1.99 (.54)
Occipital	−0.88 (.61)	−0.66 (0.59)	3.60 (.68)	3.85 (.68)	−4.39 (.87)	−4.22 (.77)	−4.05 (.93)	−2.96 (.95)

SW1, Slow Wave Segment 1; SW2, Slow Wave Segment 2.

amplitudes in the right hemisphere [$F(1,50) = 8.72$, $p = .01$]. This effect was qualified by a three-way interaction between hemisphere, attention, and soothability [$F(1,50) = 4.99$, $p = .03$]. In particular, children high in both attentional control and soothability exhibited the largest right hemisphere amplitudes. This effect held only for the frontal lobes [$F(1,50) = 11.77$, $p = .001$].

3.3.4. P3

Positive words elicited smaller component amplitudes than negative words [$F(2,100) = 3.31$, $p = .04$, $\in = 0.94$]. In addition, P3 amplitudes were smaller in the right hemisphere than in the left hemisphere [$F(1,50) = 9.01$, $p = .004$]. This main effect of hemisphere was subsumed under a three way interaction with attention and soothability [$F(1,50) = 3.18$, $p = .08$]. As in the analysis with N2, the extreme pattern (here, low P3 amplitudes in the right hemisphere) was evident in the children high in both soothability and attentional control.

3.3.5. Slow waves

For the slow negative waves, each segment showed relatively large mean amplitudes for the positive words, although neither reached significance [$F\text{s} < 2.88$, $p\text{s} > .06$, $\in\text{s} > 0.91$]. However, children in the low attentional control group exhibited greater mean amplitudes to the emotion words (both positive and negative) vs. control words in the frontal sites [$F\text{s} > 3.23$, $p\text{s} < .04$, $\in\text{s} > 0.85$].

Echoing the data from the N2 and P3 components, each wave segment also showed a main effect of hemisphere [$F\text{s} > 4.57$, $p\text{s} > 0.04$]. Larger mean amplitudes were found in the right hemisphere.

4. Discussion

A large number of studies have indicated that emotional stimuli may enjoy a privileged status within processing systems (Desimone & Duncan, 1995). That is, given an array of objects in the environment, individuals often preferentially attend to affective stimuli. This response pattern is thought to aid adaptive functioning by rooting out potential threats or rewards. The current study found that children are significantly slower in responding when presented with words that hold a meaningful social or affective content, especially social-negative words. This pattern was evident despite the fact that the semantic content of the word was irrelevant to the task at hand (i.e., gender identification).

In this respect, the 7-year-old children in this study behaved much like their adult counterparts. The data are in line with the broader literature that has found a bias for threatening stimuli, as seen in slowed reaction times in Stroop-like tasks (Williams et al., 1996) and faster responses in cued attention tasks (Derryberry & Reed, 2002). Examining the role of cognitive evaluations in affective processing, Lazarus (1966) suggested that individuals carry out a two-stage process when assessing environmental stimuli. During the primary appraisal stage, individuals judge a stimulus to be either threatening or benign. The secondary appraisal stage occurs when individuals evaluate potential adaptive responses. It is understandable that potentially harmful stimuli, in this case social negative words, would enjoy more attentional processing. However, the literature also notes that excessive attentional biases to threat have been implicated in the development and maintenance of anxiety disorders (Ehrenreich & Gross, 2002).

Our preliminary analyses found that good self-regulatory skills may moderate individual vulnerabilities to a broad range of externalizing and internalizing difficulties. In particular, children with high in soothability and attentional control exhibited fewer behavioral and emotional difficulties.

In similar selective attention tasks, poor attentional control and/or attention biases for threat have been indexed through increased RTs in response to threatening or negative stimuli (Williams et al., 1996). In the current study, therefore, one may have expected that children with poor self-regulatory skills and higher levels of behavioral difficulties (i.e., the children in the low attentional control or low soothability groups) would have had the slowest RTs to the social negative words. This assumption is bolstered by a traditional Stroop study (González, Fuentes, Carranza, & Estévez, 2001), which found that children who were either high in activity level, high in impulsivity, or low in inhibitory control showed greater Stroop interference. In addition, those children who were both high in activity level and low in inhibitory control showed the largest interference scores.

However, in the current study, the children rated low in self-regulation showed little to no differential effects across the word categories. The children rated high in self-regulation, in contrast, selectively attended to the social negative words, perhaps making a strategic response in light of the varying threat levels. The specificity of the response could be taken as an indication of the well-developed selective attention system in these children.

There are a number of additional factors that could help explain the current pattern of result. First, the use of auditory stimuli in this study may have highlighted the need for effective attentional/memory processes in this class of tasks. Anderson and Holcomb (1995) noted that "with visual stimuli, information is available from the moment of presentation and throughout the duration of the stimulus. With auditory stimuli, the information is presented over time and the physical stimulus is rapidly replaced by silence or another word" (p. 188). The rapid removal of stimuli in auditory tasks may make it more difficult for children with poor attentional skills to carry out the semantic processing needed to produce interference effects.

Second, the pattern of results may have been due to the use of emotion words as the central stimuli. The use of a more "ecologically valid" stimulus such as an emotion face (Vuilleumier, Armony, Driver, & Dolan, 2001) or the use of an explicit emotion–induction task may complicate the task for children less able to regulate acute emotional triggers. Affective words may call upon only superficial categorization or processing. Face stimuli or induction tasks may be more likely to produce emotional responses (De Houwer & Hermans, 1994; Hermans, De Houwer, & Eelen, 1994) because they have more direct access to evaluative processes (Spruyt, Hermans, De Houwer, & Eelen, 2002).

Third, these data may be shaped by the fact that the current study employed an entirely nonclinical sample. For example, Ehrenreich, Coyne, O'Neill, and Gross (1998) found that when children participated in a dot-probe task (e.g., Mogg & Bradley, 1998) using both words and emotional faces, children *low in anxiety* showed a bias toward threat cues. These data have led researchers to suggest that the pattern of attentional biases often noted in the literature is dependent on psychological concerns that rise to the level of a diagnosable disorder (McNally, Hornig, Hoffman, & Han, 1999).

Yet, recent work is beginning to suggest that there may be a developmental shift in attention patterns, thereby calling into question the clinical/nonclinical distinction seen in adults. Pine et al. (2005) recently found in a study using an emotion-face dot probe task a bias away from threat in maltreated. Similarly, Monk et al. (2006) found that healthy children displayed an attentional bias for threat faces, while anxious children directed attention away from threatening faces. Additional systematic work will be needed in order to outline the potential mechanisms and processes underlying these findings. In particular, Pine et al. (2005) have called for integrative studies that use parallel methods in children and adults to clarify these findings.

The ERP data also showed valence-linked differences in processing. However, as in the larger literature (De Pascalis, Strippoli, Riccardi, & Vergari, 2004), the data were not straightforward. In the omnibus analyses, the children distinguished between valence categories in the later, more cognitive components (i.e., P3 and the late slow wave). However, the children did not exhibit a clear pattern of enhanced amplitudes for the threatening words. When considering individual differences, significant findings were only found for the frontal sites of the late slow wave. Here, the children low in attentional control showed enhanced amplitudes for affective words. Ironically, these data reflect our behavioral hypotheses better than the actual behavioral data.

In addition, hemisphere differences were found throughout the ERP wave. Hemispheric differences in the early components were qualified by an interaction with self-regulation ability. In addition, the data indicated that children high in both soothability and attentional control had more negative going ERP waves. This shift in polarity relative to the ERP zero line led to larger N2 amplitudes and smaller P3 amplitudes in children high in both soothability and attentional control. This processing difference may to some extent be a reflection of the behavioral distinction seen in this group of children.

This complex response pattern may have been the result of the small number of participants in each group or the relatively small number of valid ERP trials available. However, the general outline of the findings is heartening, particularly with the late slow waves. A late wave in the ERP may indicate a selective processing of emotional stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). When motivational systems in the brain are activated, a negative slow wave may reflect the brain's higher-order conceptual activity (Ruchkin, Johnson, Mahaffey, & Sutton, 1988). This pattern indicates that the ERP data are pointing to real processing differences that follow-up studies may be able to probe more effectively.

A number of explanatory mechanisms can be invoked to help understand the behavioral and ERP data. For example, the affect state hypothesis (Williams et al., 1996) argues that differential responding patterns are caused when stimuli provoke a brief emotional state that interferes with the efficient retrieval of the color name. Presumably, individuals differ in their responsivity to emotional stimuli and in their threshold for emotional responses. However, given the fast-paced presentation used in most studies, and the lack of a block design in the current study, it seems unlikely that emotional mechanisms could engage and disengage quickly enough to produce the observed interference patterns.

Yet, the brief incidental presence of emotionally meaningful stimuli can induce changes in a variety of cognitive processes without leading to tonic emotional responses (Maddock & Buonocore, 1997). An alternative explanation is that differential response patterns are cognitive phenomena that are not dependent on the current affective state of the individual. Instead, response patterns are the product of competition between two strong, conditioned response paths. The emotional stimuli are in a position to compete because of the rich semantic associations individuals build for meaningful emotional stimuli (Beck, Emery, & Greenberg, 1985; Bower, 1981). These semantic associations will be more or less complex depending on the particular background of the person. This result may then lead to the individual differences documented in the literature (Schwartz, Snidman, & Kagan, 1996). From this perspective, the stimuli need not evoke an emotional response in the individual. Rather, it must simply activate the individual's semantic net, thus triggering processing, and the eventual response competition.

While most theorists have assumed a mature adult system (Ehrenreich & Gross, 2002), this work may still be applicable to a study of young children. It is likely that by age seven an individual's lexical-semantic network for emotions is quite elaborate. A child's emotional descriptive language first emerges at approximately 20 months of age and increases rapidly thereafter (Ridgeway, Waters, & Kuczaj, 1985). Therefore, the children participating in this study would have had over five years of experience to incorporate into the organization of the lexicon. They have entered school and have experienced numerous episodes of social interaction and social feedback.

The children with 'good' self-regulatory skills may be able to rely on a threat evaluation system (Mathews & Mackintosh, 1998), which effectively prioritized ongoing threat information, giving preference to the most severe danger. After assessment comes an adaptive response that allows the child to turn to the central task at hand. In this sense, the child may sacrifice rapid responses in order to satisfy self-protective mechanisms.

Acknowledgments

We would like to thank Stacey Barton, Dalit H. Marshall, Kirsten VanMeenen, and Peter Marshall for their assistance in data collection and analysis. We would especially like to thank the parents of the children who participated and continue to participate in our studies. This research was partially supported by grants from the National Institutes of Health (HD 32666 and HD 17899) to Nathan A. Fox.

Appendix A

Stimuli used in the emotional auditory processing task

NS-positive[a]	NS-negative	Social-positive	Social-negative	Controls
Tasty	Drowsy	Polite	Self-conscious	Nose
Cheerful	Gloomy	Fearless	Bully	Oven
Treasure	Tired	Outgoing	Awkward	Luggage
Toy	Sticky	Praise	Tease	Robe
Clever	Upset	Confident	Shy	Vase
Lucky	Dead	Lively	Lonely	Airport
Healthy	Sad	Brave	Dislike	Tent
Glad	Scream	Funny	Anxious	Powder
Game	Sick	Love	Fight	Window
Proud	Afraid	Liked	Ignore	Walking
Pleasure	Empty	Friendly	Hate	Stuff
Peace	Reduce	Leader	Alone	Building

[a] NS refers to nonsocial.

References

Achenbach, T. M. (1991). *Manual for the child behavior checklist/4–18 and 1991 profile*. Burlington, VT: University of Vermont.

Anderson, J. E., & Holcomb, P. J. (1995). Auditory and visual semantic priming using different stimulus onset asynchronies: An event-related brain potential study. *Psychophysiology, 32*, 177–190.

Anes, M. D., & Kruer, J. L. (2004). Investigating hemispheric specialization in a novel face-word Stroop task. *Brain & Language, 89*, 136–141.

Atkinson, C. M., Drysdale, K. A., & Fulham, W. R. (2003). Event-related potentials to Stroop and reverse Stroop stimuli. *International Journal of Psychophysiology, 47*, 1–21.

Bauer, L. O., & Hesselbrock, V. M. (1999). Subtypes of family history and conduct disorder: Effects on P300 during the Stroop test. *Neuropsychopharmacology, 21*, 51–62.

Beck, A. T., Emery, G., & Greenberg, R. L. (1985). *Anxiety disorders and phobias: A cognitive perspective*. New York: Basic Books.

Bell, M. A., & Fox, N. A. (1994). Brain development over the first year of life: Relations between EEG frequency and coherence and cognitive and affective behaviors. In G. Dawson & K. W. Vairam (Eds.), *Human behavior and the developing brain* (pp. 314–345). New York: Guilford.

Bower, G. H. (1981). Mood and memory. *American Psychologist, 36*, 129–148.

Buss, A. H., & Plomin, R. (1984). *Temperament: Early developing personality traits*. Hillsdale, NJ: Lawrence Erlbaum.

Calkins, S. D., Fox, N. A., & Marshall, T. R. (1996). Behavioral and physiological antecedents of inhibited and uninhibited behavior. *Child Development, 67*, 523–540.

Chajut, E., & Algom, D. (2003). Selective attention improves under stress: Implications for theories of social cognition. *Journal of Personality & Social Psychology, 85*, 231–248.

Clark, D. M. (1988). A cognitive model of panic attacks. In S. Rachman & J. D. Moser (Eds.), *Panic* (pp. 71–89). Hillsdale, NJ: Erlbaum.

Connolly, J. F., Phillips, N. A., Stewart, S. H., & Brake, W. G. (1992). Event-related potential sensitivity to acoustic and semantic properties of terminal words in sentences. *Brain & Language, 43*, 1–18.

Crick, N. R., & Dodge, K. A. (1994). A review and reformulation of social-information processing mechanisms in children's social adjustment. *Psychological Bulletin, 115*, 74–101.

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report. *Biological Psychology, 52*, 95–111.

Davidson, R. J. (1994). Temperament and affective style. In G. Dawson & K. W. Fischer (Eds.), *Human behavior and the developing brain*. New York: Guilford Press.

Davidson, R. J., & Fox, N. A. (1989). Frontal brain asymmetry predicts infants' response to maternal separation. *Journal of Abnormal Psychology, 98*, 127–131.

Davidson, R. J., Jackson, D. C., & Larson, C. L. (2000). Human electroencephalography. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology* (2nd., pp. 27–52). New York: Cambridge University Press.

De Houwer, J. (2003). Indirect measures of attention. In J. Musch & K. C. Klauer (Eds.), *The psychology of evaluation* (pp. 219–244). Mahwah, NJ: Erlbaum.

De Houwer, J., & Eelen, P. (1998). An affective variant of the Simon paradigm. *Cognition & Emotion, 12*, 45–61.

De Houwer, J., & Hermans, D. (1994). Differences in the affective processing of words and pictures. *Cognition & Emotion, 8*, 1–20.

De Pascalis, V., Strippoli, E., Riccardi, P., & Vergari, F. (2004). Personality, event-related potential (ERP) and heart rate (HR) in emotional word processing. *Personality & Individual Differences, 36*, 873–891.

Derryberry, D., & Reed, M. A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *Journal of Abnormal Psychology, 111*, 225–236.

Derryberry, D., & Rothbart, M. K. (1988). Arousal, affect, and attention as components of temperament. *Journal of Personality and Social Psychology, 55*, 958–966.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience, 18*, 193–222.

Dien, J. (1998). Issues in the application of the average reference: Review, critiques, and recommendations. *Behavior Research Methods, Instruments Computers, 30*, 34–43.

Ehrenreich, J. T., Coyne, L. W., O'Neill, P., & Gross, A. M. (1998). *Attentional biases to threat cues in childhood anxiety: A preliminary investigation of lexical and facial cues*. Poster session presented at the annual convention of the Association for the Advancement of Behavior Therapy, Washington, DC.

Ehrenreich, J. T., & Gross, A. M. (2002). Biased attentional behavior in childhood anxiety: A review of theory and current empirical investigation. *Clinical Psychology Review, 22*, 991–1008.

Fazio, R. H., Sanbonmatsu, D. M., Powell, M. C., & Kardes, F. R. (1986). On the automatic activation of attitudes. *Journal of Personality & Social Psychology, 50*, 229–238.

Foa, E. B., & McNally, R. J. (1986). Sensitivity to feared stimuli in obsessive-compulsives: A dichotic listening analysis. *Cognitive Therapy & Research, 10*, 477–485.

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology: General, 130*, 681–700.

Fox, E., Russo, R., & Dutton, K. (2002). Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition and Emotion, 16*, 355–379.

Fox, N. A. (1989). Psychophysiological correlates of emotional reactivity during the first year of life. *Developmental Psychology, 25*, 364–372.

Fox, N. A., Henderson, H. A., Rubin, K. H., Calkins, S. D., & Schmidt, L. A. (2001). Continuity and discontinuity of behavioral inhibition and exuberance: Psychophysiological and behavioral influences across the first four years of life. *Child Development, 72*, 1–21.

Fox, N. A., Schmidt, L. A., Calkins, S. D., Rubin, K. H., & Coplan, R. J. (1996). The role of frontal activation in the regulation and dysregulation of social behavior during the preschool years. *Development and Psychopathology, 8*, 89–102.

Francis, W. N., & Kucera, H. (1982). *Frequency analysis of English usage: Lexicon and grammar*. Boston MA: Houghton.

Gainotti, G., Marra, C., & Villa, G. (2001). A double dissociation between accuracy and time of execution on attentional tasks in Alzheimer's disease and multi-infarct dementia. *Brain, 124*, 731–738.

Geisser, S., & Greenhouse, S. W. (1958). An extension of Box's results on the use of the F distribution in multivariate analysis. *Annals of Mathematical Statistics, 29*, 885–891.

Gherstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: Performance of children $3\frac{1}{2}$–7 years old on a Stroop-like day-night task. *Cognition, 53*, 129–153.

Gilboa-Schechtman, E., Revelle, W., & Gotlib, I. H. (2000). Stroop interference following mood induction: Emotionality, mood congruence, and concern relevance. *Cognitive Therapy & Research, 24*, 491–502.

González, C., Fuentes, L. J., Carranza, J. A., & Estévez, A. F. (2001). Temperament and attention in the self-regulation of 7-year-old children. *Personality & Individual Differences, 30*, 931–946.

Gotlib, I. H., & McCann, C. D. (1984). Construct accessibility and depression: An examination of cognitive and affective disorders. *Journal of Personality & Social Psychology, 47*, 427–439.

Green, E. J., & Barber, P. J. (1983). Interference effects in an auditory Stroop task: Congruence and correspondence. *Acta Psychologica, 53*, 183–194.

Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. K. (1998). Measuring individual differences in implicit cognition: The Implicit Association Test. *Journal of Personality & Social Psychology, 74*, 1464–1480.

Hagemann, D., Naumann, E., & Thayer, J. F. (2001). The quest for the EEG reference revisited: A glance from brain asymmetry research. *Psychophysiology, 38*, 847–857.

Heinrichs, N., & Hofmann, S. G. (2004). Encoding processes in social anxiety. *Journal of Behavior Therapy and Experimental Psychiatry, 35*, 57–74.

Hermans, D., De Houwer, J., & Eelen, P. (1994). The affective priming effect: Automatic activation of evaluative information in memory. *Cognition & Emotion, 8*, 515–533.

Ilan, A. B., & Polich, J. (1999). P300 and response time from a manual Stroop task. *Clinical Neurophysiology, 110*, 367–373.

Ito, T. A., Larsen, J. T., Smith, N. K., & Cacioppo, J. T. (1998). Negative information weighs more heavily on the brain: The negativity bias in evaluative categorizations. *Journal of Personality and Social Psychology, 75*, 887–900.

Jasper, H. H. (1958). The ten–twenty electrode system of the International Federation. *Electroencephalography & Clinical Neurophysiology, 10*, 371–375.

Jerger, S., Martin, R. C., & Pirozzolo, F. J. (1988). A developmental study of the auditory Stroop effect. *Brain & Language, 35*, 86–104.

Kagan, J. (1994). *Galen's prophecy: Temperament in human nature*. New York: Basic Books.

Kagan, J., Arcus, D., Snidman, N., Feng, W. Y., Hendler, J., & Greene, S. (1994). Reactivity in infants: A cross-national comparison. *Developmental Psychology, 30*, 342–345.

Kagan, J., & Snidman, N. (1991). Infant predictors of inhibited and uninhibited profiles. *Psychological Science, 2*, 40–44.

Kagan, J., Snidman, N., & Arcus, D. (1995). The role of temperament in social development. In G. P. Chrousos, R. McCarty, K. Pacak, G. Cizza, E. Stenberg, P. W. Gold, & R. Kvetnansky (Eds.), *Annals of the New York Academy of Sciences. Stress: Basic mechanisms and clinical implications* (Vol. 771, pp. 485–490). New York: New York Academy of Sciences.

Kavcic, V., & Clarke, J. M. (2000). Hemispheric interactions during a face-word Stroop-analog task. *Neuropsychology, 14*, 579–587.

Keinan, G., Friedland, N., Kahneman, D., & Roth, D. (1999). The effect of stress on the suppression or erroneous competing responses. *Anxiety, Stress, & Coping, 12*, 455–477.

Kopp, C. B. (1982). Antecedents of self-regulation: A developmental perspective. *Developmental Psychology, 2*, 199–202.

Kopp, C. B. (2002). Commentary: The codevelopments of attention and emotion regulation. *Infancy, 3*, 199–208.

Kostandov, E., & Azumanov, Y. (1977). Averaged cortical evoked potentials to recognized and non-recognized verbal stimuli. *Acta Neurobiologiae Experimentalis, 37*, 311–324.

Lazarus, R. S. (1966). *Psychological stress and the coping process*. New York: McGraw-Hill.

Lewis, M. D., & Steiben, J. (2004). Emotion regulation in the brain: Conceptual issues and directions for developmental research. *Child Development, 75*, 371–376.

Liotti, M., Woldroff, M. G., Pérez, R., III, & Mayberg, H. S. (2000). An ERP study of the temporal course of the Stroop color-word interference effect. *Neuropsychologia, 38*, 701–711.

Logan, A. C., & Goetsch, V. L. (1993). Attention to external threat cues in anxiety states. *Clinical Psychology Review, 13*, 541–559.

MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., & Holker, L. (2002). Selective attention and emotional vulnerability: Assessing the causal basis of their association through the experimental manipulation of attentional bias. *Journal of Abnormal Psychology, 111*, 107–123.

Maddock, R. J., & Buonocore, M. H. (1997). Activation of left posterior cingulate gyrus by the auditory presentation of threat-related words: An fMRI study. *Psychiatry Research: Neuroimaging Section, 75*, 1–14.

Marshall, D. H., Drummey, A. B., Newcombe, N. S., & Fox, N. A. (2002). An event-related potential study of item recognition memory in children and adults. *Journal of Cognition & Development, 3*, 201–224.

Marshall, P. J., Bar-Haim, Y., & Fox, N. A. (2002). Development of the EEG from 5 months to 4 years of age. *Clinical Neurophysiology, 113*, 1199–1208.

Marshall, P. J., & Stevenson-Hinde, J. (1998). Behavioral inhibition, heart period, and respiratory sinus arrhythmia in young children. *Developmental Psychobiology, 33*, 283–292.

Martin, J. M., & Cole, D. A. (2000). Using the personal Stroop to detect children's awareness of social rejection by peers. *Cognition & Emotion, 14*, 241–260.

Mathews, A., & Mackintosh, B. (1998). A cognitive model of selective processing in anxiety. *Cognitive Therapy & Research, 22*, 539–560.

Mattia, J. I., Heimberg, R. G., & Hope, D. A. (1993). The revised Stroop color-naming task in social phobics. *Behaviour Research & Therapy, 31*, 305–313.

Mayer, A. R., & Kosson, D. S. (2004). The effects of auditory and visual linguistic distractors on target localization. *Neuropsychology, 18*, 248–257.

McCallum, W. C., Farmer, S. F., & Pocock, P. V. (1984). The effects of physical and semantic incongruity on auditory event-related potentials. *Electroencephalography and Clinical Neurophysiology, 59*, 477–488.

McClain, L. (1983). Stimulus–response compatibility affects auditory Stroop interference. *Perception & Psychophysics, 33*, 266–270.

McManis, M. H., Kagan, J., Snidman, N. C., & Woodward, S. A. (2002). EEG asymmetry, power, and temperament in children. *Developmental Psychobiology, 40*, 169–177.

McNally, R. J. (1995). Automaticity and the anxiety disorders. *Behaviour Research & Therapy, 33*, 747–754.

McNally, R. J. (1996). Cognitive bias in the anxiety disorders. In D. A. Hope (Ed.). *Nebraska symposium on motivation, 1995: Perspectives on anxiety, panic, and fear. Current theory and research in motivation* (Vol. 43, pp. 251–328). New York: University of Nebraska Press.

McNally, R. J., Hornig, C. D., Hoffman, E. C., & Han, E. M. (1999). Anxiety sensitivity and cognitive biases for threat. *Behavior Therapy, 30*, 51–61.

Mogg, K., & Bradley, B. P. (1998). A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy, 36*, 809–848.

Monk, C. S., Nelson, E. E., McClure, E. B., Mogg, K., Bradley, B. P., Leibenluft, E., et al. (2006). Ventrolateral prefrontal cortex activation and attentional bias in response to angry faces in adolescents with generalized anxiety disorder. *American Journal of Psychiatry, 163*, 1091–1097.

Morgan, A. L., & Brandt, J. F. (1989). An auditory Stroop effect for pitch, loudness, and time. *Brain & Language, 36*, 592–603.

Most, S. B. (April, 1999). *Auditory Stroop as a potential tool for investigating the development of implicit gender stereotypes in children*. Poster presented at the Society for Research in Child Development, Albuquerque, NM.

Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In R. J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.). *Consciousness and self-regulation: Advances in research* (Vol. 4, pp. 1–18). New York: Plenum.

Ofek, E., & Pratt, H. (2005). Neurophysiological correlates of subjective significance. *Clinical Neurophysiology, 116*, 2354–2362.

Pauli, P., Dengler, W., Wiedemann, G., Montoya, P., Flor, H., Birbaumer, N., et al. (1997). Behavioral and neurophysiology evidence for altered processing of anxiety related words in panic disorder. *Journal of Abnormal Psychology, 106*, 213–220.

Pérez-Edgar, K., Bhuiya, F., Marshall, P. J., & Fox, N. A. (October, 2000). *An ERP study of facilitation and interference effects in an auditory emotional Stroop task*. Poster presented at the Society for Psychophysiological Research, San Diego, CA.

Pérez-Edgar, K., & Fox, N. A. (2003a). Individual differences in children during an emotional Stroop task: A behavioral and electrophysiological study. *Brain & Cognition, 52*, 33–51.

Pérez-Edgar, K., & Fox, N. A. (2003b, June). *The influence of temperament on automatic and controlled processes involved in the regulation of emotion*. Paper presented at the Annual Meeting of the Society for Theoretical and Experimental Neuropsychology, Montreal, Quebec, Canada.

Pérez-Edgar, K., & Fox, N. A. (2005). A behavioral and electrophysiological study of children's selective attention under neutral and affective conditions. *Journal of Cognition and Development, 6*, 89–116.

Pérez-Edgar, K., Fox, N. A., Cohn, J. F., & Kovacs, M. (2006). Behavioral and electrophysiological markers of selective attention in children of parents with a history of depression. *Biological Psychiatry, 60*, 1131–1138.

Pine, D. S., Mogg, K., Bradley, B., Montgomery, L. A., Monk, C. S., McClure, E., et al. (2005). Attention bias to threat in maltreated children: Implications for vulnerability to stress-related psychopathology. *American Journal of Psychiatry, 162*, 291–296.

Plaut, D. C., & Booth, J. R. (2000). Individual and developmental differences in semantic priming: Empirical and computational support for a single-mechanism account of lexical processing. *Psychological Review, 107*, 786–823.

Pollak, S. D., & Tolley-Schell, S. A. (2003). Selective attention to facial emotion in physically abused children. *Journal of Abnormal Psychology, 112*, 323–338.

Posner, M. I., & Rothbart, M. K. (2000). Developing mechanisms of self-regulation. *Development and Psychopathology, 12*, 411–427.

Ragot, R., & Fiori, N. (1994). Mental processing during reactions toward and away from a stimulus: An ERP analysis of auditory congruence and S–R compatibility. *Psychophysiology, 31*, 439–446.

Richards, A., French, C. C., Johnson, W., Naparstek, J., & Williams, J. (1992). Effects of mood manipulation and anxiety on performance on an emotional Stroop task. *British Journal of Psychology, 83*, 479–491.

Ridgeway, D., Waters, E., & Kuczaj, S. A. (1985). Acquisition of emotion-descriptive language: Receptive and productive vocabulary norms for ages 18 months to 6 years. *Developmental Psychology, 21*, 901–908.

Riemann, B., & McNally, R. J. (1995). Cognitive processing of personally relevant information. *Cognition & Emotion, 9*, 325–340.

Rimm-Kauffman, S. (1996). *Infant predictors of kindergarten behavior: The contribution of inhibited and uninhibited temperamental types*. Unpublished doctoral dissertation, Harvard University, Cambridge, MA.

Rothbart, M. K. (1991). Temperament: A developmental framework. In J. Strelau & A. Angleitner (Eds.), *Explorations in temperament: Interna-*

tional perspectives on theory and measurement (pp. 61–74). New York: Plenum Press.

Rothbart, M. K., Ellis, L. K., Rueda, M. R., & Posner, M. I. (2003). Developing mechanisms of temperamental effortful control. *Journal of Personality, 71*, 1113–1143.

Rothbart, M. K., Posner, M. I., & Rosicky, J. (1994). Orienting in normal and pathological development. *Development and Psychopathology, 6*, 635–652.

Rowe, D. C., & Plomin, R. (1977). Temperament in early childhood. *Journal of Personality Assessment, 41*, 150–156.

Ruchkin, D. S., Johnson, R., Mahaffey, D., & Sutton, S. (1988). Toward a functional categorization of slow waves. *Psychophysiology, 25*, 339–353.

Ruddy, M. G. (1993). Attention shifting and temperament at 5 months. *Infant Behavior and Development, 16*, 255–259.

Schmidt, L. A., & Fox, N. A. (1998). Fear-potentiated startle responses in temperamentally different human infants. *Developmental Psychobiology, 32*, 113–120.

Schmidt, L. A., Fox, N. A., Rubin, K. H., Sternberg, E. M., Gold, P. W., Smith, C. C., et al. (1997). Behavioral and neuroendocrine responses in shy children. *Developmental Psychobiology, 30*, 127–140.

Schwartz, C. E., Snidman, N., & Kagan, J. (1996). Early temperamental predictors of Stroop interference to threatening information at adolescence. *Journal of Anxiety Disorders, 10*, 89–96.

Spruyt, A., Hermans, D., De Houwer, J., & Eelen, P. (2002). On the nature of the affective priming effect: Affective priming of naming responses. *Social Cognition, 20*, 227–256.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643–662.

Vasey, M. W., & Daleiden, E. L. (1996). Information processing pathways to cognitive interference in childhood. In I. G. Sarason, G. R. Pierce, & B. R. Sarason (Eds.), *Cognitive interference: Theories, methods, and findings* (pp. 117–138). Mahwah, NJ: Erlbaum.

Vasey, M. W., Daleiden, E. L., Williams, L. L., & Brown, L. M. (1995). Biased attention in childhood anxiety disorders: A preliminary study. *Journal of Abnormal Child Psychology, 23*, 267.

Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2001). Effects of attention and emotion on face processing in the human brain: An event-related fMRI study. *Neuron, 30*, 829–841.

West, R., & Alain, C. (1999). Event-related neural activity associated with the Stroop task. *Cognitive Brain Research, 8*, 157–164.

West, R., & Alain, C. (2000a). Effects of task context and fluctuations of attention on neural activity supporting performance of the Stroop task. *Brain Research, 873*, 102–111.

West, R., & Alain, C. (2000b). Age-related decline in inhibitory control contributes to the increased Stroop effect observed in older adults. *Psychophysiology, 37*, 179–189.

Whalen, P. J., Bush, G., McNally, R. J., Wilhelm, S., McInerney, S. C., Jenike, M. A., et al. (1998). The emotional counting Stroop paradigm: A functional magnetic resonance imaging probe of the anterior cingulate affective division. *Biological Psychiatry, 44*, 1219–1288.

White, S. H. (1996). The child's entry into the "age of reason.". In A. J. Sameroff & M. H. Haith (Eds.), *The five to seven year shift* (pp. 17–32). Chicago IL: The University of Chicago Press.

Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin, 120*, 3–24.

Williamson, S., Harpur, T. J., & Hare, R. D. (1991). Abnormal processing of affective words by psychopaths. *Psychophysiology, 28*, 260–271.