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A Behavioral and Electrophysiological Study of Children's Selective Attention Under Neutral and Affective Conditions

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Seven-year-olds completed a Posner cued attention task, under both neutral and affectively charged conditions. Compared to the traditional (affect-neutral) Posner task, performance in the affective Posner task was marked by dramatic decreases in reaction times (RTs), an increase in errors, an increased validity effect (difference in RTs to the cued vs. uncued trials), and increased electrocortical activity. Temperamentally shy children in the study differed from their non-shy peers within the affective Posner task only, exhibiting larger event-related potentials amplitudes and right electroencephalogram asymmetry. In addition, shy children preferentially attended to the negative cues presented during the task. These data reinforce the notion that the functional balance between cognition and affect is sensitive to both contextual and individual characteristics.

From the moment of birth, individuals are bombarded with an unrelenting array of sensory stimuli. To function, we must quickly learn to select those aspects of the environment that are worthy of further exploration. For example, emotional appraisals of the environment can reveal the presence of threat or reward, signaling the need to either withdraw or approach (Gray, 1987). These appraisals are, in turn, often reliant on cognitive or regulatory mechanisms that bring a stimulus to attention, instigate an evaluation, and maintain the process. As such, our ability to move about our environment in a manner that is both efficient and adaptive requires a balance between affective and cognitive processes that work together to shape behavior.

Recent work has examined the relations between cognition and affect by systematically varying cognitive load (Keinan, Friedland, Kahneman, & Roth, 1999),

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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.

For example, a number of researchers have used the emotional Stroop task to examine the attentional processing of emotional stimuli. In the emotional Stroop individuals are asked to state the color in which emotion words are presented. The task is thought to reflect the individual's ability to select between competing inputs and resolve conflicts among responses (Norman & Shallice, 1986; Whalen et al., 1998). Even though word content is irrelevant for performance, individuals are slower in responding when the words are threatening or match current concerns than when the words are affectively neutral (Williams, Mathews, & MacLeod, 1996). The inability to disregard task-irrelevant information in the emotional Stroop has been linked to poor emotional self-regulation in both children (Pérez-Edgar & Fox, 2003a) and adults (McNally et al., 1994). In these examples, affective concerns are thought to interfere with attentional processes, disrupting the balance between affect and cognition.

This study builds on this work by examining the performance of young children in a widely used attention-cueing task (Posner & Cohen, 1984). Performance was analyzed under both 'traditional' affect-neutral conditions and after the introduction of an affective–motivational manipulation. In addition, an individual difference variable (i.e., shyness) was introduced to see if the observed differences in attentional performance are moderated by variations in individual affective concerns.

In addition, this study examined the impact of the experimental manipulations on both performance effectiveness and processing efficiency. As such, behavioral (reaction time [RT] and error rates) and psychophysiological (electroencephalogram [EEG] and event-related potentials [ERPs]) data were included in the analyses. A number of researchers (Eysenck & Calvo, 1992; Murray & Janelle, 2003) have noted that experimental effects are not always found in overall performance but are instead evident in the effort required to maintain a particular level of functioning. The use of multiple levels of analysis helps insure that these effects will not be overlooked.

As previously mentioned, selective attention is vital for adaptive day-to-day functioning. When assessing the environment individuals can either focus on the *salient* features of the environment, which capture attention due to some outstanding physical or psychological characteristic, or instead focus on the *relevant* features that are more directly related to the task the individual is currently engaged in.

Developmentally, the emergence of effective control of selective attention is a central process in the development of self-regulation (Kopp, 2002). Rothbart and colleagues asserted that attentional control is a central mechanism through which an individual can minimize the overt signs of distress (Rothbart, Posner, & Rosicky, 1994). Their data suggested that infants prone to distress are less adept at shifting attention away from an aversive stimulus and have difficulty engaging in self-soothing activity (Rothbart et al., 1994; Ruddy, 1993). In addition, maternal ratings at 9 months indicate that infants who show poor attentional control are prone to distress and less likely to show spontaneous smiles (Pérez-Edgar & Fox, 2003b). At 4 years of age, these same children also show greater signs of social reticence. This is also observed in adulthood. For example, Derryberry and Rothbart (1988) found that adults who find it difficult to shift attention across different foci show greater signs of fearfulness and frustration in their daily lives.

In the laboratory, the Posner cued-attention task (Posner & Cohen, 1984) is one of the most common methods used to assess this core regulatory skill. The Posner task has been used extensively as a marker task for a "bottom-up" system of sensory representations (Hugdahl & Nordby, 1994), controlling orienting to sensory stimuli. Controlled orienting serves to support accurate object recognition and processing, in part by decreasing the level of processing allocated to irrelevant or competing stimuli (Rothbart, Posner, & Hershey, 1995). Thus, stimuli at or near the foci of attention are processed more efficiently than are those that are farther away. This efficiency is translated quantitatively into increased detection ability, increased stimulus discrimination, and decreased RTs (Hillyard, Luck, & Mangun, 1994).

Across a wide array of methodological variations a stable pattern of findings have emerged for the Posner task. Individuals are consistently faster in responding to stimuli that appear in a previously cued location (valid trials) versus stimuli that are not cued (invalid trials; Posner & Cohen, 1984). This gap in RTs has been termed the validity effect. By including catch trials involving either a neutral (uninformative) cue or no cue at all, researchers have shown that the effect can usually be attributed to the costs associated with the invalid cue (Nobre, Sebestyen, & Miniussi, 2000).

In responding to an invalid cue the individual must interrupt ongoing activity, shift attention to the target location, and then reengage attention (Hugdahl & Nordby, 1994). This process, unnecessary during a valid trial, leads to slower RTs and the observed validity effect. This pattern of findings is very stable, emerging as early as 3 months of age (Hood, Willen, & Driver, 1998) and remaining across variations in the form and location of the cue and targets (Derryberry & Reed, 2002; Driver et al., 1999).

Despite this stability, performance on the cued attention task is not impervious to contextual and individual characteristics. This reflects the fact that the process underlying performance, selective attention, is sensitive to affective or motivational states and to idiosyncratic biases in the response to affect and stress (Ellenbogen, Schwartzman, Stewart, & Walker, 2002). For example, Elaine Fox (Fox, Russo, Bowles, & Dutton, 2001) has argued that individuals prone to anxiousness are quite concerned with identifying fear-relevant stimuli in their environment. As a result, they are quick to detect aspects of their environment that conform to their biases. This is in part due to the fact that the 'bottom-up' sensory system tapped by cued-attention tasks is linked to an attentional 'top-down' mechanism that can be swayed by stimuli characteristics above and beyond physical or sensory salience (Desimone & Duncan, 1995).

The general consensus is that affect negatively impacts cognitive or attentional performance, as illustrated in Simpson et al.'s (2000) summary of the affect-cognition literature: "when arousing negatively valenced stimuli are confronted but incidental to the performance of a cognitive task, performance on the task deteriorates, heightened autonomic responses are elicited, and many but certainly not all structures in the brain thought to be concerned with emotion processing exhibit changes in activity" (p. 166). However, recent work (Chajut & Algom, 2003) suggested that impact of affect on attention need not be uniformly negative but rather dependent on specific contextual and individual characteristics.

Along these same lines, Eysenck and Calvo (1992) argued that the impact of affect, in their case cognitive anxiety or worry, during a task could take on a number of forms. First, the concerned individual may experience an increase in motivation, leading to better performance on the task at hand. Second, anxiety may consume processing resources and lead to poor performance. This may be particularly true if the individual is prone to high levels of trait anxiety. Third, rather than affect the overall level of performance, anxiety may push an individual to allocate disproportionately more attention to events perceived as threatening. Again, this attentional bias may be more pronounced in high trait anxious individuals. A great deal of study will be needed to determine the circumstances under which each of these potential outcomes is observed.

For example, Ellenbogen and colleagues (2002) recently had adults participate in a modified Posner task in which neutral, positive, and negative emotion words were used as the cues. Before engaging in the task, participants were assigned to one of three mood-induction conditions: a negative stress condition (continued losses regardless of performance on a Stroop Color-Word Interference task), a positive stress condition (continued gains regardless of performance), or a neutral condition (no points involved). Ellenbogen and colleagues (2002) found that participation in the negative stress condition primed participants to react to the negative emotion cues. In addition, individuals with high levels of depression had difficulty shifting attention in the negative stressor condition, regardless of the emotional valence of the cue. Similarly, Derryberry and Reed found that in a series of studies using punishment and reward cues to prime attention introverted (Derryberry & Reed, 1994) and anxious (Derryberry & Reed, 2002) individuals focus on negative threat cues in the affective Posner task.

In this study, children were told that their overall performance on the task was being monitored. In the affective condition, the children were told that they would be required to give an embarrassing speech if they performed poorly. This set of instructions has been used in the past to induce anxiety or stress in young children (Schmidt, Fox, Schulkin, & Gold, 1999a; Schmidt, et al., 1999b). When preparing for the speech (the speech is never actually given), children, particularly if temperamentally shy, show increases in the hormone cortisol (Schmidt et al., 1999b, but not Schmidt, et al., 1999a), greater right frontal EEG activity, and an increase in heart rate (Schmidt, et al., 1999a).

Baron (1986) suggested that socially induced stressors reduce the range of cues an individual will focus on during a task. As a result, individuals may be expected to rely on cues that are most salient to them, either because the cues are relevant to the task at hand or due to the fact that the cues match idiosyncratic individual biases. The nature of these biases as well as their strength in shaping the deployment of attention may help fuel observed individual differences in performance. This is in line with the argument by Eysenck and Calvo (1992) noted previously that affect need not have a uniform effect on attentional performance.

To explore potential individual differences in performance within the affective Posner task, the children in this study were rated and grouped for temperamental shyness. Individual differences in the tendency to experience 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 preschoolers (Fox, Henderson, Rubin, Calkins, & Schmidt, 2001; Rimm-Kauffman, 1996). There also appears to be a biological component to shyness, as these children are also prone to showing greater right frontal EEG activation (Fox et al., 1996), shorter, less variable, heart periods (Calkins, Fox, & Marshall, 1996), and higher levels of the hormone cortisol (Schmidt, et al., 1999b).

We believe that the impact of these individual differences in temperament on behavior is context specific. That is, individual differences in the tendency to exhibit a particular trait (i.e. shyness) must be studied in the context of stimuli appropriate for the solicitation of a particular pattern of behavior. Individual differences in shyness, and the behavior it produces, do not function independently from the external environment. The central assumption is that differences in performance due to shyness will be relatively inconsequential in an affect-neutral environment. However, when this affect neutrality is breached due to the addition of an emotional component, differences may emerge. For example, when asked to give a speech in public, anxious adults focus on negative environmental stimuli (Veljaca & Rapee, 1998). In much the same way, children rated as unpopular by their peers will attend more closely to socially negative words than do popular children (Martin & Cole, 2000).

The behavioral data (i.e., RTs, error rates) produced by the Posner tasks were supplemented with psychophysiological measures collected during testing, namely the EEG and ERP. One of the central advantages of the EEG and ERP, and psychophysiological measures in general, is that they allow the researcher greater insight into the processes bridging stimulus presentation and response detection (van Hooff, Brunia, & Allen, 1996). Although the EEG and ERP do not have the localization abilities of Position Emission Tomography (PET) and Functional Magnetic Resonance Imaging (fMRI) technology, they do have the advantage of being able to reflect real time neural activity. This makes the technology particularly useful in a study such as this one because the core phenomena of emotion and attention are brief and require fast in resolution order to accurately reflect timing and intensity (Davidson, 1994).

There are a growing number of studies using ERP measures to observe neural activity during the traditional Posner task. ERPs have been used to address the timing of attentional mechanisms triggered by the Posner task and the data indicate that the presentation of the cue engages attention during early perceptual processing (Luck, Heinze, Mangun, & Hillyard, 1990). As such, early ERP components (e.g., P1, N1) generated by stimuli that were preceded by valid cues have greater amplitudes than ERP components corresponding to stimuli that were invalidly cued. The findings are most pronounced for posterior electrode sites. These results have been replicated in both children (Perchet & García-Larrea, 2000; Pollak & Tolley-Schell, 2003) and adults (Hillyard et al., 1994).

In summary, this study compared performance in a Posner attention-cueing task under both neutral and affective conditions. We expected that the children would replicate the behavioral (e.g., validity effect in RTs) and psychophysiological (e.g., validity effect in ERP amplitudes) literature when engaged in the traditional Posner task. In addition, performance in the affective version of the task would be marked by relatively faster RTs and increased errors (Rothbart et al., 1995). This is in part due to the speed-accuracy tradeoff often seen in RT studies. We also predicted that greater cortical activity, in the form of decreased EEG power and increased ERP amplitudes, would be detected (Wallace & Newman, 1998). To examine potential individual differences in response to the experimental manipulation, we also included temperamental shyness as a moderating variable. We hypothesized that under the affective manipulation, the shy children would experience greater difficulty in performing the task (as seen in RTs and errors). These children were also expected to pay closer attention to the negative-valence cues presented during the task.

METHOD

Participants

Families were recruited from the metropolitan area surrounding the University of Maryland, College Park, for a longitudinal study of the behavioral and physiological correlates of temperament. A total of 207 children (95 boys, 112 girls) were screened for participation in the study. At 4 months of age, 81 of these children were selected for inclusion based on measures of behavioral reactivity. This group was subsequently seen at 9 months, 14 months, 24 months, and 4 years of age. At each of these visits, numerous physiological and behavioral measures were taken (Calkins et al., 1996). For this study, 64 children (33 boys, 31 girls) returned to the Child Development Lab at age 7 years. Data from two of the children (both girls) were not included in the analyses due to mechanical error at time of testing. Data from one child (a boy) were not included in the analyses due to the diagnosis of a serious psychological disorder.

Shyness Ratings

Shyness was assessed through 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 ranging from 1 (*not at all/strongly disagree*) to 5 (*a lot/strongly agree*) on six factors pertaining to different dimensions of child temperament. These include emotionality, activity, attention, soothability, shyness, and sociability. Two additional scores, "impulsivity" (i.e., emotionality plus activity) and "emotion disregulation" (i.e., emotionality minus soothability), were also computed (see Coplan, Rubin, Fox, Calkins, & Stewart, 1994; Rubin, Coplan, Fox, & Calkins, 1995, respectively). Data on the reliability and validity of the CCTI can be found in Rowe and Plomin (1977).

The children were divided into two groups based on a median split of their shyness scores. Of the children who also participated in the Posner task, there were 29 and 31 children in the low shy and high shy groups, respectively. Overall, shyness ratings ranged from 1.0 to 4.6 with an overall mean of 2.18 ($SD = 0.75$). For the low shy group, the mean rating was 1.61 ($SD = 0.37$), whereas the mean rating for the high shy group was 2.71 ($SD = 0.60$).

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 ranging from 1 (*very true or often true*) to 3 (*not true*) to rate how descriptive a series of behavior problems are of their own child. The CBCL yields eight narrow-band factors: Social withdrawal, somatic problems, anxiety or 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 this sample were rated in the clinical range for either internalizing or externalizing problems.

As part of the larger experimental battery, the children also participated in a group play session with three unfamiliar, same sex, same age peers. Each quartet consisted of one socially inhibited child, one noninhibited child, and two average children. The children were assigned to quartets based on their social play and reticence behavior at 4 years of age (for details see N. A. Fox et al., 1995, 2001).

The four children were led into a playroom where several age-appropriate toys were accessible. The visit was split into several episodes, a complete description of which may be found in N. A. Fox and colleagues (1995). For purposes of this study, data from two 15-min free play sessions were used. Behaviors were coded with Rubin's (1989) Play Observation Scale (POS), scoring 10-sec intervals for social participation and the cognitive quality of play. Three independent observers, with reliability greater than 0.8, coded the POS. Three behavioral indices were computed: solitary-passive behavior (summing the proportion of coding intervals spent in solitary-exploratory or solitary-constructive play), social reticence (the sum of onlooking and unoccupied behavior), and social play (the sum of peer conversation and group play; see Coplan et al., 1994).

In this sample, higher CCTI shyness ratings were associated with greater reticence, $r(52) = .38$, $p = .005$, and less social play, $r(52) = –.36$, $p = .008$, in the quartets as well as marginally greater solitary passive behavior, $r(52) = .27$, $p = .06$. In addition, shyness was linked to higher scores in the CBCL broadband factor of internalizing problems, $r(55) = .28$, $p = .04$. This was partially due to a significant relation with the narrow-band factor of social withdrawal, $r(55) = .45$, $p = .001$. CCTI shyness was also negatively associated with two additional factors from the CCTI: activity, $r(55) = –.29$, $p = .03$, and sociability, $r(55) = –.55$, $p < .001$.

When directly comparing the children in the shyness groups, the high shy children displayed more reticence, $t(50) = – 2.06$, $p = .05$, and less social play, $t(50) = 2.16$, $p = .04$, in the play quartets, and were rated as more withdrawn with the CBCL, $t(53) = – 2.60$, $p = .01$, and less sociable with the CCTI, $t(53) = 2.76$, $p = .01$. The groups did not differ on maternal ratings of attention for either the CBCL, $t(53) = 1.30$, $p = .20$, or the CCTI, $t(53) = .31$, $p = .76$.

Posner Tasks

Traditional Posner task. Children were shown a fixation point appearing in the center of a NANAO FlexScan 550i monitor (EIZO, Ishikawa, Japan). They were then presented with three boxes outlined in white arranged horizontally across the screen. Each trial began with the presentation of a cue, which consisted of one of the boxes turning from black to blue in color. Cues were distributed so that they appeared in the central box in 20% of trials, and equally in the right-most and left-most boxes for the remaining trials. The target, a small white box, then appeared in either the left-most or right-most box (interstimulus interval = 200 ms). A valid trial had the cue and target appearing in the same location. In invalid trials, the cue appeared in the outer-most box opposite from where the target appears. Trials in which the cue appeared in the center box served as controls. A total of 50 trials were presented with a 20%, 40%, 40% distribution of control, valid, and invalid trials, respectively. Trial order was chosen at random. The cue and target measured 6 cm × 4.2 cm and subtended 10 degrees of visual angle.

Children were given a 12 cm × 7 cm × 3 cm response box connected to the data acquisition computer. The box had three buttons, each corresponding to the display boxes in the task. The children were asked to indicate the location of the target by pressing the corresponding button using their thumbs as quickly as possible. Stimulus presentation (inter-trial interval = 4000 msec; time-out latency = 2000 msec) was controlled by the STIM stimulus presentation system from the James Long Company (Caroga Lake, NY). RTs and errors were collected for each trial.

Affective Posner task. After completing the 50 trials of the traditional Posner task, the children completed an additional set of 50 trials. This set of trials (the affective Posner task) was identical to the traditional Posner task except that involved manipulations designed to affect the emotional context of testing. The children were told that their performance during the affective Posner task would determine if they had to give an embarrassing speech. This instruction had been used in earlier studies of social reticence to heighten levels of stress in the children (e.g., Schmidt et al., 1999a, 1999b).

The children were told that performance would be judged based on a reward or punishment design. A plus or minus sign was placed over the right-most and left-most display boxes as the researchers described the task to the child. These symbols were used to remind the children of the incentive value for each location. In the positive (plus) location the child could gain points if he or she responded quickly and accurately. In the negative (minus) location, points would be lost if the child did not respond quickly and accurately. The children were asked to indicate the positive and negative location and testing did not begin until the child understood the new aspects of the task.

The location of the positive and negative cues was counter balanced across subjects. After every set of 10 trials the computer reported that the child had lost additional points. After the entire block of trials, all the children were informed that they did indeed have to give the embarrassing speech.[1]

In every case, the children completed the traditional Posner task before the affective Posner task. This was done to manipulate motivation and affect in the affective Posner task while maintaining an emotionally neutral context for the traditional Posner task. Were the tasks reversed, there is the danger that the emotional residue of the affective manipulation would alter performance on the traditional Posner task. Recently, Lewis and colleagues (Lewis & Stieben, 2004) had children perform a traditional and affective version of a Go/No-Go task using an ABA (Baseline-Variable-Baseline) design. They found that although the last block of trials (A') reversed the point losses inflicted during the affective block of trials (B),

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[1] This instruction was used for the benefit of subsequent testing. The speech was in the end never given.

electrophysiological measures indicated that the anxiety and disappointment induced in the second block still lingered, affecting performance.

The lack of counterbalancing leaves open the possibility that the results are simply due to an order effect. Although the strength of the data presented in the following paragraphs suggests that this is not the case, an additional series of statistical comparisons were completed. A preliminary analysis compared performance in the traditional and affective Posner tasks by pooling RTs from individual trials into 10-trial sets. As such, there were 5 sets of trials in the traditional Posner task and 5 sets of trials for the affective Posner task.

Paired-sample t tests comparing sets of trials found no significant changes in RTs, ts < 1.58, ps $> .12$, except when comparing the last set in the traditional Posner task to the first set of the affective Posner task, $t(60) = 8.18$, $p < .001$. A repeated measures analysis of variance (ANOVA) indicated there was a main effect for trial set, $F(4, 232) = 4.01$, $p = .01$, $\in = .75$, however post hoc comparisons found that none of the pair-wise comparisons reached significance. The tendency to have longer RTs in the first set of trials did not differ between the traditional and affective Posner tasks, $F(4, 232) = .30$, $p = .80$, $\in = .65$. No significant findings were evident when shyness group was added to the analyses as a between subjects factor, Fs $< .19$, ps $> .88$.

These results indicate that the pattern of data presented in the following resulted from the experimental manipulations of the study and not the gradual effects of increasing boredom and practice. Indeed, a second study comparing performance on the traditional and affective Posner tasks found significant changes in performance only with the introduction of the affective component, even though there were 100 trials per condition (Rich et al., in press).

Physiological Data

EEG collection. EEG signals were collected at the beginning of the child's visit to the laboratory. They were brought into a testing room and seated in a large comfortable chair. The purpose of the EEG procedure ("To measure the electricity your brain makes") was explained to the child. Because this study was part of a larger longitudinal study of temperament, the children were relatively comfortable with the collection procedures. Indeed, this was the fifth time these children had participated in EEG collection in our laboratory.

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).[2] Impedances were kept lower than 5 kΩ. The data from each channel were digitized at a 512 Hz sampling rate

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

and calibrated to a .477 volt 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, whereas 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 or movement related artifact. Eye-movement related artifacts were kept low by having the children use a mobile button box for responses, allowing the child to hold the box near them and minimizing eye shifts to the location of the response buttons. 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 .10 and 100 Hz and a 60 Hz notch filter. The signal was digitized using Snapshot-Snapstream™ acquisition software (HEM Data Corp., Southfield, MI). The data from the remaining 36 children were collected with SA Instruments (San Diego, CA) isolated bioelectric amplifiers using high- and low-pass filters of .10 and 100 Hz. The signal was digitized with the Snapmaster™ Data Acquisition System (HEM Data Corp., Southfield, MI). 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, $F(1, 56) = .01, p = .93$.

Event-related potentials. ERPs were collected to the presentation of each target, referenced to a 100 msec baseline. Included trials were artifact free for the 1000 msec following target presentation and had been responded to correctly. ERPs generated by the valid and invalid trials were separated out into two individual files. These trials were then averaged together to create mean ERPs for each child. On average, 15.6 valid trials and 14.8 invalid trials were artifact free per child for the traditional Posner task. This difference was significant, $t(57) = 2.55, p = .03$. There was no significant difference in the number of useable trials (15.9 vs. 15.2) for the affective Posner task. In addition, there were no significant changes in the mean number of useable trials in the affective Posner task versus the traditional Posner task.

The data from the mean ERPs were used in the data analyses. ERP components were chosen for analysis based on a review of the grand average ERPs. The grand average ERPs were created by averaging together the ERPs from all of the participating children.

ERPs to the valid and invalid trials were compared for the following components: N1 (50–170 ms), P2 (130–260 ms), N2 (170–330 ms), P3 (200–400 ms), and N4 (330–500 ms). For each component the peak amplitude within the designated time window was used for the analyses. In addition, the mean amplitude of the positive slow wave was calculated for the 500–1,000 msec time window (see Figure 1). Data were analyzed separately for each of the EEG collection channels.

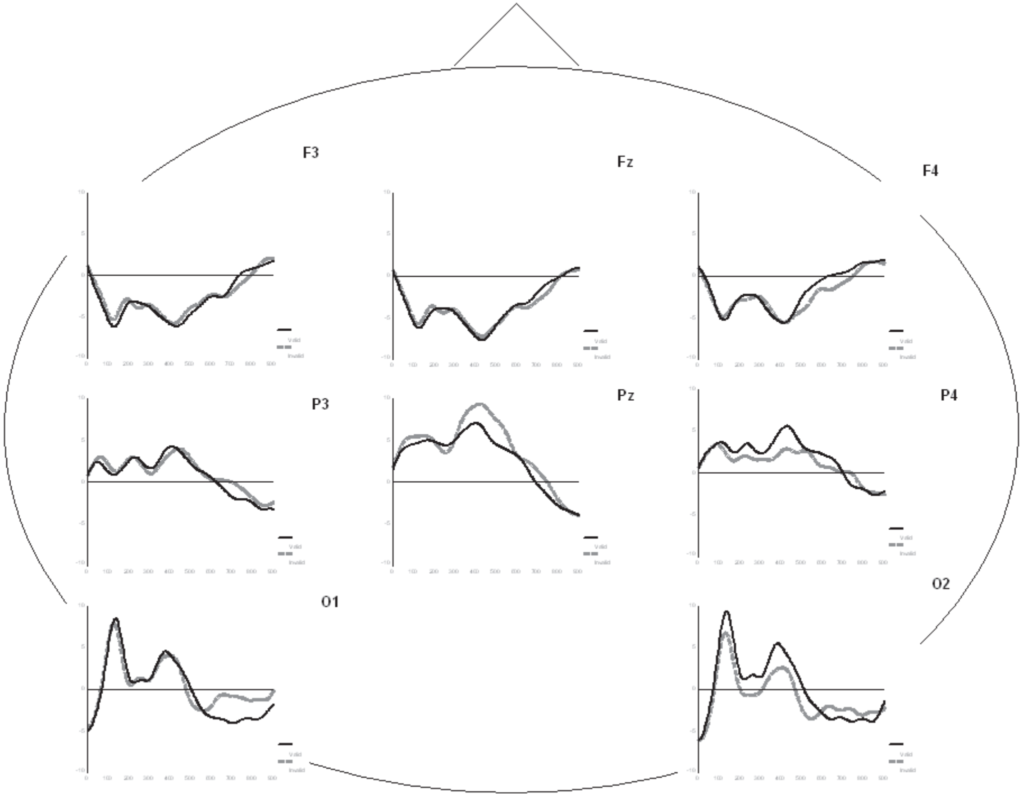

FIGURE 1 Event-related potentials generated by valid and invalid trials in the traditional Posner task.

As in other studies involving the relation of electrocortical activity to emotional and cognitive development (D. H. Marshall, Drummey, Newcombe, & Fox, 2002; P. J. Marshall, Bar-Haim, & Fox, 2002; Pérez-Edgar & Fox, 2003a), this study used average referencing in analyzing the EEG and ERP data. Although there is some controversy about using the average reference with small electrode arrays (Davidson, Jackson, & Larson, 2000; Hagemann, Naumann, & Thayer, 2001), the scalp distribution of the electrodes in this study was extensive enough to justify use of this reference configuration (P. J. Marshall et al., 2002).

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. In discussing these data, the components will be labeled based on their appearance in the ERPs produced by the frontal electrodes (Dien, 1998).

EEG power. EEG data collected during the Posner tasks were submitted to a discrete Fourier transform analysis that utilized a Hanning window with 50% overlap. This analysis quantified the power in picowatt ohms (or micro-volts squared) for each electrode site. Power was calculated for sets of 10 trials each. The sets were demarcated by the presentation of negative feedback in the affective Posner task. An analogous analysis was run for the data collected during the traditional Posner task. Spectral power data from 1 to 30 Hz were computed in single Hz frequency bins for each set of trials at each of the collection sites. Power in the alpha band (6–9 Hz) was computed for each site by summing the individual power measures for the 6-, 7-, 8-, and 9-Hz bins. Power and activation are thought to be reciprocally related (Davidson, 1988; Lindsley & Wicke, 1974). High power reflects low activation at a particular electrode site. In total, 10 sets of EEG measures were calculated for each site—5 sets in the neutral condition and 5 sets in the affective Posner task.

Statistical Analysis

The following analyses employ repeated measures ANOVAs. 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 (1977) test. These precautions are similar to those used in previous studies collecting both behavioral (RT) and psychophysiological (ERP) measures during the Posner task (e.g., Perchet & García-Larrea, 2000; Wright, Geffen, & Geffen, 1995).

Analyses with RT data were first run using the raw means for each trial type. The data were then reanalyzed to compare the relative cost and benefit of valid and invalid cueing. To assess the benefits accrued through valid cueing, the RTs to trials with valid cues were subtracted from the RTs to neutral cues. In the same way, the cost of invalid cueing was calculated by subtracting RTs to invalid trials from trials with neutral cues. A positive number would indicate a gain in speed, whereas a negative score indicates a loss of speed. To directly compare the *magnitude* of the costs and benefits of cueing without regard to the direction of the effect (e.g., positive or negative numeric values), the analyses were also conducted using the absolute values of the effect.

RESULTS

Traditional Posner Task

Behavioral data. 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.

An initial validity effect ANOVA was first run with validity (valid vs. invalid cue) as a within-subjects factor and shyness group as the between-subjects factor. As in previous studies, there was a significant main effect of validity, such that RTs to the invalid trials were consistently and significantly slower than RTs to the valid trials, $F(1, 58) = 50.11$, $p < .01$ (see Table 1). The effect was robust with over one-third of the children showing a validity effect of at least 50 msec. The interaction between validity and shyness was not significant in the traditional Posner task, $F(1, 58) = .08$, $p = .78$.

A repeated measures ANOVA examining the costs and benefits of cueing indicated that there was a significant difference between the benefits (+29.7 msec) and costs (–5.3 msec), $F(1, 57) = 15.20$, $p < .001$. However, an analysis of the absolute values of the effect suggested that although the children enjoyed a significant benefit to performance after a valid cue, $t(59) = –3.05$, $p = .003$, invalid cueing did not

TABLE 1
Mean Reaction Times and Standard Deviations in Milliseconds in the Traditional and Affective Posner Tasks, by Trial Type and Shyness Group

Trial Type	*Overall*[a]		*High Shy*[b]		*Low Shy*[c]	
Posner Task	*M*	*SD*	*M*	*SD*	*M*	*SD*
Traditional						
Valid	848.7	130.1	856.1	112.2	845.1	148.7
Invalid	885.2	132.3	896.1	118.8	874.9	148.7
Neutral	877.7	141.3	884.8	127.3	870.9	159.6
Affective						
Valid	657.9	96.6	667.0	73.1	649.8	118.4
Invalid	718.8	104.4	725.6	86.8	711.1	123.1
Neutral	687.8	92.7	698.7	74.7	677.8	109.6

[a] $N = 60$. [b] $n = 31$. [c] $n = 29$.

produce a significant cost to performance, $t(59) = .80$, $p = .43$. The interaction with shyness group was not significant, $F(1, 57) = .32$, $p = .58$.

Event-related potentials. For each component an initial 2 × 3 × 2 × 2 ANOVA was calculated. Cue validity (valid vs. invalid), scalp electrode location (frontal, parietal, occipital), and hemisphere (right vs. left) were within subject factors. Shyness group was used as the between-subject factor. There were no consistent findings involving the subject groups. Therefore, only the main effects of validity will be discussed in the following paragraphs.

For N1, there was a significant main effect for validity, $F(1, 57) = 7.76$, $p = .01$, such that the valid trials had larger amplitudes. In addition, there was a significant interaction between validity and electrode scalp location, $F(2, 114) = 5.31$, $p = .01$, $\in = .98$. Although in the same direction for each electrode pair (F3-F4, P3-P4, O1-O2), post hoc tests showed that none of the paired comparisons reached significance.

At N2, the valid trials had significantly larger amplitudes than the invalid trials, $F(1, 57) = 8.30$, $p = .01$. In addition, there was a significant interaction between validity and electrode location, $F(2, 114) = 4.12$, $p = .02$, $\in = .93$. Post hoc tests indicated that the difference between valid and invalid trials was significant for the occipital sites.

For the slow wave, the valid trials had a larger mean amplitude than the invalid trials, $F(1, 57) = 4.53$, $p = .04$. Unlike the earlier components, this did not differ with electrode location.

There were no main effects of validity for the P2, P3, and N4 components.

The findings for N1 and N2 are in line with the data published in studies of children (Perchet & García-Larrea, 2000) and adults (Hillyard et al., 1994). As expected, these early perceptual findings are concentrated in the posterior sites (Luck et al., 1990).

Affective Posner Task

Behavioral data. As in the traditional Posner task, there was a significant main effect of validity during the affective Posner task, $F(1, 58) = 57.16$, $p < .01$ (see Table 1). In addition, a 2 (valid vs. invalid cue) × 2 (traditional vs. affective Posner task) ANOVA indicated that RTs decreased dramatically in the affective Posner task, $F(1, 58) = 296.38$, $p < .001$. Indeed, 26 of the children showed a drop in RTs of over 200 msec. There was also a significant interaction, indicating that the validity effect was larger in the affective Posner task (36.5 ms vs. 60.9 ms), $F(1, 58) = 6.23$, $p = .02$. There were no significant interactions involving shyness group, $F\text{s} < .41$, $p\text{s} > .52$.

The data were then analyzed in terms of the relative benefits and costs of the valid and invalid cues. In the affective Posner task, there was a significant difference in the benefit (+29.6 msec) and cost (–29.4 msec) to cueing, $F(1, 57) = 54.16$, $p < .001$. The absolute values of the effect on RTs were also each significant, *t*s > 4.15, *p*s < .001. However, the magnitude of the benefits and costs did not differ from each other, $F(1, 57) = .00$, $p = .99$. A repeated measures ANOVA comparing the benefits and costs of cueing in the traditional and affective Posner tasks indicated that although the relative benefit of valid cueing was stable across both forms of the Posner task, the cost of invalid cueing increased in the affective task, $F(1, 57) = 5.60$, $p = .02$. Again, there were no significant interactions with shyness group, *F*s < .29, *p*s > .59.

Because errors were fairly rare in the traditional and affective Posner tasks, errors within 10-trial sets were pooled for analysis. The average number of errors per set increased significantly in the affective Posner task (.41 vs. .85), $F(1, 58) = 17.56$, $p < .01$. This is in line with the dramatic drop in RTs and the expected response-accuracy tradeoff. Again, there were no significant interactions involving shyness group, *F*s < 1.6, *p*s > .21.

Although the previous analyses centered on the children's overall abilities to orient attention during the Posner task, by focusing on the type of cue (positive vs. negative) the following analyses will be able to address the attentional biases the children may have brought to the task.

A 2 (valid vs. invalid cue) × 2 (positive vs. negative cue) × 2 (shyness group) ANOVA indicated that although, as expected, the validity effect was still significant, $F(1, 58) = 57.19$, $p < .01$ (see Table 2), there was no significant main effect when comparing positive and negative cues, $F(1, 58) = .19$, $p = .67$. However, there was a significant interaction with shyness group, $F(1, 58) = 4.01$, $p = .05$. The low shy children were faster in responding to the positive cue versus the negative cue (672 msec vs. 689 msec), whereas the opposite was true for the high shy children (702 msec vs. 691 msec). Subsequent paired and independent t-tests indicated that

TABLE 2
Mean Reaction Times and Standard Deviations in Milliseconds by Trial Type and Shyness Group to the Positive and Negative Cues in the Affective Posner Task

	Overall[a]		*High Shy*[b]		*Low Shy*[c]	
Trial Type	*M*	*SD*	*M*	*SD*	*M*	*SD*
Neutral	687.8	92.7	698.7	74.7	677.8	109.6
Valid positive	647.6	107.4	665.2	73.2	631.0	135.0
Valid negative	668.0	109.8	669.5	100.3	667.7	122.5
Invalid positive	726.9	106.1	739.5	91.3	713.2	121.7
Invalid negative	712.1	119.0	713.1	103.0	710.7	137.8

[a] $N = 60$. [b] $n = 31$. [c] $n = 29$.

the RTs for the affective cues did not differ significantly within, ts < 1.96, ps > .06, or between groups, ts > 1.23, ps > .22.

Again, a cost-benefit analysis was then completed. Here, the comparison was between neutral and cued trials in the affective Posner task, taking into account the valence of the cue. As in the previous analyses, the presence of valid and invalid cueing significantly affected RTs relative to the neutral trials, $F(1, 58) = 57.19, p < .001$. However, the absolute values of the costs and benefits were not significant, $F(1, 58) = .01, p = .94$. When comparing the relative costs and benefits of affective cueing (see Table 3), there was no main effect of valence, $F(1, 58) = .19, p = .67$. However, the interaction was significant, $F(1, 58) = 4.01, p = .05$, such that children in the high shyness group showed a relative response advantage when the cue was negative (+7.40 msec) and a disadvantage when the cue was positive (–3.63 msec). The opposite was true for the children in the low shyness group (–11.4 msec vs. + 5.72 msec).

The data, in light of the previous findings, suggest that any potential group differences are found in subtle variations in the relative response to affective stimuli. When an invalid trial is presented in the negative location, the relative cost in RT may be smaller for the shy child versus the nonshy child. The data indicate that this is the case (–14.35 msec vs. –32.86 msec). By the same token, the relative benefit (neutral vs. valid trial) of a negative cue may be greater for the shy child (+29.10 msec) than for the low-shy child (+10.10 msec).

Event-related potentials. An initial 2 (valid vs. invalid cue) × 2 (traditional vs. affective Posner task) × 3 (scalp electrode location: frontal, parietal, occipital) × 2 (right vs. left hemisphere) ANOVA was run for the ERPs generated in the Posner tasks (see Figure 2).

For N1, there was a significant main effect when comparing the traditional and affective Posner tasks, $F(1, 57) = 4.67, p < .001$, such that the amplitudes were larger in the affective Posner condition. Although there was a significant interac-

TABLE 3
Mean Reaction Time and Standard Deviations in Milliseconds Costs
and Benefits of Affective Cues for the Affective Posner Task, by Trial Type
and Shyness Group

	Overall[a]		*High Shy*[b]		*Low Shy*[c]	
Trial Type	*M*	*SD*	*M*	*SD*	*M*	*SD*
Positive benefit	41.2	73.7	33.5	66.6	46.8	81.0
Negative benefit	20.8	76.8	29.2	80.7	10.1	73.4
Positive cost	–38.1	63.4	–40.8	64.3	–35.4	64.6
Negative cost	–23.3	68.3	–14.4	68.0	–32.9	69.7

[a] $N = 60$. [b] $n = 31$. [c] $n = 29$.

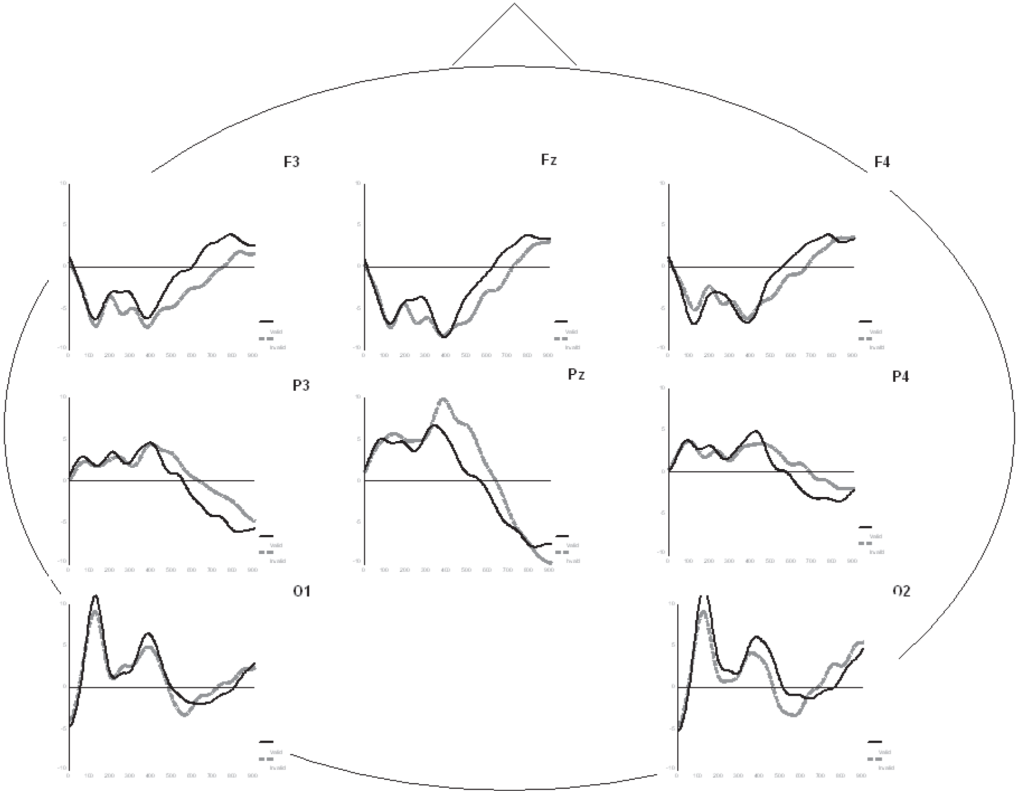

FIGURE 2 Event-related potentials generated by valid and invalid trials in the affective Posner task.

tion between the form of the Posner task and electrode location, $F(2, 114) = 3.34$, $p = .04$, $\in = .94$, none of the post hoc pairwise comparisons reached significance.

There were no main effects for the positive slow wave. However, there was a significant interaction between the form of the Posner task and electrode location, $F(2, 114) = 18.73$, $p < .001$, $\in = .89$. Post hoc tests indicated that the effect reached significance in the frontal and occipital sites.

There were no effects of task context for the components P2, N2, P3, and N4.

The data show a tendency for greater amplitudes in the affective Posner task versus the traditional task. However, the general trend only reached significance for N1 and the positive slow wave, bookending the ERP wave generated by the task.

Shyness group was added as a between-subjects factor to the 2 × 2 × 3 × 2 ANOVA previously noted. There was one series of consistent findings involving the shyness groups. Namely, the children in the high shy group showed a larger increase in ERP amplitude across the tasks than did the children in the low shy group. This was significant (see Table 4) for the frontal sites at N1, $F(1, 55) = 8.56$, $p = .01$, N2, $F(1, 55) = 9.94$, $p < .01$, and N4, $F(1, 55) = 5.02$, $p = .03$.

EEG power. To assess EEG alpha power during the affective and traditional Posner task, the EEG signal was pooled across 10-trial sets, as in the behavioral error analysis. ANOVAs comparing task (traditional vs. affective Posner task), trial set (5 sets for each version of the Posner task), and electrode location (right vs. left hemisphere) were carried out individually for the frontal, parietal, and occipital sites.

In each analysis, shyness group was used as the between subjects factor.

In the frontal sites, there was a significant main effect for task format, such that EEG power was significantly lower in the affective Posner task, $F(1, 47) = 22.76$, $p < .001$. In addition, there was a significant task format by set interaction, $F(4, 188) = 2.64$, $p = .05$, $\in = .81$. Very low power levels for the first set of trials drove these effects in the affective condition (see Figure 3).

The parietal sites produced a very similar pattern of results. Again, the affective Posner task had significantly lower power levels than the traditional task, $F(1, 46) = 15.94$, $p < .001$. There was also a main effect of trial set, $F(4, 184) = 7.12$, $p < .001$, $\in = .77$, and a trial set by task format interaction, $F(4, 184) = 4.55$, $p < .01$, $\in = .92$. Again, this was driven by the data derived from the first set of trials in the affective Posner task.

The occipital sites also showed a significant main effect for trial format, $F(1, 46) = 27.56$, $p < .001$. Although there again was a main effect of set, $F(4, 184) = 11.06$, $p < .001$, $\in = .45$, the set by block interaction did not reach significance, $F(4, 184) = 1.62$, $p = .17$.

The data from the three analyses clearly indicate that the affective Posner task caused a significant amount of alpha desynchronization. In addition, the significant interaction effect indicates that the first set of trials, immediately following the introduction of the motivational component, was particularly arousing. Al-

TABLE 4
Mean ERP Amplitudes and Standard Deviations in Microvolts Generated by the Traditional and Affective Posner Tasks for Three Components (N1, N2, and N4) at Each of the Electrode Locations (Frontal, Parietal, and Occipital) Separately for Each Shyness Group

Electrode Location	*N1*				*N2*				*N4*			
Shyness Group	*High Shy*		*Low Shy*		*High Shy*		*Low Shy*		*High Shy*		*Low Shy*	
Posner Task	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Traditional												
Frontal	–7.05	0.66	–7.47	0.70	–7.04	0.66	–7.79	0.70	–8.70	0.89	–9.31	0.93
Parietal	–5.15	0.70	–5.99	0.73	–5.42	0.67	–6.78	0.70	–6.34	0.78	–7.57	0.83
Occipital	–9.81	1.04	–11.94	1.09	–7.15	0.87	–9.55	0.91	–6.44	1.15	–9.40	1.21
Affective												
Frontal	–8.61	0.65	–7.39	0.68	–8.97	0.66	–6.59	0.70	–9.90	0.90	–8.30	0.94
Parietal	–5.56	0.55	–5.68	0.58	–5.65	0.55	–5.96	0.58	–6.65	0.72	–7.51	0.76
Occipital	–11.53	1.03	–13.18	1.09	–8.77	0.84	–9.04	0.88	–8.10	1.22	–9.17	1.29

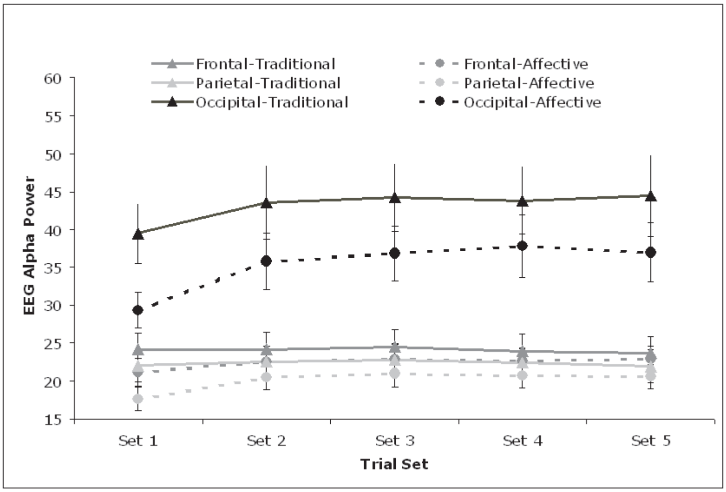

FIGURE 3 EEG power levels across trials in the traditional and affective Posner tasks.

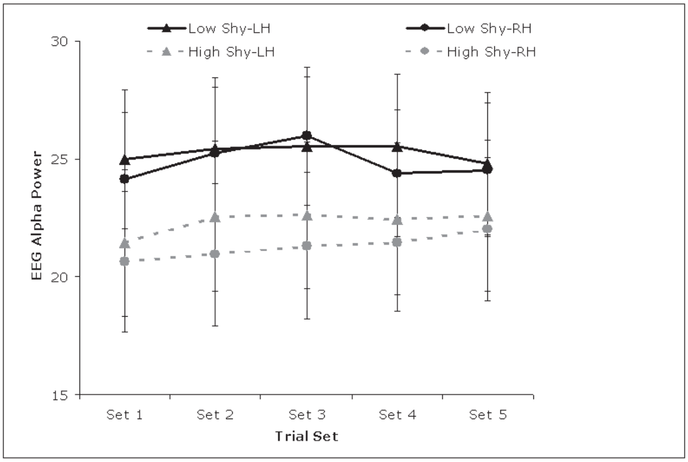

FIGURE 4 EEG power levels across trials for the shyness groups.

though the children quickly habituated, they never returned to the power levels seen for the traditional, affect neutral, Posner task.

The analyses found no main effects for shyness group, *F*s < .61, *p*s > .44. However, there was a significant hemisphere × trial set × group interaction for both the frontal, $F(4, 184) = 2.38$, $p = .05$, ∈ = .86, and parietal, $F(4, 184) = 2.63$, $p = .05$, ∈ = .70, sites (see Figure 4). For each set of sites, the high shyness group showed less power (greater cortical activation) in the right hemisphere than in the left. These data are in line with previous findings concerning the relations between EEG asymmetry and emotional processing. In particular, right frontal EEG activation has been linked to negative or withdrawal emotions, whereas left frontal EEG activation has been linked to positive or approach emotions (Davidson & Fox, 1989; Fox, 1991). Previous studies also linked parietal asymmetry to shyness and sociability (Schmidt & Fox, 1994) as well as clinical indications of depression and anxiety (Davidson, Schaffer, & Saron, 1985).

DISCUSSION

This study was designed to observe the interaction between affect and attention in children by carefully observing both the context of the task and the traits and biases that the children brought to the situation. Overall, the children were significantly slower in responding to the invalid versus valid trials in the traditional Posner task. The data replicate both the adult and developmental literature (E. Fox et al., 2001; Hugdahl & Nordby, 1994; Perchet & García-Larrea, 2000). In addition, the ERP data replicated previous studies of children (Perchet & García-Larrea, 2000) and adults (Hillyard et al., 1994). As expected, neither the behavioral nor psychophysiological data varied as a function of shyness.

With the affective Posner task, children had faster RTs, increased errors, and greater electrocortical arousal than in the traditional Posner task. The motivational manipulation impacted both the overall speed and the quality of performance. In addition, the size of the validity effect and the calculated costs of invalid cueing grew significantly. Relative to their performance on the valid trials, the attentional disengagement and shifting required for the invalid trials was more difficult when an affective component was added to the task. The pattern of data, coupled with recent studies of children and adults (E. Fox et al., 2001; Pollak & Tolley-Schell, 2003), suggested that the affective Posner task requires more processing resources than does the traditional task.

The psychophysiological data, which show a tendency for greater ERP amplitude in the affective Posner versus the traditional task, point in the same direction. For the EEG data, there was a significant drop of alpha (6–9 Hz) power across all of the electrode sites, in line with data indicating that alpha desynchronizes during visual attention tasks (Mulholland, 1969, 1995). The additional desynchronization seen in the affective Posner task may reflect greater engagement brought on by the motivational manipulation. Indeed, generalized EEG activation has been associated with the intensity of arousal accompanying different motivational states (Dawson, 1994). It also is seen as a marker of a vigilant state, reflecting a lower threshold of neuronal excitability, and an increased readiness to detect incoming stimuli (Parasuraman, Warm, & See, 1998). This interpretation is in line with our current data indicating increased ERP amplitudes and larger behavioral validity effects in the affective version of the task. In fact, significant response costs from invalid cueing were only present in the affective Posner task.

The change in EEG signal across sets also indicated that the children showed a great deal of alpha desynchronization when first presented with the affective Posner task. However, they quickly habituated, although maintaining lower levels of EEG power than in the traditional Posner task. Habituation is not regularly seen in the traditional Posner task (Oken, Kishiyama, & Salinsky, 1995), suggesting that the increase in alpha desynchronization may have been due to the arousal or stress effects of the speech manipulation.

It was expected that differences between the shyness groups would emerge in this highly charged environment. However, other than targeted differences in ERP amplitude and EEG asymmetry, the data indicated that there were no global differences in performance or processing as a function of temperament. As such, these data are somewhat limited in scope.

However, the data do indicate that the shy children differed from their nonshy peers in where they allocated their attentional resources. The central prediction concerning the shy children in the study was that they would preferentially attend to cues in the punishment location. Adult studies indicate that introverted (Derryberry & Reed, 1994) and anxious (Derryberry & Reed, 2002; E. Fox et al., 2001) individuals focus on negative threat cues in the affective Posner task. Like anxious adults, temperamentally shy children exhibit signs of anxiety and social discomfort, which may lead them to focus on stimuli that mirror their concerns (Pauli et al., 1997). This may in turn play a role in both sustaining and exacerbating social and affective maladjustment (E. Fox et al., 2001).

When comparing the RTs to positive and negative cues, the shy children responded more quickly to the negative cue versus the positive cue, whereas the opposite was true for the nonshy children. However, individual comparisons were not significant. A review of the full data further indicates that the relations between attention and childhood shyness are not as straightforward as theory would suggest. The complexity of these data can be seen in the additional information found in the analysis of relative costs and benefits. In invalid trials, the need to disengage and then shift attention to accurately detect the target, can be seen in slower RTs relative to both valid trials and trials with a central (neutral) cue. In the case of the affective Posner task, theory would suggest that the relative cost of an invalid cue would differ as a function of its punishment or reward value. That is, rather than attend to the center of the visual field, equidistant from each potential cue or target location, or sweep attention equally to each potential location, the temperamentally shy children in this study appeared to preferentially attend to the negative location. This can be seen in the analyses comparing the cost and benefits of the positive and negative cues.

A comparison of the analyses using the "raw" RTs for the valid and invalid trials to analyses of relative benefit and cost indicate the subtle permutations in the relations between individual differences and attention. These data echo a recent affective Posner study of physically abused children. Pollak and Tolley-Schell (2003) found that although individual differences in responses to affective cues (happy and angry faces) were inconsistent when using "raw" RTs, a cost-benefit analysis indicated that the abused children, unlike controls, differentiated between the affective cues. They argued that abused children have difficulty disengaging from threatening stimuli (e.g., angry faces). In this study, the data suggest that the groups do not differ in their ability to disengage attention from a particular cue, without regard to valence. Rather, any differences in performance appear to arise from initial attentional biases and the differential "travel" times to target locations that result.

This study differed in four respects from previous studies of attentional biases: (a) the age of the participants, (b) the inclusion of both neutral and affective contexts, (c) the extensive use of electrophysiological data, and (d) the focus on individual differences in temperamental shyness.

In terms of age, the children's performances were comparable to the performance of adults in both the traditional and affective Posner (Derryberry & Reed, 1994, 2002; E. Fox et al., 2001; Hugdahl & Nordby, 1994). Also, children of the same age have been shown to track adult behavior in other attention tasks, particularly the color-word and emotional Stroop (Martin & Cole, 2000; Pérez-Edgar, 2001; Pérez-Edgar & Fox, 2003a). Thus, it appears that the mechanisms underlying these tasks are quite early appearing.

There was some indication that although the overall pattern of responses seen in this study are similar to those with adults, there may be subtle age-related differences. Previous work with adults (Nobre et al., 2000) indicated that the validity effect can be attributed to the costs associated with invalid cueing. However, in this study, the children's responses indicated that cueing produced only significant benefits in the traditional task and both benefits and costs in the affective task. It may be that young children are more sensitive than their adult counterparts to attentional cues. This could, in part, be attributed to relatively immature executive control systems, which often act to regulate orienting mechanisms (Ruff & Rothbart, 1996). This enhanced sensitivity may hint at a developmental mechanism for current theories in the adult literature, which argue that individual differences in personality are both reflected in and perpetuated by differences in attentional control and attentional biases. Early sensitivity to environmental stimuli may shape which aspects of the environment a child responds to and processes, thereby shaping the child's worldview.

The second component of the study dealt with the context of performance. In its original form the Posner cued attention task has proven to be a robust measure of automatic attentional processes. In the Posner task, participants are compelled to attend to peripheral cues even when they are of no benefit to overall performance (Hillyard et al., 1994). The addition of a motivational component allows one to observe the impact cognitive-emotional networks have on basic attentional mechanisms. For the affective Posner task, this was reflected in a distinct pattern of data that included dramatic decreases in RT, significant increases in errors, and higher levels of cortical arousal.

Third, this study incorporated electrophysiological measures into our analyses. These data were particularly useful when interpreting the affective manipulation by pointing to global changes in arousal and vigilance in the children. Also, these data pointed to a potentially subtle shift in effect localization such that task-based findings were centered in the posterior sites, whereas individual differences were clustered in the anterior sites.

Indeed, the fourth component of this study addressed the role of individual differences in temperamental shyness. Attention can vary across individuals in three basic ways. First, children may differ in the general ease with which they can direct attentional resources. The data from the traditional Posner task indicate that the children did not differ in this respect. Second, children may differ in the way attention mechanisms respond to environmental context. Overall, the children in the two shyness groups were quite similar in their responses to the tasks, in both its neutral and affective forms. Third, children may differ in the ways they choose to deploy limited attention resources. This appears to be the case when comparing the positive and negative cues in the affective Posner task. The form of the stimuli interacted with individual difference variables to produce a distinct pattern of behavior.

Limitations

This discussion must be tempered by the limitations of this study. First, in an effort to balance two competing methodological concerns, this study chose to protect the integrity of the affective manipulation by having the affective Posner task always follow the traditional Posner task. This leaves open to question the role order effects may have played in the findings. The preliminary analyses and the strength of the observed behavioral and physiological differences between the two tasks indicate that order effects are not likely to have played a large role. However, the issue cannot be ruled out unequivocally.

Second, the addition of the positive and negative cues to the affective Posner task altered the visual display for the children and may have added to the cognitive (e.g., remembering the rules associated with each symbol) and attentional demands of the task, above and beyond the addition of the affective component. In addition, they may have altered the perceptual characteristics of the task, thus affecting the EEG and ERP findings. Although this issue will need to be addressed empirically in future studies, we do not believe that this factor played a large role in shaping our findings. This is based in part on our own analyses as well as data indicating that static distracters placed near a target produce relatively little interference during a selective attention task (Driver & Baylis, 1989).

Third, due to time constraints during testing, the task was limited to 100 trials in total. Although this was sufficient for robust behavioral data, the ERP analyses would have benefited from a larger, more stable pool of data. The small number of trials may have reduced power, masking potentially significant task and group differences. In addition, ERP analyses were limited to comparisons between valid and invalid trials and could not take into account variations in cue valence. More extensive psychophysiological data should help draw a closer link between observed behavior and underlying neural processes.

Summary

This study supports the proposition that differences in attentional behavior do not necessarily reflect fundamental differences in the structure, function, or control of core attentional mechanisms. Rather, the deployment of attention is often bound to contexts that tap into individual concerns that are often central to affective processes. Recent studies have suggested that temperamental shyness may be marked by both a vigilance for and a sensitivity to signs of threat in the environment. The exact parameters of these behaviors are still unclear. However, these data suggest that temperamentally shy children do not differ from their nonshy peers in their general ability to control attention. Instead, initial biases lead shy children to preferentially attend to threat cues in their environment. Further study will be needed to see if these initial biases serve as developmental mechanisms for observed differences in social behavior.

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