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Selective Attention to Facial Emotion in Physically Abused Children

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The ability to allocate attention to emotional cues in the environment is an important feature of adaptive self-regulation. Existing data suggest that physically abused children overattend to angry expressions, but the attentional mechanisms underlying such behavior are unknown. The authors tested 8–11-year-old physically abused children to determine whether they displayed specific information-processing problems in a selective attention paradigm using emotional faces as cues. Physically abused children demonstrated delayed disengagement when angry faces served as invalid cues. Abused children also demonstrated increased attentional benefits on valid angry trials. Results are discussed in terms of the influence of early adverse experience on children's selective attention to threat-related signals as a mechanism in the development of psychopathology.

In 1998, more than 2 million children were victims of substantiated child maltreatment in the United States (U.S. Department of Health and Human Services, 2000). Although child abuse is a known risk factor for the development of psychopathology (Kendler et al., 2000; MacMillan et al., 2001; Malinosky-Rummel & Hansen, 1993), the precise mechanisms linking the experience of maltreatment earlier in life to the development of psychopathology are largely unknown. Even before the emergence of psychopathological syndromes, maltreated children often evince unusual patterns in their abilities to recognize, express, and regulate emotional states (Camras et al., 1990; Camras, Sachs-Alter, & Ribordy, 1996; Pollak, Cicchetti, Hornung, & Reed, 2000). Relatedly, social information processing studies have revealed that when compared with nonabused aggressive children, physically abused aggressive children may be distinguished by biases in early stages of information processing (Dodge, Bates, & Pettit, 1990; Dodge, Lochman, Harnish, & Bates, 1997; Weiss, Dodge, Bates, & Pettit, 1992). It appears that these patterns of information processing may mediate the relationship between maltreatment and later behavioral problems (Dodge, Pettit, Bates, & Valente, 1995). However, few investigations have targeted the specific physiologic, perceptual, and cognitive processes affected by maltreatment that may, over time, act as proximal determinants of maladaptive patterns of social information processing.

The paucity of research in this area is due in part to the difficulty of designing objective, child-appropriate techniques for isolating and studying discrete aspects of affective information processing. A candidate mechanism that could link maltreated children's socioemotional difficulties with their early experiences concerns the selective allocation and control of attention. Several paradigms have been used to study such aspects of attention in adults with anxiety disorders. These studies suggest that anxious adults demonstrate attentional biases that facilitate the processing of threatening information (Mineka, Rafaeli-Mor, & Yovel, 2003; Vasey & MacLeod, 2001; Williams, Mathews, & MacLeod, 1996). Yet, one difficulty in interpreting the results of these studies is that the tasks typically used (i.e., emotional Stroop and dot probe) do not allow disambiguation of attentional processes such as enhanced orienting and engagement to, versus delayed disengagement from, threat. For example, one interpretation of emotional Stroop performance is that anxious individuals show rapid engagement of threatening information, even when such information is task irrelevant (Williams et al., 1996). Yet, it is also possible that anxious individuals have difficulty disengaging from threatening information (Derryberry & Reed, 2002; Fox, Russo, & Dutton, 2002). Either facilitated engagement to or delayed disengagement from a stimulus could increase a person's response to threat.

Dot probe and emotional Stroop methodologies have also been used to study anxious children, yet results have been inconsistent (Vasey & MacLeod, 2001). These tasks use emotionally evocative stimuli that are irrelevant to the child's primary task of either target detection (dot probe) or color naming (Stroop task). One reason that emotional dot probe and Stroop tasks fail to reliably discriminate between anxious and nonanxious children (younger than age 11) may be the fact that most young children have insufficient attentional or executive control to filter out task-irrelevant information that overlaps with a task-relevant stimulus. We reasoned

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that when studying younger children, emotional information must be made task relevant to examine this issue.

Variants of Posner's (1980) orienting task make it possible to use threatening stimuli that are relevant rather than irrelevant to the task. In such tasks, participants respond to the onset of a peripheral (right or left) target. The probable location of the target is fore-warned by a visual cue that indicates either the correct (*valid* trials) or the incorrect (*invalid* trials) target location. Valid cues promote rapid and accurate responses because an attentional focus, or *spotlight,* has been given a head start to move to the correct target location. Responses are typically slower and less accurate after invalid cues because the attentional spotlight is incorrectly deployed and must be disengaged from the incorrect location and moved to the correct location. Disengagement and engagement operations of spatial selective attention are believed to be linked to discrete neural systems that may be selectively disrupted (Posner & Raichle, 1994; Posner, Snyder, & Davidson, 1980; Posner, Walker, Friedrich, & Rafal, 1984).

The functions of engaging, disengaging, and shifting attention are thought to be accomplished by a posterior attention system that is functionally mature early in life (Posner & Petersen, 1990; Posner & Rothbart, 2000) and undergoes only minor developmental changes after early childhood (Brodeur, Trick, & Enns, 1997). In contrast, a later developing anterior attention system, which includes the anterior cingulate cortex, is thought to serve an executive control function by regulating the posterior orienting system to provide voluntary control over attention (Posner & Petersen, 1990). These attentional operations need not be mutually exclusive: Physiologic systems may strengthen engagement and orienting to threat with downstream effects on disengagement or the anterior system may override reactive orienting to threat either by directly activating posterior parietal areas involved in disengagement or by suppressing engagement. Thus, younger children whose executive control of attention is immature might engage and continue processing task-irrelevant threatening stimuli, but with increased frontal lobe development, this tendency would come under increasing strategic control. Likewise, with increasing maturity, metastrategies allowing for flexible, regulated processing of relevant threatening stimuli also appear.

Pollak, Cicchetti, and Klorman (1998) have proposed that the effects of maltreatment on children's attention to emotional cues may be understood in terms of general immaturity of sensory and perceptual systems. On this developmental view, maturational limitations on information-processing resources aid children's learning about emotion by requiring the child to filter or select some aspects of information from the environment over others (see also Bjorklund, 1997). If the child must be selective in what is attended to, then the development of emotion systems will be contingent on the child's experience. For the physically abused child, displays of anger are likely to be a salient cue related to threat. Accordingly, cues related to anger would be expected to recruit a greater proportion of physically abused children's attentional resources. A number of recent empirical findings are consistent with this conceptual account. For example, physically abused children exposed to a perceptual scaling task perceived angry faces as highly salient and more distinctive relative to other emotion categories (Pollak et al., 2000), displayed broader perceptual category boundaries for perceiving anger than nonabused children (Pollak & Kistler, 2002), and, on a perceptual gating task, required less visual information to detect the presence of angry facial expressions as compared with age- and IQ-matched controls (Pollak & Sinha, 2002). Further studies have used event-related potentials (ERPs), an index of central nervous system (CNS) functioning thought to reflect the underlying neural processing of discrete stimuli. One ERP component, P3b (also called P300), is thought to reflect CNS activity involved in attentional resource allocation (Coles & Rugg, 1995; Kramer & Spinks, 1991; Polich & Kok, 1995). These ERP studies reveal that whereas nonmaltreated children and adults responded uniformly when attending to happy, fearful, and angry faces, physically abused children displayed relative increases in P3b amplitude only when actively searching for angry faces. These data suggest that stimulus salience and later attentional processes directed toward detecting angry cues distinguish maltreated children's emotion processing (Pollak, Cicchetti, Klorman, & Brumaghim, 1997; Pollak, Klorman, Thatcher, & Cicchetti, 2001).

However, two issues about maltreated children's information processing remain unclear. The first issue concerns which aspects of attention are affected by maltreatment. Although it is adaptive for salient stimuli to elicit attention, successful regulation includes some flexibility and control over attention. Such control might include strategic filtering or timely disengagement from stimuli that do not require undue attention. Therefore, one possibility is that early experiences of abuse may affect developing perceptual systems in part by shaping the sensory threshold that anger-related stimuli must pass to recruit focused attention. If abused children orient rapidly and strongly to signals of threat, then prolonged attention may result, and disengagement would be delayed. Therefore, in the present study we examined whether physically abused children experienced problems disengaging from angry faces. This hypothesis is based on the premise that latency to disengage from a cue appears to be a function of the depth of processing or strength of engagement of that cue (Derryberry & Reed, 2002; Fox et al., 2002; Laberge, 1995). Problems with disengagement would also be consistent with the view that abused children may be less able to use strategic attentional control once signals of interpersonal threat have been engaged.

A second issue left unresolved from our prior ERP studies is whether differential processing of emotional cues on the part of maltreated children reflected increased processing of anger-related cues or attenuated processing of positive cues. Hyperresponsiveness to anger on the part of maltreated children is certainly consistent with extant behavioral studies. Yet, physically abused children may devote fewer resources to processing happy faces, in keeping with theories suggesting that classes of stimuli are underprocessed if they are less central to the observer's emotional experience (Bower & Cohen, 1982). Thus, we sought to measure physically abused children's attention to and memory for happy and angry faces.

Electrophysiological investigations of spatial selective attention have indicated that two ERP components (P1 and N1) are involved in early stages of perceptual processing (Mangun & Hillyard, 1991). The processes indexed by P1 and N1 are dissociable, with P1 amplitude reflecting correctly directed spatial attention and N1 reflecting discrimination of attended stimuli (Mangun, 1995). Invalid trials, in contrast, recruit later attentional processes related to context updating, reflected in the appearance of later components, including P3b (Eimer, 1994; Mangun & Hillyard, 1991). Previous

ERP studies of children's performance on nonaffective Posner-type tasks have reported reaction time benefits for valid trials, but attentional modulation of P1 and P3 were not consistently observed (Novak, Solanto, & Abikoff, 1995; Perechet & Garcia-Larrea, 2000; Swanson et al., 1991). These inconsistent findings may be attributable to differences across studies such as ages of the children, variations in parameters such as stimulus-onset asynchrony between cue and target, and relatively few trials available for averaging.

Hypotheses

The first hypotheses to be tested concerns general effects of selective attention. In keeping with prior research, all children are expected to respond faster to valid as compared with invalid cues as well as to display increased amplitudes of the target-evoked P1 component; these results would be consistent with an early processing advantage for valid targets. Across samples, we expect that invalid trials will result in increased reaction times as well as the emergence of the P3b component, which is associated with the updating of contextual information. The primary hypothesis of the present study concerns the effects of physical abuse on selective attention. Physically abused children are expected to expend more processing resources disengaging from angry cues than are control children. This differential allocation of resources will be reflected in behavioral (relative increases in RTs after invalid trials in the angry condition as opposed to invalid trials in the happy condition) and psychophysiological (increased P3b amplitude after invalid trials cued by angry relative to happy faces) measures. Although it is plausible that engagement processes may also influence abused children's processing of angry faces, recent formulations suggest that flexible use of attentional disengagement is a more critical regulatory strategy (Carver & Scheier, 1990; Derryberry & Reed, 2002, 2003; Mischel, Shoda, & Rodriguez, 1989; Posner & Rothbart, 2000; Vasey & MacLeod, 2001). Note that we are not expecting a general attentional deficit in physically abused children; rather, we are examining whether the processes involved in selective attention will be differentially affected by the presence of angry as opposed to happy faces. Finally, two additional planned, exploratory analyses will be undertaken to examine the effects of physical abuse on processing and memory for faces. Group differences in P1 and N170, associated with processing of the faces, will be measured before children's awareness of trial validity. Additionally, we test whether physically abused children show enhanced recognition memory for angry faces.

Method

Participants

The sample consisted of 14 physically abused and 14 nonabused children ranging in age from 8 to 11 years. Physically abused children were recruited by letters forwarded by the Dane County (WI) Department of Human Services to families with substantiated cases of child maltreatment. Nonmaltreated children were recruited by flyers posted in the same neighborhoods from which abused children were drawn. Attempts were made to match samples on child variables such as sex, race, and age and on family demographic variables such as percentage of single-parent status and number of children in the home (see Table 1). All children had normal or corrected-to-normal vision and, at the time of testing, were in good health and free of all medications. To supplement the maltreatment information obtained from judicial agencies, parents completed the Parent–Child Conflict Tactics Scale (PCCTS; Straus, Hamby, Finkelhor, Moore, & Runyan, 1998). The PCCTS measures the extent to which a parent has carried out specific acts of physical aggression toward the child. A Physical Abuse summary score was calculated by summing scores on three subscales (Minor Physical Assault, Physical Assault–Maltreatment, and Severe Physical Maltreatment) of the PCCTS. Sample items include the presence and frequency of the following acts toward children: "Beat him/her up, that is, you hit him/her over and over as hard as you could"; "Grabbed him/her around the neck and choked him/her"; "Burned or scalded him/her on purpose"; "Threatened him/her with a knife/gun." Parents of children in the control group endorsed far fewer aggressive behaviors toward children ($M = 7.25$, $SD = 9.03$) as compared with physically abusive parents ($M = 49.80$, $SD = 16.10$), $t(25) = 6.22$, $p < .01$. The aggressive behaviors endorsed by parents of children in the control group were limited to items reflecting corporal punishment, including slapping on the arm or leg, pinching, and spanking with an open palm. To achieve greater homogeneity of children's early experience, only children who experienced direct physical abuse were included in this study.

Table 1
Means (and Standard Deviations) of Psychodemographic Characteristics of Sample

Characteristic	Physically abused	Control
No. boys	8	9
Age (years)	10.1 (1.2)	10.0 (1.1)
Children in family	3.5 (1.5)	3.0 (1.2)
Hollingshead[a]	33.5 (10.1)	39.1 (18.4)
Race (%)		
Caucasian	15	23
Black	70	60
Hispanic	15	17
Parents in home (%)		
One	62	54
Two	38	46

Note. There were no statistically significant group differences between any variable reported in Table 1.
[a] The Four Factor Index of Social Status (Hollingshead, 1975) reflects family socioeconomic status on the basis of parent education and occupational status.

We measured the child's own and the parent report of the child's anxiety to ensure that group differences in attention were attributable to maltreatment status as opposed to group differences in anxiety. Measures included the Revised Children's Manifest Anxiety Scale (RCMAS; Reynolds & Richmond, 1978) and the Internalizing subscale of the Child Behavior Checklist (Achenbach, 1991). The groups did not differ on self-reported total anxiety symptoms (control $M = 45.15$, $SD = 4.65$; abused $M = 45.23$, $SD = 11.49$), $t(24) > 1$, *ns*, or parent-reported internalizing symptoms (control $M = 52.61$, $SD = 8.10$; abused $M = 51.0$, $SD = 13.08$), $t(24) > 1$, *ns*.

Parents received detailed information about the study protocol before giving informed consent. After being shown the study apparatus, children verbally assented to participation. Children were rewarded with age-appropriate prizes, and families received $35 for their participation in the study in addition to the cost of transportation. One child in each group was unable to complete the task; they are not included in the final sample. An additional participant in the control sample had invalid ERP data due to excessive head and eye movement, but his behavioral data were retained.

Stimuli and Apparatus

Six happy (3 female and 3 male), 6 angry (3 female and 3 male), and 12 neutral (6 female and 6 male) face cues were created by editing slides scanned from two validated sets of pictures of facial affect (Ekman & Friesen, 1976; Matsumoto & Ekman, 1990). Images were reproduced in gray scale using Adobe Photoshop. Twelve additional faces (6 happy and 6 angry) served as distractors on a test of recognition memory. Facial images were presented on a Viewsonic computer monitor, and responses were obtained from a Neuroscan Stimpad response box. Behavioral responses were detected with a resolution of approximately 2 ms from 0 ms through 1,200 ms poststimulus. Stimulus presentation and psychophysiological data acquisition were controlled by separate PCs.

Procedure

Children were tested individually during the late afternoon. After attachment of the scalp electrodes, children sat in a dimly lit, electrically shielded, and sound-attenuated room at a distance of 100 cm from the computer screen. The 20-cm screen was positioned so that the stimuli occurred on the participant's horizontal straight ahead line of sight. Trials began with a fixation cross presented in the middle of a black screen for 200 ms. After the offset of fixation, a face was presented either 5° to the left or to the right of the center of the screen for 500 ms. Two hundred ms after face offset, a target (red star) appeared 5° to the left or right of the center of the screen for 200 ms (see Figure 1). The participant's task was to press the right or left button to indicate the target location. Participants used their thumbs to press the left- and rightmost buttons to indicate the left and right sides of the screen, respectively. The intertrial interval between the star offset to the onset of the next face was 2,300 ms. A schematic of the experimental design is presented in Figure 2. The target appeared with equal probability on the left and right sides of the screen. Cues were valid when the target followed in the same location and invalid when the target followed in the opposite location. The probability of cues being valid was held constant at 78% across both conditions.

Participants received 50 practice trials using faces that did not appear in the experimental blocks, to ensure that they understood and could complete the task. Children received feedback and guidance after each practice block. After the practice trials, each child completed two blocks of angry-cue trials and two blocks of happy-cue trials in random order. Blocks consisted of 160 trials each (total trials = 640). The probability structure of 78% valid cues was constant across conditions. In the happy and angry conditions, six different models' emotional faces appeared as cues in a randomized order.

To incorporate emotion processing into the task and to ensure that children attended to the affective stimuli, some trials required the participant to withhold a response to the target. On these trials, a neutral face rather than an emotional face was presented as the cue (each model provided one emotional and one neutral pose). Neutral face trials were randomly interspersed among normal trials, so that they occurred at the average rate of 1:4. Half of the neutral trials appeared in the angry-cue condition, and the other half appeared in the happy-cue condition. These trials were included to motivate the participant to actively process the emotion in faces, and not to simply orient to the screen at the appearance of a star. To maintain the participant's expectation that cues predict target appearance, these cues were also 78% valid.

Recognition memory for emotion faces. After completion of all trials of the selective attention task, children completed a recognition memory test of the stimulus faces. Children indicated with a button press whether they remembered seeing each of 24 faces, 12 of which actually appeared, in the preceding task. The 12 distractors were matched to the target faces for gender and emotion.

ERP recording. The electroencephalogram (EEG) was detected from Ag-AgCl electrodes attached to the scalp with a lycra Electro-Cap at Fp1, Fp2, F3, Fz, F4, F7, F8, C3, Cz, C4, Pz, T3, T4, T5, T6, O1, Oz, and O2 electrode sites of the International 10–20 System and referenced to linked earlobes. A midforehead electrode served as ground. For eye movement detection, four channels of electro-oculogram-recorded horizontal and vertical eye movements from facial electrodes lateral to the left and right outer canthi and supra- and infraorbital ridges, respectively. NeuroScan amplifiers (with 16-bit A-D conversion) were set for half-amplitude bandpass at 0.01 to 100 Hz, and EEG was sampled at 250 Hz. Skin impedances at all electrode sites were maintained below 5 Kohms.

Behavioral performance scoring. The following were computed to describe performance on the selective attention task: (a) mean and within-participant standard deviation of reaction time for correct responses, (b) difference scores for each emotion, calculated by subtracting reaction time on valid cue trials from reaction time on invalid cue trials, (c) hit rate for each emotion condition, and (d) premature reactions (<200 ms). Furthermore, three types of error associated with responding to the target were recorded: (a) location errors (i.e., pressing a button that does not map onto target location), (b) commission errors (i.e., responding to a target that was preceded by a no-response cue), and (c) omission errors (not responding at all to a target requiring a response). The signal-detection statistics d' and C, which index sensitivity and bias, respectively, were calculated to describe recognition memory performance

Event-related potential scoring. EEG and EOG were averaged off-line for epochs of 2,200 ms, starting with 100 ms before offset of fixation and ending 1,000 ms after target offset. All measures were taken relative to the mean voltage of the 100-ms interval of fixation. Trials with overt response errors or amplifier blocking were excluded from the ERP analysis. EEG was digitally filtered with a bandstop filter of .1 to 30 Hz, then baseline corrected. Any epochs with voltage in any of the channels exceeding 250 μV were automatically excluded. To eliminate ocular artifact on EEG, EEG data were adjusted for their regression on EOG, separately for blinks and other eye movements (Gratton, Coles, & Donchin, 1983). As a result,

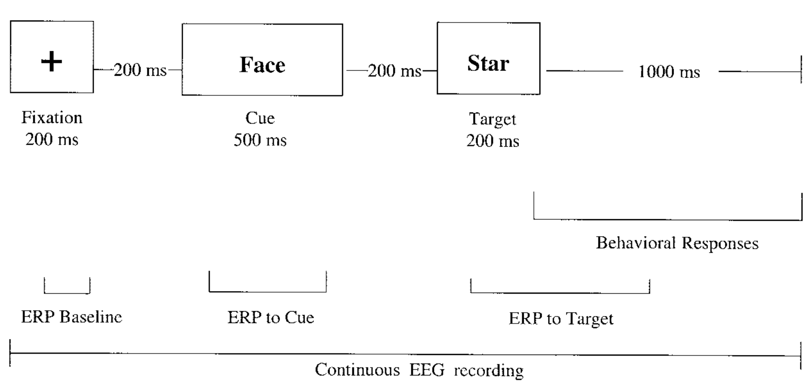


Figure 1. Illustration of experiment showing electroencephalograph (EEG) recording and participant response windows in relation to stimulus presentation. ERP = event-related potential.

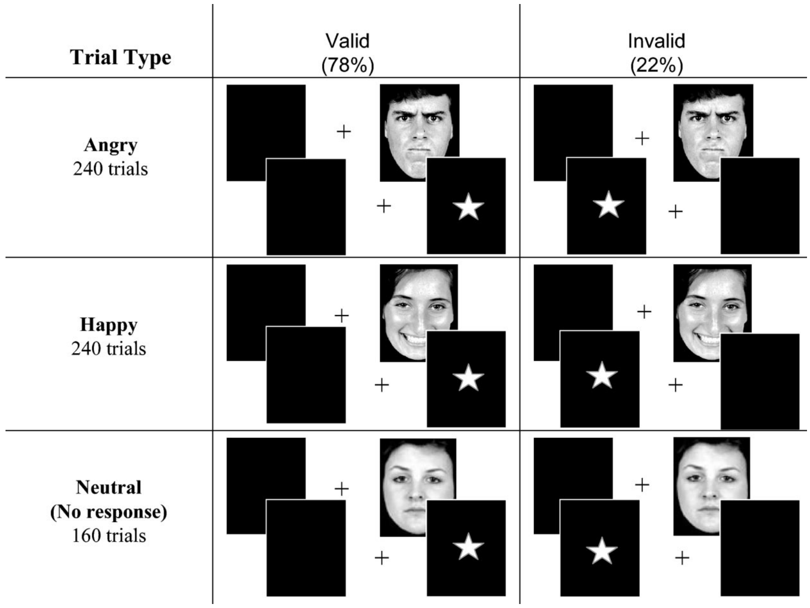


Figure 2. Sample stimuli and schematic of types of trials. The order of the happy and angry conditions was counterbalanced across participants. Half of the neutral (no-response) trials occurred in each of the happy and angry conditions. The images are from a set of photographs entitled *Japanese and Caucasian Facial Expressions of Emotion (JACFEE)* by D. Matsumoto and P. Ekman, University of California, San Francisco, 1988. Copyright 1988 by D. Matsumoto and P. Ekman. Reprinted by permission.

the adjusted EEG data have no correlation with the corresponding EOG data. Finally, ERPs were derived by averaging the EEG data separately for each combination of cue emotion (happy, angry), cue validity (valid, invalid), side of presentation (left, right), and electrode site. To score amplitude for ERP components of interest, a computer algorithm identified the largest positive or negative value of the participant's grand average at the electrode site at which the component is maximal within a time window based on the entire sample's average.

The following ERP components elicited by the faces were analyzed: P1 (maximal at occipital sites, 80–180 ms postpresentation of the face) and N170 (maximal at temporal sites, 160–230 ms postpresentation of the face). The following ERP components were analyzed in response to targets: P1 (maximal at occipital sites, 80–180 ms posttarget) and P3b (maximal at parietal sites, 350–700 ms posttarget). The average percentage of trials retained for averaging, after excluding trials with response errors or excessive movement artifact, was 88% for valid trials and 86% for invalid trials.

Both ERP and performance data were submitted to repeated measures analyses of variance using maltreatment status (physical abuse, control) and gender as between-subjects factors and cue emotion (happy, angry), validity (valid, invalid), and target hemifield (left, right) as within-subjects factors. Children's chronological age was used as a covariate to reduce error variance and to describe potential developmental trends. No specific hypotheses were advanced for the hemifield or gender factors; however, we included these factors in initial analyses to reduce error variance. Race was added as a between-subject variable in ERP analyses; however, no significant main effects or interactions involving race emerged, and the variable was not included in analyses reported here. Similarly, gender and age were dropped from final analyses in the absence of a main effect of gender or age or their contribution to a lower order interaction. When appropriate, Greenhouse–Geisser corrections were applied to offset violations of the sphericity assumption of repeated measures analysis of variance. The magnitude of effect size is reported as partial omega-squared (ω_p^2; Keppel, 1991, pp. 380–382).

Results

The main goal of the present study was to determine whether physically abused children evince attentional problems when processing angry faces. Accordingly, data will be presented in the following order. First, we present the behavioral and psychophysiological effects of cue validity, to demonstrate that the attentional manipulation was effective despite modifications from the standard Posner task. Next, we present the a priori tests of physical abuse on attentional processes that bear on our hypotheses. Finally, we present exploratory analyses of children's encoding of facial cues.

Effects of Cue Validity on Selective Attention

We tested the following four predictions: (a) Children will be more accurate after valid cues, (b) children will respond faster to valid cues, (c) children will display increased amplitudes of the target-evoked P1 component for valid trials, and (d) invalid trials will result in the emergence of the P3b component for all children. All of these predictions were confirmed.

As predicted, children responded faster to targets preceded by valid than invalid cues, $F(1, 24) = 23.15$, $p < .001$, $\omega_p^2 = .33$ (see Table 2, Response time). There were no significant group differences in any type of error, including responding to no-response trials (commission errors; Table 2, Omissions, Premature responses, Location errors, and Commission errors). Children made fewer location errors after validly cued trials as compared with invalidly cued trials, $F(1, 24) = 4.43$, $p < .05$, $\omega_p^2 = .08$ (see Table 2, Location errors). In addition, children were better able to withhold responding on a no-response trial when the cue was valid,

Table 2
Behavioral Performance Measures by Condition (With Standard Errors)

Variable	Valid		Invalid	
	Happy	Angry	Happy	Angry
Response time (ms)				
Control	442 (29)	445 (27)	487 (26)	475 (29)
Physically abused	464 (34)	418 (29)	494 (19)	496 (22)
Standard deviation of response time (ms)				
Control	126 (10)	142 (10)	106 (10)	120 (10)
Physically abused	135 (12)	137 (13)	116 (9)	130 (11)
Hits				
Control	91 (2)	88 (2)	89 (2)	88 (2)
Physically abused	93 (2)	90 (2)	92 (2)	88 (2)
Omissions				
Control	1 (2)	3 (4)	1 (2)	3 (7)
Physically abused	1 (3)	3 (7)	1 (2)	3 (8)
Premature responses				
Control	7 (2)	7 (2)	3 (3)	2 (5)
Physically abused	5 (3)	6 (2)	3 (2)	2 (7)
Location errors				
Control	1 (3)	2 (5)	7 (2)	7 (5)
Physically abused	1 (7)	1 (6)	4 (4)	7 (2)
Commission errors				
Control	12 (4)	19 (4)	19 (5)	28 (5)
Physically abused	9 (4)	13 (4)	18 (5)	18 (5)

Note. Unless otherwise indicated, all values are percentages.

$F(1, 24) = 5.09$, $p < .05$, $\omega_p^2 = .09$ (see Table 2, Commission errors for valid vs. invalid trials).

Psychophysiological responses for which we had a priori hypotheses, P1 and P3b elicited by the target, are depicted in Figure 3. P1, in response to the target, was measured at occipital (O1, Oz, O2) and temporal sites (T5, T6) ipsilateral and contralateral to target hemispace. P1 amplitude was not significantly different across these sites $F(2, 42) = 2.91$, $p = .09$, and peaked approximately 125 ms poststimulus. Latency of P1 was not affected by cue validity, cue emotion, or maltreatment status. However, as expected, P1 amplitude was enhanced for valid relative to invalid targets at the occipital midline and at occipital and temporal sites ipsilateral, $F(1, 21) = 8.12$, $p = .01$, $\omega_p^2 = .13$, but not contralateral, $F(1, 21) < 1$, *ns*, to the target. There was no significant influence of child age on P1 elicited by targets, $F(1, 21) < 1$, *ns*.

A later positive component peaked at approximately 430 ms at Pz (see Figure 4). This waveform appears consistent with P3b: As indicated in Table 3, P430 was largest at posterior relative to frontal sites, $F(2, 46) = 10.10$, $p < .01$, and was sensitive to cue validity, with increased amplitudes following rare, invalidly cued trials, $F(1, 23) = 9.95$, $p < .01$. A significant Validity × Site interaction, $F(2, 46) = 35.34$, $p < .01$, reflects that the difference in P430 amplitude for invalidly versus validly cued targets was greatest over parietal regions and continued to decrease from central to frontal sites. In keeping with previous developmental findings, P430 latency decreased with children's age at all midline sites $F(1, 22) = 19.24$, $p < .01$. P430 latency was not significantly affected by cue validity.

Effects of Physical Abuse on Selective Attention

The central hypothesis to be tested in this study was that physically abused children would show attentional difficulties processing angry cues as reflected in (a) behavioral performance differences after angry versus happy targets or (b) increases in P3b amplitude after invalid trials cued by angry relative to happy faces. The first prediction was partially confirmed, and the second prediction was confirmed.

Groups did not differ in overall hit rate or in the overall rate of any particular type of error. Across samples, children were more accurate in the happy condition than in the angry condition, $F(1, 23) = 25.17$, $p < .01$ (see Table 2, Hits). No specific type of error distinguished between the angry and happy conditions. An Emotion × Group × Validity interaction on children's reaction time, $F(1, 24) = 6.45$, $p < .05$, $\omega_p^2 = .05$, reflects that physically abused children responded more quickly to targets validly cued by angry as compared with happy faces, $F(1, 12) = 4.42$, $p < .06$, $\omega_p^2 = .21$. In contrast, control children responded similarly to targets cued by happy or angry faces, $F(1, 12) < 1$, *ns* (see Table 2, Response time, Valid). Contrary to our expectation, though, there were no significant group differences in mean reaction time to invalid targets, $F(1, 24) < 1$, *ns* (see Table 2, Response time, Invalid); nor were abused children significantly slower to respond on invalid angry trials than on invalid happy trials, $F(1, 12) < 1$, *ns*.[1] Yet, difference scores (RT invalid – RT valid) calculated to gauge the change in performance arising from the combination of reaction time benefit on valid trials and cost on invalid trials yielded a significant Group × Emotion interaction, $F(1, 22) = 5.39$, $p < .05$, $\omega_p^2 = .10$. Physically abused children had greater average difference scores in the angry condition than in the happy condi-

[1] Some higher order interactions involving gender and hemispace of presentation emerged. However, because of the small sample size and because gender effects were not a central part of the present study, these results are not discussed further in this article.

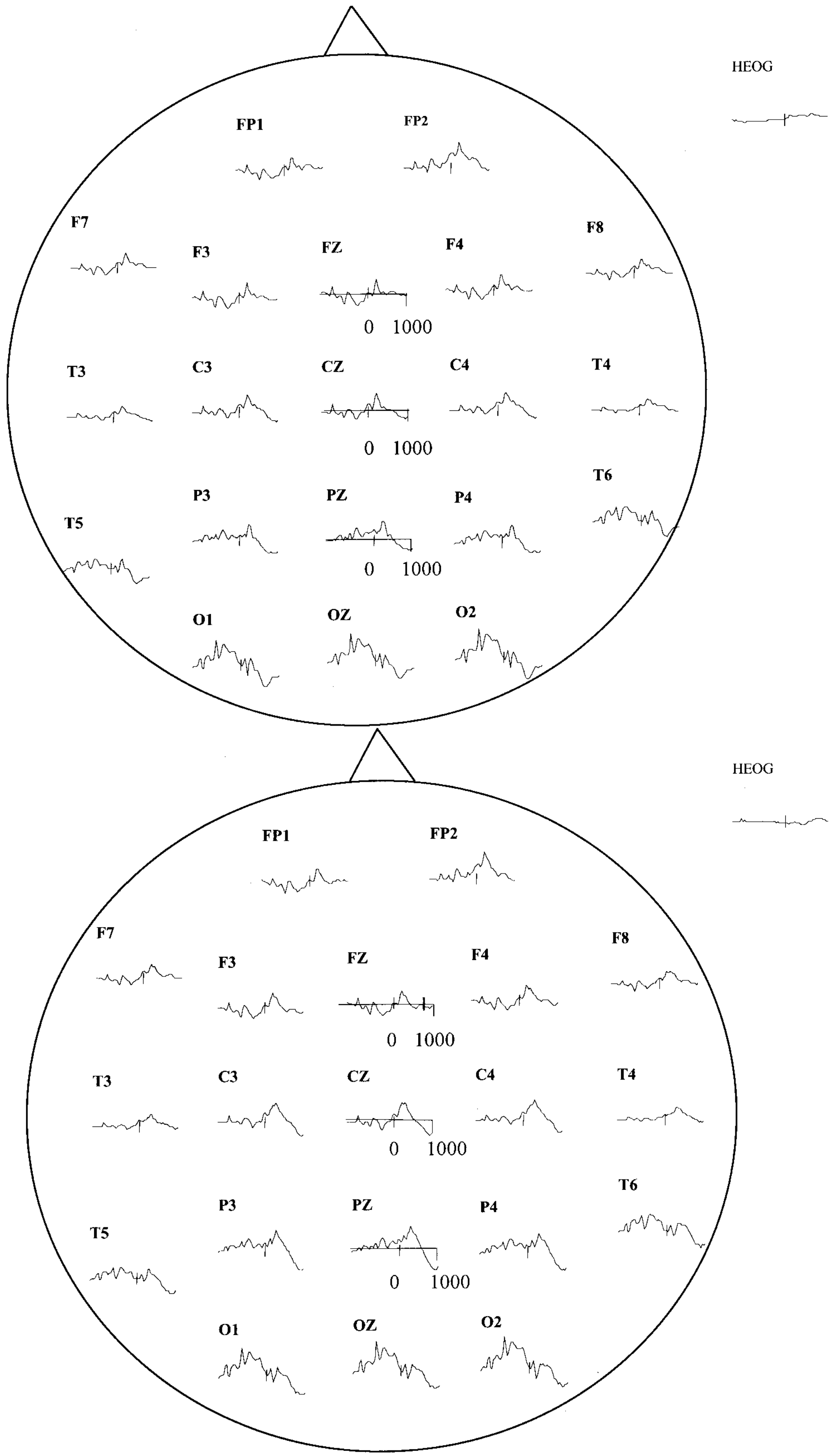


Figure 3. Waveform plots for all participants during valid (top) and invalid (bottom) trials. HEOG = horizontal electro-oculogram.

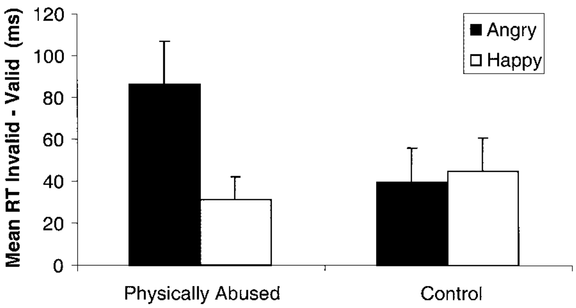


Figure 4. Increase in response latency for invalidly cued trials by group and emotion. Difference scores were calculated by subtracting reaction time (RT) on valid trials from reaction time on invalid trials; thus, this figure depicts the magnitude of the difference between valid and invalid trials in each condition.

tion $F(1, 12) = 6.07$, $p < .05$, $\omega_p^2 = .18$, whereas control children's difference scores were similar in the happy and angry condition, $F(1, 12) < 1$, *ns* (see Figure 4).

We analyzed P430 separately for valid and invalid trials. As expected, the Group × Emotion interaction was significant for invalid trials, $F(1, 23) = 8.30$, $p < .01$, $\omega_p^2 = .13$, but not for valid trials, $F(1, 23) = 1.63$, *ns*. These differences reflect that as predicted, the P430 amplitudes of physically abused children were larger than those of controls after invalid anger cues $F(1, 23) = 8.58$, $p < .01$, $\omega_p^2 = .23$, but not invalid happy cues, $F(1, 23) < 1$, *ns*. This effect is depicted in Figure 5. Further within-group analyses suggest differential effects of emotion cue on P430 amplitude across the midline electrodes for physically abused children but not control children. Physically abused children had larger P430 amplitude at Pz for angry trials as compared with happy trials, an effect that approached significance, $F(1, 12) = 3.96$, $p = .07$, $\omega_p^2 = .10$, whereas no such trend was apparent for control children, $F(1, 11) < 1$, *ns* (see Figure 6 for a topographic depiction and Figures 7 and 8 for difference waveforms).

Effects of Physical Abuse on Encoding of Facial Cues

To examine physically abused children's encoding of facial emotions, we first measured ERP components associated with face processing before the presentation of targets. Next, we measured children's recognition memory for the facial stimuli used in the experiment.

Two ERP components were elicited by facial stimuli. The first component, P1, peaked at 122 ms poststimulus and was greater at occipital as opposed to temporal or parietal sites, $F(2, 42) = 71.22$, $p < .01$ (see Table 4). Latency of P1 to faces was not modulated by emotion, maltreatment group, or side of presentation. A signif-

Table 3
Target-Evoked-Component Amplitude in μVs by Electrode Site and Condition

	Valid				Invalid			
	Angry		Happy		Angry		Happy	
Electrode site	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
P100								
Oz								
Physically abused	5.63	5.69	5.36	4.53	4.05	8.64	4.48	6.13
Comparison	3.54	3.36	4.21	3.51	−.60	4.90	2.91	4.64
O1								
Physically abused	5.20	7.11	4.04	4.59	2.67	9.07	3.04	7.12
Comparison	4.74	4.09	3.44	3.93	2.48	6.45	1.18	5.14
O2								
Physically abused	6.30	5.59	5.79	4.71	3.59	12.27	3.51	9.06
Comparison	2.69	4.09	3.44	3.93	−4.77	4.29	−.04	4.67
T5								
Physically abused	2.92	4.99	2.89	3.32	6.30	4.71	5.37	5.54
Comparison	3.02	3.31	2.35	4.08	1.61	3.25	1.07	4.25
T6								
Physically abused	4.50	3.66	2.95	3.47	4.58	9.43	5.37	5.54
Comparison	2.72	3.56	3.45	3.11	−.84	4.15	−.47	5.54
P430								
Fz								
Physically abused	8.78	6.04	8.13	6.54	9.27	8.14	6.55	5.44
Comparison	5.75	7.18	6.19	5.80	5.66	5.91	6.17	8.62
Cz								
Physically abused	10.07	4.84	8.28	5.81	14.35	7.79	9.90	5.29
Comparison	8.72	8.26	9.53	6.37	8.99	7.84	10.70	7.09
Pz								
Physically abused	8.32	3.98	6.68	3.84	17.03	6.17	13.89	5.77
Comparison	7.28	7.55	7.69	5.74	9.14	7.28	12.16	6.80

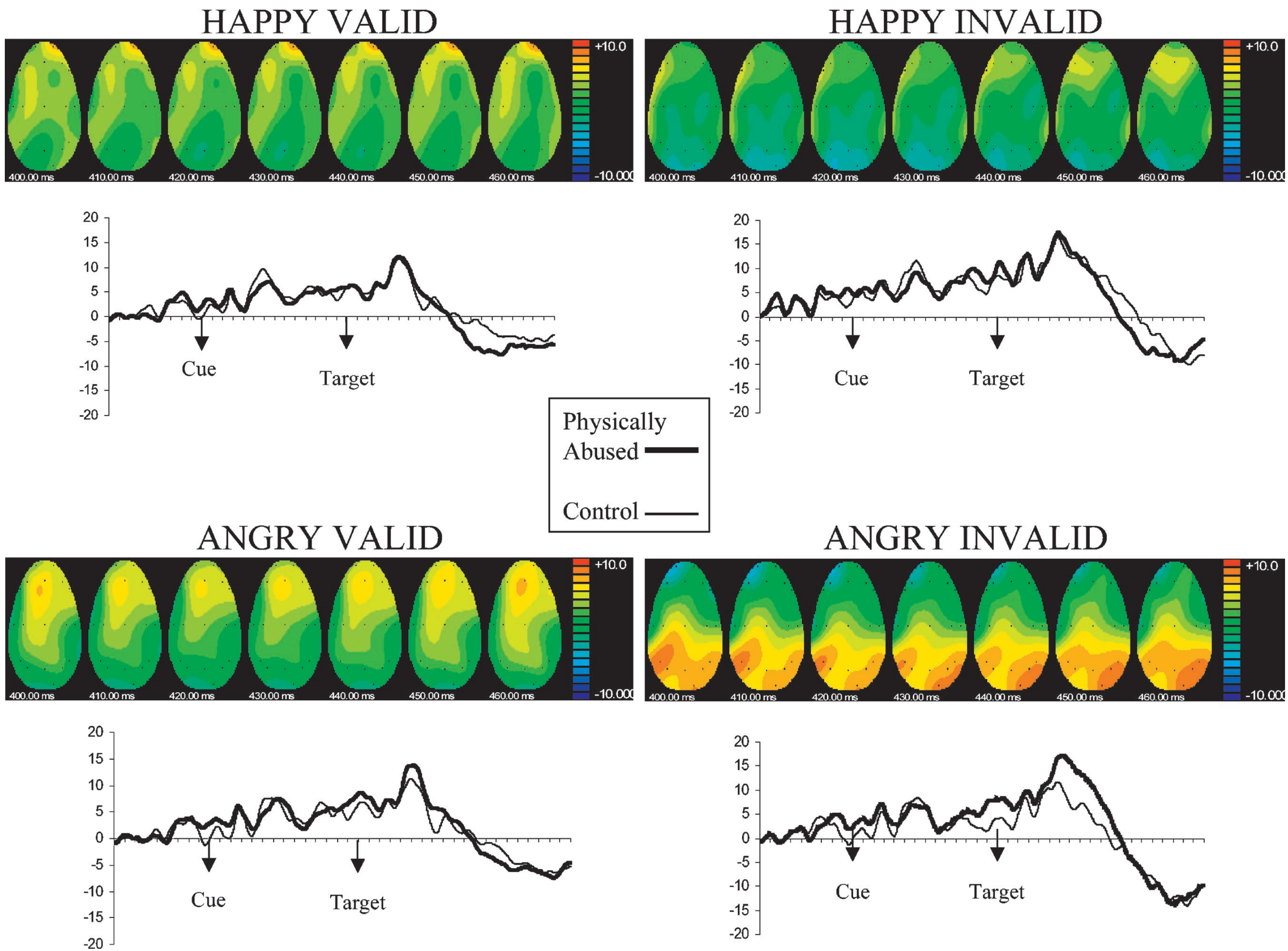


Figure 5. Grand average waveforms derived from the parietal (PZ) electrode site by condition and group. Topographic maps from 400 ms to 460 ms indicate the magnitude of voltage differences as a function of emotion and validity, reflecting the average event-related potentials (ERPs) of the physically abused minus the average ERPs of the control children.

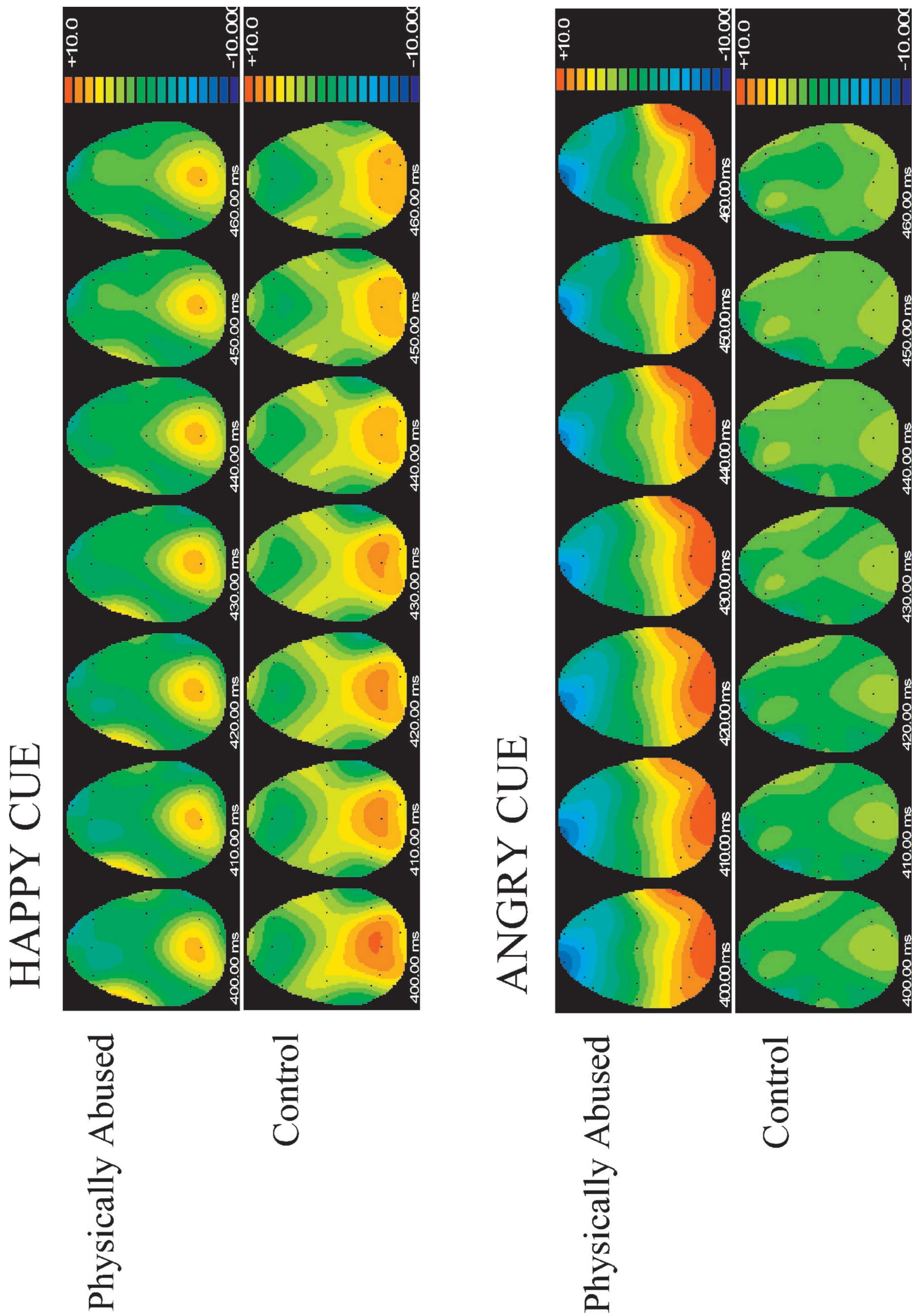


Figure 6. Topographic map showing within-group event-related potential differences for invalid – valid trials by maltreatment group and emotion.

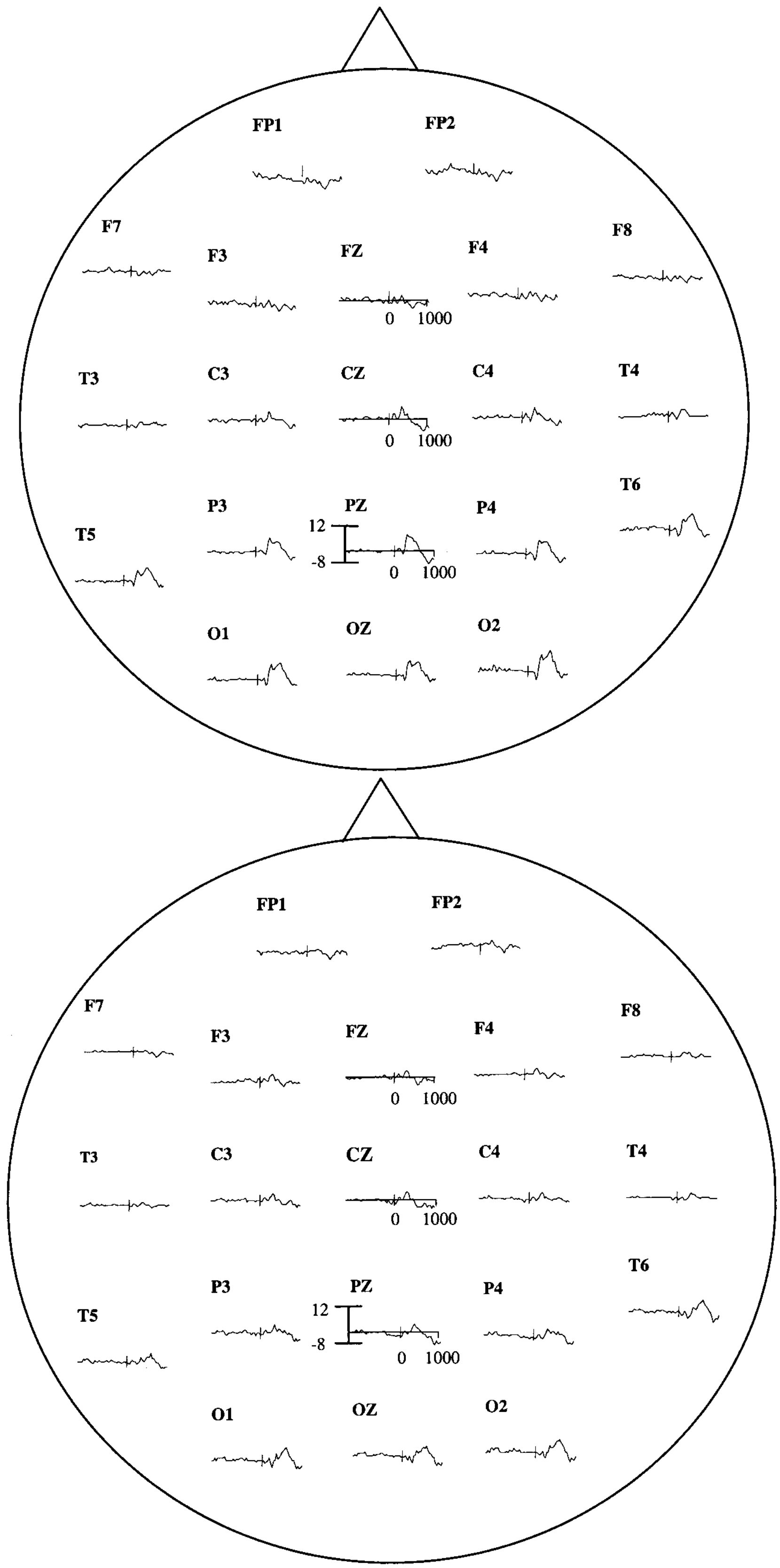
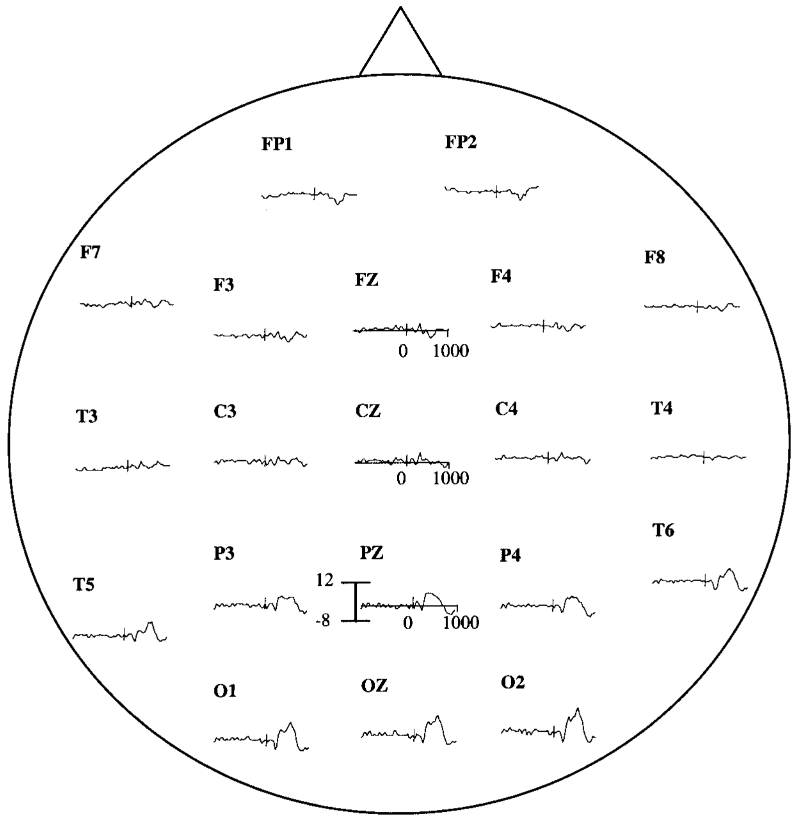


Figure 7. Difference waveforms (invalid – valid) for the angry conditions for physically abused (top) and control (bottom) children.



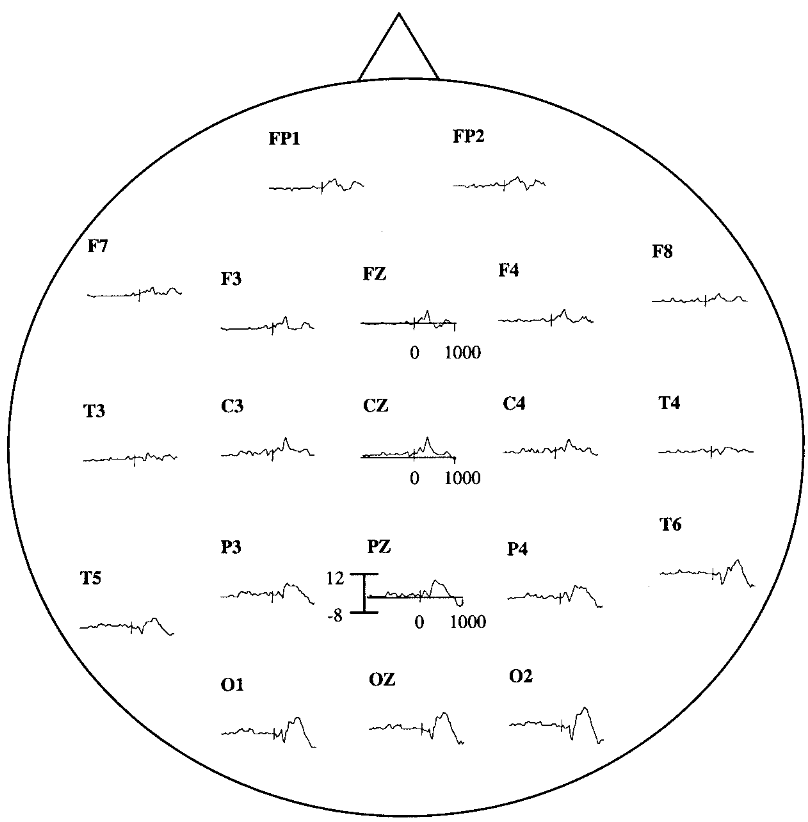


Figure 8. Difference waveforms (invalid – valid) for the happy conditions for physically abused (top) and control (bottom) children.

Table 4
Cue-Evoked-Component Amplitude in μVs by Electrode Site and Condition

	Angry				Happy			
	Left		Right		Left		Right	
Electrode site	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
P100								
Oz								
Physically abused	17.31	7.33	15.98	5.33	14.01	6.13	14.77	4.34
Comparison	14.49	6.17	17.20	6.62	16.78	5.77	16.16	6.78
O1								
Physically abused	16.04	6.42	16.13	4.90	13.75	6.39	14.92	7.12
Comparison	13.55	6.41	17.36	5.65	15.91	5.62	15.62	5.14
O2								
Physically abused	18.51	7.70	17.14	6.75	15.54	8.53	14.04	6.41
Comparison	15.57	7.01	16.05	7.25	18.00	6.25	15.29	7.47
T5								
Physically abused	8.24	5.06	8.41	4.48	6.93	3.57	7.78	3.56
Comparison	6.31	3.47	6.61	3.35	6.55	3.74	6.20	3.58
T6								
Physically abused	11.63	5.31	9.96	3.23	8.71	5.32	7.80	4.10
Comparison	8.43	6.86	7.91	6.88	8.31	5.42	7.11	6.76

icant Emotion × Side × Group interaction for P1 amplitude, $F(1, 24) = 4.62$, $p < .05$, reflects that averaging across occipital electrodes, physically abused children showed larger P1s for angry faces on the left ($M = 17.31$, $SE = 1.88$) than did controls ($M = 14.80$, $SE = 1.90$); groups did not differ for angry faces on the right and had equivalent P1 amplitudes for happy faces. P1 was followed by a negative wave, which peaked at approximately 180 ms poststimulus and was largest at temporal sites. This N170 was larger for faces appearing in the left hemispace, reflected by larger amplitude on the right side (T6, O2) than on the left side (T5, O1) of the head, $F(4, 20) = 3.91$, $p < .05$. There were no significant effects of emotion or maltreatment status on N170 amplitude or latency; however, a marginally significant interaction of Group × Emotion on N170 amplitude was obtained for faces on the left. Follow-up tests, conducted separately for each group, revealed that control children produced larger N170s for angry faces on the left than for happy faces on the left, $F(1, 9) = 4.19$, $p = .06$. Physically abused children's N170s were similar for angry and happy faces on the left, $F(1, 10) < 1$, *ns*.

To evaluate children's recognition memory, we calculated signal-detection statistics d' and C. Sensitivity, or d', indexes the participant's ability to discriminate between previously viewed and novel items. C is an index of response bias, which gauges the participant's internal standard for classifying stimuli as familiar, independent of changes in discriminability across items (Snodgrass & Corwin, 1988). Lack of a response bias would be reflected in a C value of 0. A conservative standard for evaluating stimulus familiarity yields positive C value, and a liberal standard yields a negative C value. As shown in Table 5, physically abused children were less sensitive than control children in discriminating between familiar and novel happy faces, $F(1, 22) = 4.80$, $p < .05$, $\omega_p^2 = .13$. However, the groups did not differ with respect to response bias for happy faces $F(1, 22) = < 1$, *ns*.

Discussion

To investigate physically abused children's attention to facial emotion cues, we adapted a well-validated visual selective attention paradigm to include an affective component. The central hypothesis tested in the present study was that physically abused children would have difficulties disengaging attention from angry facial cues. Psychophysiological data conformed to our prediction, with abused children demonstrating a selective increase in P3b on invalid angry trials, reflecting increased resources required to disengage from the previously cued location. In contrast, motor RTs on invalid angry trials were not slowed relative to invalid happy trials. Additionally, faster RTs in the angry condition are

Table 5
Recognition Memory for Faces

	Happy		Angry	
Variable	*M*	*SD*	*M*	*SD*
Hits (%)				
Control	85	9	82	18
Physically abused	72	20	83	11
FA (%)				
Control	25	24	20	18
Physically abused	26	17	17	12
d'				
Control	3.20	1.47	3.10	1.50
Physically abused	1.99	1.63	3.11	1.12*
C				
Control	0.18	.45	0.10	.56
Physically abused	0.08	.54	0.13	.53

Note. Hits = correct recognition; FA = false alarm; d' = sensitivity; C = response bias.
* $p < .05$.

consistent with the view that physically abused children orient rapidly to locations primed by anger.

Effects of Physical Abuse on Emotion Processing

Physically abused children were expected to devote relatively more processing resources disengaging attention from angry, but not happy, cues. In keeping with our prediction, abused children's P430s were larger than those of control children for invalid trials in the angry condition, but not in the happy condition. That groups did not differ in ERP activity on invalid happy trials is consistent with the hypothesis that physically abused children have a specific, or differential, deficit involving attentional processing of anger. Importantly, there were no group differences in target-evoked ERP activity associated with valid angry trials, which, although they still require the child to engage and process an angry face, do not require disengagement of attention.

Although we expected that physically abused children would respond more slowly to targets after invalid angry cues, this prediction was not confirmed. Priming a location with a valid angry cue resulted in a facilitory effect for the attended location: Abused children responded more rapidly on valid angry trials than valid happy trials, with no decrement in accuracy (i.e., no speed–accuracy trade-off). In fact, abused children's responses were faster on valid trials in the angry condition than control children's responses on either happy or angry valid trials. The presence of angry cues may lower children's thresholds for initiating motor responses. If this is the case, then comparing mean RT on invalid trials across the two conditions would not be a particularly sensitive index of relative differences in disengagement time. Future studies might address this issue by including uncued trials to test this proposal. (Although uncued trials may introduce a different confound—that of surprise or unanticipated stimuli). Nonetheless, the facilitory effect we observed, combined with enhanced P1 responses to angry faces, is consistent with behavioral studies highlighting the salience of anger for physically abused children, even when they receive minimal perceptual input (Pollak & Kistler, 2002; Pollak & Sinha, 2002; Pollak et al., 2000), as well as the arousing aspects of aggression-related stimuli for abused children (Cummings, Hennessy, Rabideau, & Cicchetti, 1994; Hennessy, Rabideau, Cicchetti, & Cummings, 1994).

Measurement of Selective Attention

The present study also introduces a novel methodology in that an affective processing component was integrated to a well-validated spatial cueing task. The use of complex facial cues did not impact the robust validity effects typically observed on this type of task. In fact, affectively valenced cues may even elicit stronger attentional engagement (Fox et al., 2002; see also Posner, Rafal, Choate, & Vaughn, 1985). The present task also required children to respond via two, rather than one, buttons. We elected to use a two-button response to limit the number of trials lost to premature responding and also to reduce the likelihood that changes in response latencies would result from participants' decreasing their response threshold (Mangun, 1995). The use of multiple response buttons does not appear to undermine the attentional effects elicited by this type of task (Mangun, 1995; Perechet & Garcia-Larrea, 2000; Posner et al., 1980). Finally, we required that children withhold responses on certain trials. This was done to make emotion discrimination task relevant, thus minimizing age-related differences in ability to inhibit task-irrelevant information and to ensure that children were motivated to attend to the facial expressions. Both groups of children performed this go/no-go task comparably; however, below we consider the possibility that this additional demand on executive functions may have affected children's performance. Most important, these modifications allowed us to examine children's attention to emotional cues while still yielding comparable effects on reaction time, ERP indices, and error rates as have been reported with this paradigm using standard cueing paradigms. First, in keeping with findings from more standard variants of this paradigm, valid cues resulted in increased P1 amplitude and decreased RTs, a robust finding in the spatial cueing literature, thought to reflect early effects of selective attention in gating incoming sensory information (Mangun, 1995; Novak et al., 1995; Perechet & Garcia-Larrea, 2000).[2] Second, we expected that all children would respond faster to valid as compared with invalid cues. The average difference score (mean RT invalid – mean RT valid) of approximately 40 ms observed in our nonmaltreated sample closely parallels that obtained in other studies with children using similar paradigms (Brodeur et al., 1997; Novak et al., 1995; Perechet & Garcia-Larrea, 2000). Third, invalid cues resulted in increased amplitude of a late positive complex, with timing and topography consistent with P3b. At least one other study with children also observed consistent increases in P3b amplitude after invalid trials (Novak et al., 1995), and the authors reached a similar interpretation concerning functional significance of P3b modulation. Finally, children's recognition memory performance provided ancillary support that participants did indeed process the affective cues.

Limitations

Three issues emerged from the present study that should be followed up in future research. First, it is not possible to gauge how much of the anger effect evident in abused children's behavioral performance is attributable to faster responses on valid versus slower responses on invalid trials because we did not include uncued trials. We made this decision because uncued trials may introduce other confounds (such as surprise) and thus may not be a valid index of a baseline responding (Jonides & Mack, 1984). A second issue is that the long stimulus-onset asynchrony necessary to record ERPs to both faces and targets may have decreased the sensitivity of the behavioral indices to slight changes in disengagement; future studies could address this by incorporating a shorter stimulus-onset asynchrony (and perhaps forgoing recording of

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[2] Our P1 validity effect appeared at ipsilateral as opposed to contralateral scalp sites. This difference from most other reports may be attributable to the use of a peripheral, as opposed to a central, symbolic cue to direct attention. The P1 validity effect may be less robust when peripheral cues are used, perhaps because of a form of sensory overload in visual processing areas (e.g., Eimer, 1994). Alternatively, an earlier contralateral and a slightly later ipsilateral peak are sometimes reported in the adult spatial selective attention literature (Mangun, 1995). Our measures may have been more sensitive to a later ipsilateral peak because of variability in the offset between face-evoked and onset of target-evoked peaks across children or variation in intrahemispheric transfer time among young participants.

ERPs to facial cues). Third, although our goal was to isolate specific aspects of attentional subprocesses influenced by maltreatment, the experimental task clearly involves multiple cognitive operations, including executive functions required for emotion discrimination. Although the data are consistent with the view that abused children have difficulty disengaging from angry faces, this difficulty may be enhanced by the taxing of executive functions. Indeed, when frontally mediated executive functions are taxed, it may be more difficult for the anterior attention system to send a signal to the posterior attention system that voluntary suppresses engagement or directly activates the disengagement. It would be possible to test this prediction with a within-subjects design that incorporated a high-demand and a low-demand condition.

Conclusion

The present data are consistent with the proposal that physically abused children do not experience global disturbances in attention; rather, threat cues affect the flexibility and control of these children's selective attention. In keeping with this view, poorly modulated attentional control in response to anger-related cues could contribute to observed social–cognitive biases in maltreated children (Dodge et al., 1990, 1997; Rieder & Cicchetti, 1989). Furthermore, the present data suggest that previous reports of differential processing for angry faces by maltreated children (Pollak et al., 1997, 2001) may be more specifically tied to both enhanced processing of anger and reduced processing of happy cues among physically abused children. Replication and extension of this work are clearly necessary to explore the parameters under which attentional problems are observed and to explore possible contributions of child age, gender, and clinical status. At present, it appears that difficulty controlling attention when processing threatening interpersonal signals may make it difficult for abused children to accurately perceive and regulate emotions in social contexts. This may constitute a developmental mechanism conferring risk for psychopathology.

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