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Physical Abuse Amplifies Attention to Threat and Increases Anxiety in Children

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Two experiments using event-related potentials (ERPs) examined the extent to which early traumatic experiences affect children's ability to regulate voluntary and involuntary attention to threat. The authors presented physically abused and nonabused comparison children with conflicting auditory and visual emotion cues, posed by children's mothers or a stranger, to examine the effect of emotion, modality, and poser familiarity on attention regulation. Relative to controls, abused children overattended to task-relevant visual and auditory anger cues. They also attended more to task-irrelevant auditory anger cues. Furthermore, the degree of attention allocated to threat statistically mediated the relationship between physical abuse and child-reported anxiety. These findings indicate that extreme emotional experiences may promote vulnerability for anxiety by influencing the development of attention regulation abilities.

Keywords: ERP, attention regulation, emotion, anxiety, physical abuse

The phenomenon of early trauma in the form of child abuse has begun to take center stage in considerations of the relative contributions of nature and nurture to the ontogenesis of emotion. The past decade has seen an increase in efforts to understand the neurobiological correlates of maltreatment and the developmental mechanisms linking children's early emotional environments to aspects of brain development (e.g., De Bellis, Hooper, Sapia, Vasterling, & Brewin, 2005). All forms of child abuse (neglect, sexual, emotional, and physical abuse) have been associated with detrimental child outcomes. Here, we focus on the developmental consequences of physical abuse as a forum for understanding the effects of exposure to an emotional environment where signals of anger are likely to be especially salient and may be associated with the potential for physical threat or harm directed at the child.

Recent approaches to understanding the association between child abuse and the development of psychopathology have emphasized the neuroplasticity of perceptual and attentional systems (Pollak, 2003). According to this view, developmental limits on information-processing capacity may lead children in threatening environments to disproportionately attend to some cues over others. Consistent with this view, relative to nonabused peers, physically abused children have been shown to develop broader perceptual boundaries for categorizing anger (Pollak & Kistler, 2002), accurately identify angry facial expressions using sparse perceptual information (Pollak & Sinha, 2002), devote more attentional resources to the processing of angry faces (Pollak, Cicchetti, Klorman, & Brumaghim, 1997; Pollak, Klorman, Thatcher, & Cicchetti, 2001), and have greater difficulty disengaging attention from angry faces (Pollak & Tolley-Schell, 2003). Collectively, these data suggest that abused children are not passive recipients of abuse but instead develop a greater sensitivity to facial expressions of anger as a form of adaptation to an environment in which threat signals may predict the occurrence of abuse. Given these attentional effects and the prevalence of anxiety-related problems in abused children (Cohen, Brown, & Smailes, 2001), we examined the link between children's experiences, emotion processing, and symptoms of anxiety (Gotlib, MacLeod, Burack, & Enns, 1997; Lonigan, Vasey, Phillips, & Hazen, 2004).

It is unclear whether abused children learn to control and voluntarily deploy their attention to signs of potential threat or, alternatively, whether children's processing of threatening information is relatively involuntary.[1] These two general types of processing are not mutually exclusive, and both promote healthy self-regulation. Voluntary allocation of attention toward or away from certain environmental cues is a mechanism that allows children to effectively regulate emotional states (Posner & Rothbart, 1998; Rothbart, Ellis, Rueda, & Posner, 2003). In contrast, the

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[1] Our intent here is simply to contrast differences in children's processing of stimuli to which they explicitly attend versus ignore and not to resolve ongoing debates about the ways in which attentional processes have been parsed, such as voluntary/involuntary, endogenous/exogenous, automatic/controlled, and so forth (Berger, Henik, & Rafal, 2005; Posner & Petersen, 1990). Therefore, we use the terms *voluntary* and *involuntary* throughout merely as notational shorthand for children's processing of information to which they were instructed to attend versus information that was irrelevant to the task.

adaptive nature of involuntary attention allocation lies in its ability to quickly alert an organism to a possible danger or other significant event (Sussman, Winkler, & Schröger, 2003). However, lack of flexibility or excessive biases in attentional processing has been associated with a variety of psychological difficulties, including anxiety-related (Mathews & MacLeod, 2002; Monk et al., 2004; Sussman et al., 2003) and aggressive disorders (Dodge, Pettit, Bates, & Valente, 1995).

To specify the ways in which early trauma affects both voluntary and involuntary attention, we manipulated the task relevance of conflicting affective cues and used event-related potentials (ERPs) to measure children's cognitive processing. ERPs, which are scalp-derived changes in brain activity over time, are a noninvasive method that is well suited for studying the neural mechanisms underlying emotion processing in clinical populations of children. Additionally, ERPs allow for the precise temporal measurement of earlier aspects of cognitive processing, which cannot be revealed through techniques such as functional MRI. Of relevance to the present study, the P3b component of the ERP is a positive deflection that is maximal over the central-parietal region of the scalp. This component is thought to reflect processes involved in attentional resource allocation (Isreal, Chesney, Wickens, & Donchin, 1980), difficulty of stimulus categorization and evaluation (Fabiani, Gratton, & Coles, 2000), and the updating of environmental context in working memory (Donchin & Coles, 1988); and its amplitude varies as a function of such factors as emotional salience (Keil et al., 2002; Miltner et al., 2005), stimulus probability, and stimulus relevance (Fabiani et al., 2000). Because it is modulated by task relevance, P3b was used to index children's voluntary processing of emotional cues.

Also of interest in the present study is the N2, a fronto-central ERP associated with cognitive inhibition process needed to suppress an incorrect tendency to respond (Nieuwenhuis, Yeung, van den Wildenberg, & Ridderinkhof, 2003). N2 emerges in paradigms that induce response conflict and the need for cognitive control, such as Stroop (Simon-Thomas, Role, & Knight, 2005), Flanker (Bartholow et al., 2005) and go/no-go tasks (Lamm, Zelazo, & Lewis, 2006). A key feature of tasks that elicit an N2 is that the stimuli contain irrelevant and potentially distracting information that is sometimes associated with an alternative but incorrect response. For example, in Flanker tasks, factors that increase the processing of flanker stimuli tend to result in increased N2 amplitude, because they increase interference from irrelevant information (Yeung & Cohen, 2006). Thus, the amplitude of the N2 component in the present study was expected to vary to the extent that task-irrelevant emotional information led to processing conflict, as well as the need to exert cognitive control, and was used to index children's involuntary processing of emotion cues. Depending on the paradigm, peak latencies for the N2 have varied from 200 to 450 ms poststimulus in adults and children (Bartholow et al., 2005; Curtin & Fairchild, 2003; Jonkman et al., 1999; Liotti, Woldorff, Perez, & Mayberg, 2000).

The present experiments allowed us (a) to examine abused children's neural and behavioral responses to information to which they were instructed to attend and (b) to contrast that with their responses to task-irrelevant background emotional information. We also examined a number of ancillary issues that have implications for understanding the nature of children's processing of emotional information: familiarity, sensory modality, and affective responses to stimuli. The first issue concerns the role of children's familiarity with the individual conveying the emotion. Although most extant research on emotion perception relies upon standardized sets of adult faces, participants show poorer selective attention when confronted with familiar, compared with unfamiliar, faces (Ganel & Goshen-Gottstein, 2004). Additionally, abused children appear more likely than nonabused children to label ambiguous emotional expressions as "angry" when the expressions are produced by their own mother rather than by a stranger (Shackman & Pollak, 2005). Therefore, to test the effects of familiarity, we contrasted children's responses to emotions conveyed by their own mothers with their responses to emotions conveyed by mothers of other children in the experiment, who were unfamiliar to each child being tested.

A second issue concerns children's responses to auditory versus visual emotional information. Auditory information, even when task irrelevant, has the ability to interfere with visual processing: Participants appear to monitor task-irrelevant auditory tones during visual task performance (Escera, Yago, Corral, Corbera, & Nunez, 2003) and also involuntarily allocate attention toward change in the acoustic environment (Escera, Corral, & Yago, 2002). Similarly, children have difficulty inhibiting the processing of salient but task-irrelevant information, as reflected by increased ERP responses to distracting sounds (Gumenyuk, Korzyukov, Alho, Escera, & Naatanen, 2004). However, little is known regarding the effect of salient visual cues on the processing of auditory stimuli.

Third, we examined whether children's physiological reactivity to emotional stimuli was related to their attentional control. This was motivated by a recent finding that physically abused children showed an increase in tonic skin conductance levels (SCLs) when overhearing anger cues, indicating poor arousal regulation when presented with this task-irrelevant information (Pollak, Vardi, Bechner, & Curtin, 2005). Skin conductance responses (SCRs) are useful for measuring changes in electrodermal activity in response to discrete stimuli and are thought to reflect affective arousal and orienting (Dawson, Schell, & Filion, 2000). Such a measure of physiological reactivity may help us understand the role that abused children's arousal in response to anger plays in their ability to regulate attention.

In summary, in these two experiments, we used ERPs to index online neural processing of discrete emotional stimuli. In Experiment 1, we examined how children responded when they were instructed to attend to visual affective information and ignore auditory affective information. In Experiment 2, we measured how children responded when they were instructed to attend to affective auditory information and ignore affective visual information. We predicted that abused children would show enhanced voluntary processing of angry cues in both modalities, manifested as increased P3b amplitudes. Additionally, we predicted that abused children would involuntarily attend to task-irrelevant anger cues, indicated by an enhanced N2 component of the ERP, and would show more evidence of behavioral distraction relative to controls. We also predicted that both voluntary and involuntary processing of anger would be enhanced when children's own mothers expressed emotions, that abused children would show enhanced affective arousal in response to anger cues, and we undertook exploratory analyses to examine the degree to which these measures of attentional processing helped clarify the association between children's experiences of abuse and the emergence of anxiety.

Experiment 1

In Experiment 1, we examined children's processing of emotion when their attention was directed to facial expressions of emotion. Vocal expressions of emotion served as task-irrelevant distractors, which children were instructed to ignore.

Method

Participants

Thirty children (16 physically abused, 14 nonabused) participated in this experiment. Physically abused children and their families were recruited by letters forwarded by the Department of Human Services in Dane County, WI, to families with substantiated cases of physical maltreatment. Among the sample of abused children, mothers were verified as the abusive parent in all cases. We recruited nonabused children by posting fliers in the same neighborhoods from which physically abused children were drawn. Parents completed the Parent–Child Conflict Tactics Scale (PC-CTS; Straus, Hamby, Finkelhor, Moore, & Runyan, 1998), a 20-item measure of the frequency with which a parent has carried out specific acts of physical aggression toward the child. To qualify as controls in the present study, children were required to have scores below 10 on the PC-CTS. Children whose parents scored at least 20 on the PC-CTS and/or had substantiated cases of physical abuse on record with the Dane County Department of Human Services were classified as abused. As shown in Table 1, abused and control children had similar psychodemographic characteristics. All children had normal or corrected-to-normal vision. Just before testing, we assessed children's hearing following the guidelines of the American Speech–Language–Hearing Association. Children's anxiety was measured with the Revised Children's Manifest Anxiety Scale (Reynolds & Richmond, 1978). Internal consistency for this measure has been reported at .83, and test–retest reliability is between .60 and .88 (Reynolds & Richmond, 1978). We chose to rely primarily on child report instruments for anxiety because parents tend to be relatively poor at reporting accurately on their child's internalizing symptoms before adolescence, and it was unclear whether abusive parents would be reliable reporters of their children's emotional states (Choudhury, Pimentel, & Kendall, 2003; Safford, Kendall, Flannery-Schroeder, Webb, & Sommer, 2005).

Stimuli

Facial and vocal stimuli were created individually for each child. Each child's mother was asked to pose facial and vocal expressions of anger, happiness, and sadness. To facilitate this process, we asked mothers to recall a memory or imagine a situation that would help them to accurately express the desired emotion on their faces and through their voices, and they were given the opportunity to practice their emotional expressions using a mirror. Facial images were captured using a Sony Mavica digital camera (MVC-CD400). Next, mothers read five semantically neutral two-word sentences using happy, sad, and angry vocal tones. Vocal stimuli consisted of semantically neutral two-word utterances (e.g., "They left," "He's back," "I'm home"), and they were recorded with a Sony MiniDisc recorder (MZ-N1) and edited with Cool-Edit software to equalize the volume and length of each utterance (approximately 700 ms). Mothers reviewed both the photographs and vocal recordings and, along with the experimenter, selected the exemplars they felt best depicted their targeted emotional state. Digital photographs were edited with Adobe Photoshop so that each facial stimulus was similar in size, contrast, and luminance.

Because we utilized nonstandardized facial and vocal stimuli in the interest of examining children's processing of familiar facial expressions, we examined potential differences in mothers' emotion posing abilities. To do so, we asked 140 undergraduate students (88 female, 52 male) to rate each facial and vocal expression produced by each mother on the basis of its prototypicality. A 10-point scale was used, with 0 *indicating a poor expression* and 9 *indicating an excellent expression.* Before evaluating the facial expressions, raters were presented briefly with all of the stimulus items. Raters viewed two presentations of each face and then heard each of the five vocal samples, grouped by emotion.

Procedure

Children were tested individually in a sound-attenuated room, at a distance of 1 m from the computer screen. Facial images were presented on a 19-in. (47-cm) Viewsonic monitor, and auditory stimuli were presented through insert earphones. Behavioral re-

Table 1
Means ± Standard Errors for Sociodemographic Characteristics of Samples for Experiments 1 and 2

	Experiment 1			Experiment 2		
Characteristic	Control	Abused children	Statistical test	Control	Abused children	Statistical test
% Boys	57%	44%	$\chi^2(1) = 0.54$, *ns*	50%	36%	$\chi^2(1) = 0.58$, *ns*
Age in years (range = 7–12)	9.54 ± 1.85	9.81 ± 1.85	$t(28) < 1$, *ns*	9.51 ± 2.00	9.42 ± 1.87	$t(26) < 1$, *ns*
SES[a] (range = 20–53)	37.07 ± 2.92	34.88 ± 10.31	$t(28) < 1$, *ns*	39.36 ± 7.75	35.32 ± 9.89	$t(26) = 1.20$, *ns*
Race (% Caucasian)	64%	38%	$\chi^2(1) = 2.14$, *ns*	71%	50%	$\chi^2(1) = 1.35$, *ns*
PC-CTS Scores[b]	1.64 ± 2.44 (range = 0–8)	30.75 ± 22.50 (range = 1–77)	$t(28) = 5.14$, $p < .001$	3.21 ± 3.29	32.50 ± 22.31	$t(26) = 4.86$, $p < .001$

[a] The Four Factor Index of Social Status (Hollingshead, 1975) reflects family socioeconomic status on the basis of parent education and occupational status. [b] PC-CTS scores are taken from the Physical Abuse scale on the Parent-Child Conflict Tactics Scale and include items that reflect frequency and severity of corporal punishment techniques (Straus et al., 1998).

sponses were obtained from a two-button response box and detected with a resolution of approximately 2 ms. 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 $40 for their participation in the study.

Children then performed a modified oddball emotion recognition task involving elements of both stimulus categorization and response inhibition (for other examples of multimodal oddball tasks, see Andrés, Parmentier, & Escera, 2006; Brown, Clarke, & Barry, 2006; Isoglu-Alkaç, Kedzior, Karamürsel, & Ermutlu, 2007). On all blocks, children were instructed to attend to the facial expression of emotion (angry, happy, or sad) while ignoring the emotion in the voice. On any particular block, children were instructed to press a button when a designated infrequent *target* facial expression appeared (e.g., happy face) and to withhold responding when *nontarget* facial expressions (e.g., angry or sad faces) were presented. Four trial types were presented in each block and were created by crossing the two factors: target emotion presented in the attended modality (yes/no) and target emotion presented in unattended modality (yes/no). All target trials contained the target emotion presented in the attended modality and constituted 30% of all trials. Half the target trials were *congruent*, meaning the emotion expressed in the face and voice was identical, and half were *incongruent*, meaning that the target emotion only appeared in the face but not in the voice. Nontarget trials were of two types. *Distractor nontarget* trials contained the target emotion in the voice (unattended modality), but not in the face, and thus involved a degree of conflict, as children were required to withhold a response to the target emotion presented in the nontarget modality. *Nondistractor nontarget* trials did not contain the target emotion in either modality. Of all the nontarget trials, 33% were distractors. See Table 2 for a description of the experimental paradigm.

On any given trial, children heard and saw one of three individuals with equal probability: the child's own mother or one of two unfamiliar mothers (one abusive, one nonabusive). Familiar voices were always paired with familiar faces, and unfamiliar voices were always paired with unfamiliar faces. Unfamiliar (abusive and nonabusive) voices and faces were those of mothers of other children who participated in the study, matched to the race of each child participant.

Table 2
Design of Modified Oddball Task

Trial type	Target emotion: Anger	Happiness	Sadness
Target trials			
Congruent	AA	HH	SS
Incongruent	AH/AS	HA/HS	SA/SH
Nontarget trials			
Distractor	HA/SA	AH/SH	AS/HS
Nondistractor	HS/HH/SH/SS	AS/AA/SA/SS	HS/HH/AH/AA

Note. Children responded to trials when the target emotion was presented in the designated modality. This occurred infrequently on 30% of all trials. For Experiment 1, the first letter in each pair denotes the emotion presented visually, and the second letter in each pair denotes the emotion presented vocally (A = angry, H = happy, S = sad). For Experiment 2, the first letter denotes the emotion presented vocally, and the second letter denotes the emotion presented visually.

Children completed a short practice, during which they received verbal feedback, followed by two experimental blocks for each target emotion. Each block contained 195 trials presented in a quasi-random order. The order of the six blocks was counterbalanced between participants. Trials began with the simultaneous onset of an emotionally intoned sentence, lasting for approximately 700 ms (ranging from 638 to 759 ms), and an emotional facial expression presented in the center of the computer screen for 400 ms. Visual stimuli occluded an area of 500 $\times$ 650 pixels, with a screen resolution of 1024 $\times$ 768 pixels. Following face offset, a fixation cross appeared in the middle of the screen until the start of the next trial. The intertrial interval (ITI) between voice offset and the onset of the next face and voice varied between 1250 and 1750 ms, with an average ITI of 1500 ms. A schematic of the experimental task is presented in Figure 1.

Before performing the experimental task, children were asked to watch and listen as they were presented with congruent face–voice pairs while electrodermal activity (EDA) was continuously acquired. EDA is a direct measure of sympathetic activation, produced by eccrine sweat glands innervated solely by the sympathetic branch of the autonomic nervous system; it is therefore relatively free from parasympathetic influences. SCRs are phasic changes in EDA elicited in response to the presentation of discrete stimuli (Dawson et al., 2000). For the collection of EDA, each emotion (anger, happiness, sadness) expressed by each individual was presented three times in a quasi-random order, for a total of 27 trials. Faces and voices were presented for the same duration as described earlier, with an ITI of 10 s, to allow for SCRs to return to baseline between trials.

Electrophysiological recording. The electroencephalogram (EEG) was recorded 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, according to the International 10–20 system, and referenced online to linked earlobes. An electrode mounted on the cap between the frontal pole (Fpz) and the frontal site (Fz) served as the ground. Horizontal and vertical eye movements were detected through four channels of electrooculogram (EOG), recorded 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 bandpass from .01 to 100Hz, and EEG was sampled at 1000 Hz. Skin impedances at all electrode sites were maintained below 5 KΩ. EDA was recorded using Beckman Ag–AgCl cup electrodes, attached to the thenar and hypothenar eminences of the palm of the nondominant hand, and filled with a skin conductance gel (0.5% saline). A constant current of 0.5 A was applied across the electrodes. EDA was sampled with NeuroScan amplifiers at 1000 Hz. Electrodes were removed from children's hands before beginning the experimental task.

Behavioral performance scoring. The following were computed to measure performance on the selective attention task: (a) within-participant mean reaction time (in milliseconds), and standard deviation, for correct responses; (b) percentage of correct responses (hits) for each category of target stimulus; and (c) commission errors, measured separately for distractor and nontarget trials.

ERP and SCR scoring. EEG data were inspected visually, and any artifact related to gross motor movement and muscle tension was removed manually. EEG and EOG were then averaged offline for epochs of 1800 ms, beginning 200 ms before face/voice onset and ending 900 ms after offset of the auditory stimulus. All measures were taken relative to the mean voltage of the 200-ms baseline interval before face/voice onset. Trials with overt response errors or amplifier blocking were excluded from ERP analysis. EEG was then digitally low-pass filtered at 30 Hz and baseline corrected. Epochs with voltage in any of the channels exceeding 75 μV were automatically excluded. To eliminate ocular artifact on EEG, we adjusted EEG data for their regression on EOG, separately for blinks and other eye movements (Gratton, Coles, & Donchin, 1983). As a result, 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 target emotion (angry, happy, and sad), stimulus familiarity (own mother, unfamiliar nonabusive mother, and unfamiliar abusive mother), trial type (congruent target, incongruent target, distractor nontarget, and nontarget), and electrode site (Fz, Cz, and Pz), for trials eliciting correct responses. To score amplitude for ERP components, we used a computer algorithm to identify the average amplitude value within a time window based on the entire sample's average. The following ERP components were of primary interest: P3b elicited in response to target faces (maximal at Pz, 570–770 ms posttarget) and N2 elicited in response to distractor nontarget trials (maximal at Fz, 300–500 ms poststimulus). After eliminating trials with overt response errors or excessive movement, the mean percentage of trials retained for averaging was 92% for congruent targets (controls: $M = 92.7$, $SD = 2.9$; abused children: $M = 91.4$, $SD = 1.9$), 90% for incongruent targets (controls, $M = 90.6$, $SD = 3.1$; abused children, $M = 89.8$, $SD = 3.5$), 87% for distractors (controls, $M = 87.2$, $SD = 4.8$; abused children, $M = 87.6$, $SD = 4.1$), and 89% for nontarget trials (controls, $M = 89.2$, $SD = 4.7$; abused children, $M = 89.9$, $SD = 3.7$). Groups did not differ on percentage of trials eliminated because of excessive artifact; all $ps > .1$.

Electrodermal activity was low-pass filtered (30 Hz; 24 dB/octave) and baseline corrected. We obtained SCRs by identifying the maximum deflection, in microsiemens (μS), during a window occurring 1 to 5 s after stimulus onset. We performed a log transformation (log [SCR + 1]) to normalize the data (Bradley, Codispoti, Cuthbert, & Lang, 2001).

Results

Physiological and behavioral data were submitted to repeated measures analyses of variance (ANOVAs) using maltreatment status (physically abused, control) as a between-participants factor and target emotion (angry, happy, and sad), stimulus familiarity (own mother, unfamiliar nonabusive mother, and unfamiliar abusive mother), and trial type (congruent target, incongruent target, distractor nontarget, and nondistractor nontarget) as within-participant factors. Children's race, age, and gender were initially included in the analyses as between-participants variables; however, no significant main effects or interactions emerged, nor did including these factors alter the results. Therefore, these variables are not included in the analyses reported here. Additionally, across

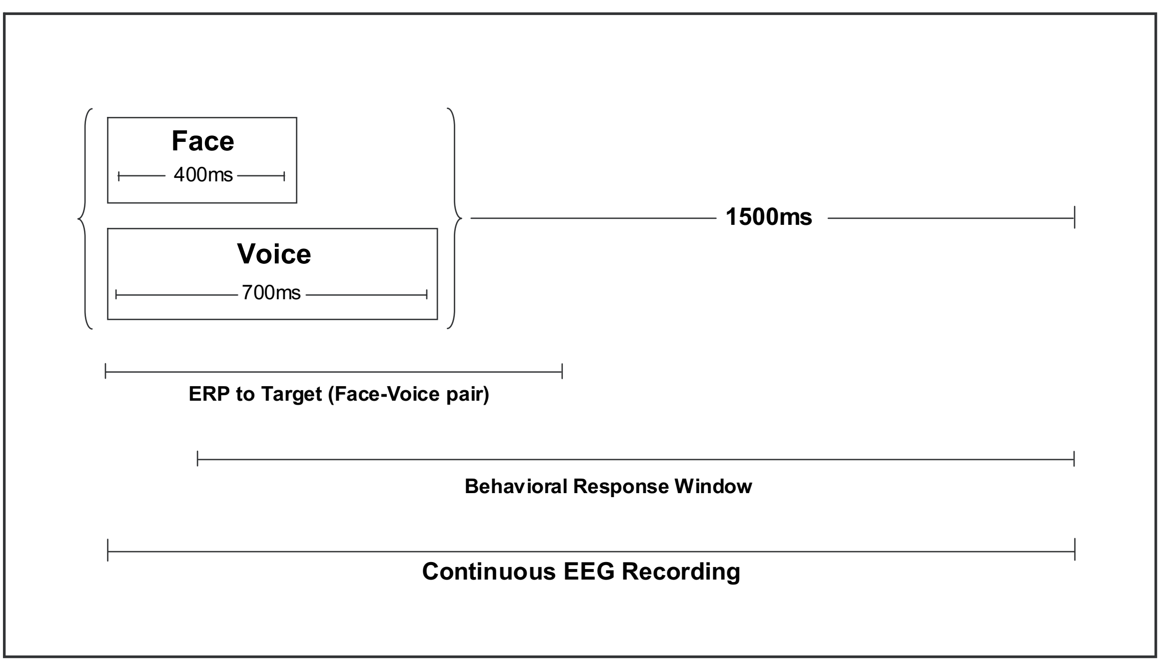

Figure 1. Illustration of experiment showing electroencephalogram (EEG) recording and behavioral response windows in relation to presentation of stimuli. All of these parameters were identical for Experiments 1 and 2. However, in Experiment 1, children were instructed to attend to the face while ignoring the voice, whereas in Experiment 2, children were instructed to attend to the voice and ignore the face. ERP = event-related potential.

all analyses, no differences in children's behavioral or electrophysiological responses were found between unfamiliar nonabusive and unfamiliar abusive mothers. Thus, these two categories were collapsed to create two levels of poser familiarity (own mother, unfamiliar mother) for all analyses reported herein. Probability values are reported with Greenhouse–Geisser corrections to offset violations of sphericity.

Data on children's performance are summarized in Table 3. As expected, children responded faster to congruent trials relative to incongruent trials, $F(1, 28) = 25.03$, $p < .001$; and were more accurate on congruent trials compared with incongruent trials, $F(1, 28) = 5.59$, $p < .05$. A main effect of emotion on reaction time revealed that both groups of children responded more quickly when the target emotion was happiness, compared with when the target emotion was anger or sadness, $F(1, 28) = 17.36$, $p < .001$; and more accurate on happy trials compared with angry and sad trials, $F(1, 28) = 10.07$, $p < .001$.

Voluntary Attentional Processing of Emotion

We first sought to test our prediction that abused children would show enhanced processing of angry facial cues. To do so, we examined the P3b component of the ERP. Overall, children showed the largest P3b amplitude to angry target faces ($M = 12.84$ μV, $SE = 0.81$), followed by sad faces ($M = 11.25$ μV, $SE = 1.43$) and happy faces ($M = 10.48$ μV, $SE = 1.17$), $F(2, 56) = 3.74$, $p < .05$. When examined separately, control children showed equivalent P3b amplitudes to angry ($M = 12.17$ μV, $SE = .86$), happy ($M = 10.82$ μV, $SE = 1.59$), and sad faces ($M = 12.26$ μV, $SE = 1.97$), $F(2, 26) < 1$, *ns*; but abused children exhibited larger P3b amplitudes to angry faces ($M = 13.51$ μV, $SE = 1.32$) compared with happy ($M = 10.15$ μV, $SE = 1.71$) and sad faces ($M = 10.23$ μV, $SE = 2.05$), $F(2, 30) = 7.25$, $p < .01$. Our next hypothesis, that abused children's processing of anger cues would be most pronounced when their abusive mothers were expressing emotion, hinged on a Group × Emotion × Familiarity interaction, which was significant, $F(2, 112) = 3.70$, $p < .05$. This effect reflects that the P3b amplitudes of abused children were larger, compared with those of controls, for trials on which these children responded to their own mother's angry face, $t(28) = 2.13$, $p < .05$; the groups' P3b amplitudes did not differ when responding to a stranger's angry face, $t(28) = 1.02$, *ns* (see Figure 2). Latency of P3b was not affected by trial type, emotion, or poser familiarity.

Involuntary Attentional Processing of Emotion

We next examined whether abused children were more distracted than controls on the trials containing task-irrelevant auditory anger. Children's commission errors revealed a Group × Emotion × Familiarity interaction, $F(2, 112) = 2.69$, $p < .05$. To test our a priori hypotheses, we examined angry trials separately. Abused children had no more difficulty inhibiting incorrect responses to angry distractor trials than did control children, $t(28) = 0.61$, *ns*. However, abused children made more errors in the presence of their mothers' vocal anger cues relative to unfamiliar vocal anger cues, $F(1, 30) = 4.61$, $p < .05$; whereas control children did not, $F(1, 26) = 1.80$, *ns*. No differences in error rates were observed for abused and control children on happy, $t(28) = 0.97$, *ns*; or sad distractor trials, $t(28) = 0.41$, *ns*.

To further investigate the neural processing of task-irrelevant emotion cues, we examined the N2 component of the ERP. N2 emerged approximately 400 ms poststimulus and was maximal at Fz ($M = -9.03$ μV, $SE = 0.62$ μV) relative to Cz ($M = -5.92$ μV, $SE = 0.79$ μV) and Pz ($M = 1.05$ μV, $SE = 0.98$ μV), $F(2, 56) = 120.7$, $p < .001$; thus the analyses reported here were performed only at Fz. No main effects or interactions emerged on the basis of familiarity, so subsequent analyses reflect effects collapsed across this variable. Because distractor trials contained the target emotion in the voice, whereas nontarget trials did not contain the target emotion, N2 was expected to occur only on distractor trials. A Group × Emotion × Trial Type interaction, $F(2, 56) = 5.35$, $p < .01$, revealed that abused children showed a larger N2 relative to controls only on angry distractor trials, $t(28) = 3.87$, $p < .001$ (see Figure 3); the groups did not differ on happy distractor trials, $t(28) = 1.64$, *ns*; or sad distractor trials, $t(28) = 0.53$, *ns*. We further confirmed that the N2 component reflected conflict processing by examining this component on nontarget trials that did not contain conflict (congruent). The amplitude of the N2 was significantly larger on distractor trials containing conflict relative to congruent nontarget trials across all emotions, $F(1, 28) = 6.55$, $p < .05$; and no group differences emerged in N2 amplitude for congruent trials, $ps > .2$. An analysis of ERP latency revealed that N2 emerged earlier for abused children ($M = 381$ ms, $SE = 17$ ms)

Table 3
Means ± Standard Errors for Behavioral Performance Measures for Experiment I

	Control children			Abused children		
Measure	Angry	Happy	Sad	Angry	Happy	Sad
Reaction time (in ms)						
Congruent	879 ± 52	743 ± 55	864 ± 56	910 ± 49	787 ± 51	888 ± 52
Incongruent	913 ± 62	737 ± 56	930 ± 60	946 ± 58	800 ± 52	918 ± 56
% Hits						
Congruent	86.5 ± 2.1	95.6 ± 2.2	81.9 ± 4.0	90.2 ± 1.9	92.7 ± 2.0	86.7 ± 3.7
Incongruent	87.4 ± 3.8	95.1 ± 3.5	77.3 ± 5.3	83.4 ± 3.6	88.5 ± 3.2	82.3 ± 4.9
% Commission errors						
Distractor nontargets	11.5 ± 4.2	3.9 ± 3.4	12.0 ± 3.2	16.5 ± 3.9	8.4 ± 3.1	12.2 ± 3.0
Nondistractor nontargets	7.7 ± 2.0	3.5 ± 2.0	12.2 ± 3.5	5.1 ± 1.8	4.3 ± 1.9	9.5 ± 3.3

Note. Column labels refer to the target emotion block.

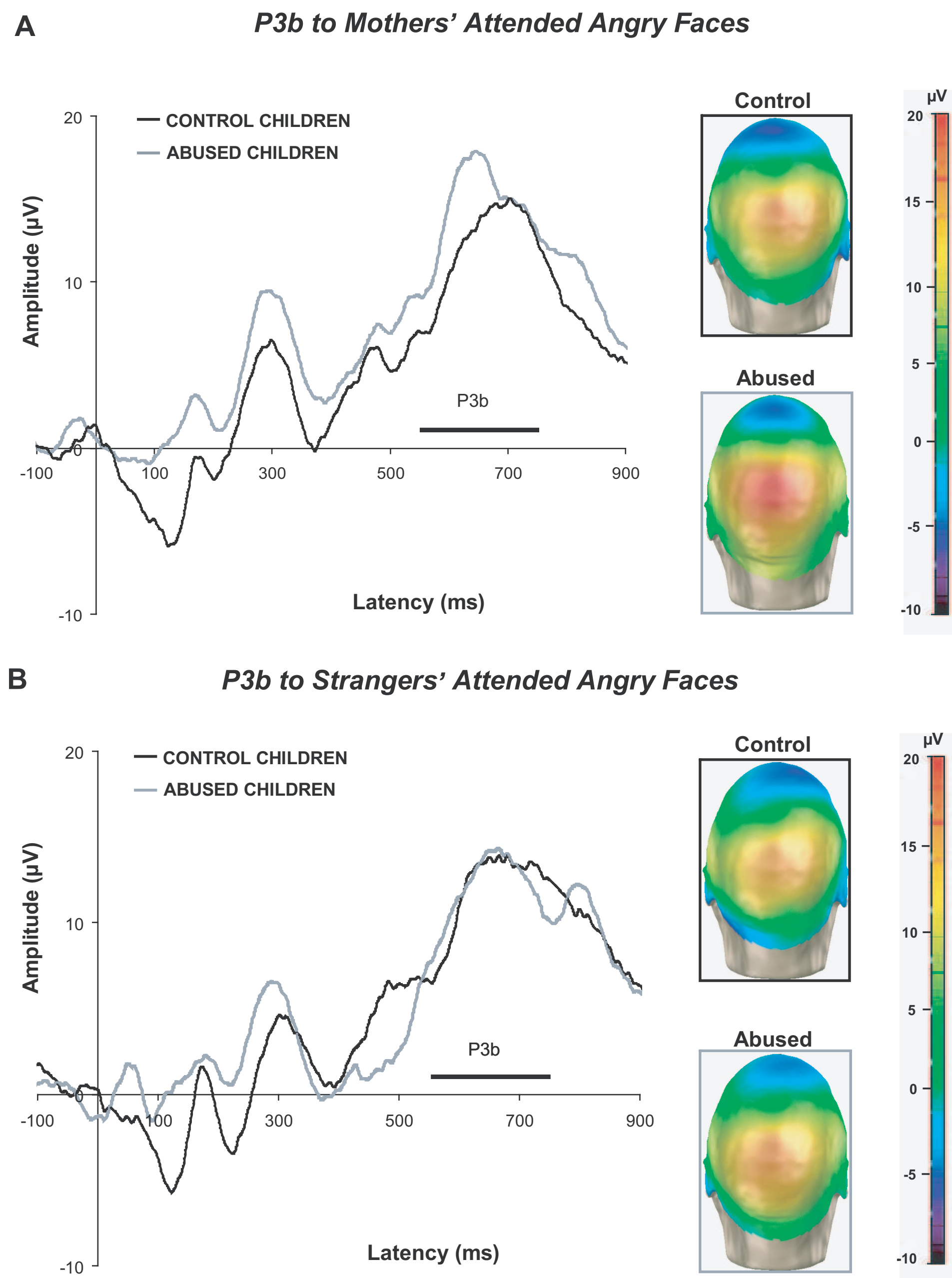

Figure 2. P3b (570–770 ms) to attended angry faces from Experiment 1. (Panel A) Grand average waveforms derived from Pz electrode site while children viewed task-relevant angry faces expressed by their mothers. The window used to compute average P3b amplitude is indicated by a horizontal line. Topographic maps for control (top) and abused (bottom) children are presented next to the waveforms and show the average P3b amplitude for attended angry faces expressed by children's mothers. (Panel B) P3b to attended angry faces at Pz expressed by a stranger. The window used to compute average P3b amplitude is indicated by a horizontal line. Topographic maps show the average P3b amplitude for attended angry faces expressed by a stranger.

relative to control children (M = 437 ms, SE = 18 ms) on angry distractor trials, $F(1, 28) = 4.83$, $p < .05$.

Attention Processing and Arousal

To explore whether abused children's voluntary and involuntary attentional processing was related to their affective reactions to the stimuli, we examined children's peripheral physiological responses. Abused children showed a larger SCR to anger relative to happiness and sadness, whereas controls showed a larger SCR to happiness relative to anger and sadness; Group × Emotion $F(2, 52) = 7.94$, $p < .01$. A Group × Familiarity interaction, $F(1, 26) = 9.08$, $p < .01$, indicated that abused children had a larger

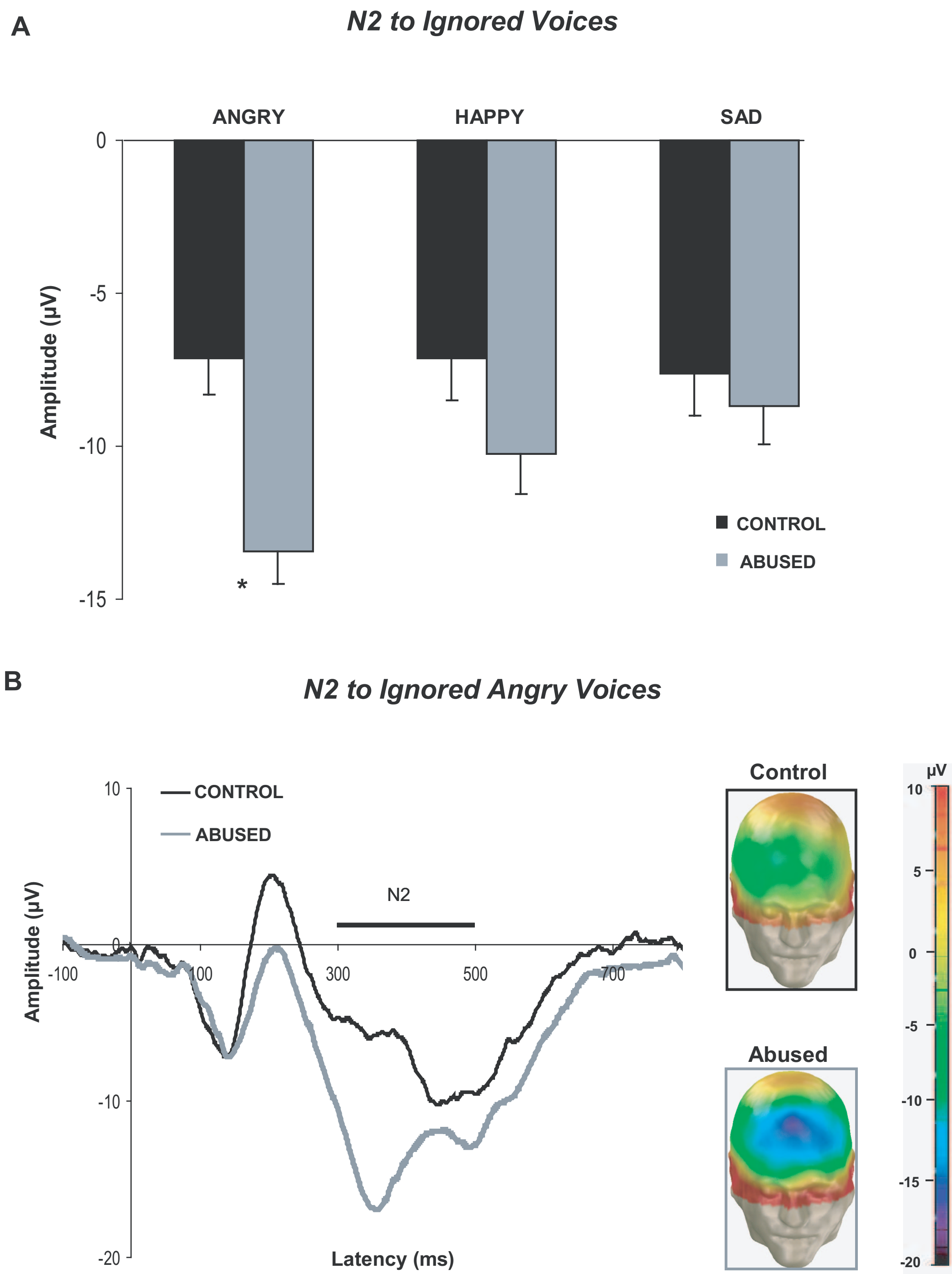

Figure 3. N2 (300–500 ms) to ignored voices for Experiment 1. (Panel A) Average amplitude of the N2 to ignored voices at Fz. The interaction between group and emotion was significant, $F(2, 56) = 5.35$, $p < .01$. Asterisk indicates that abused children showed a larger N2 to angry voices compared with controls, $t(28) = 3.87$, $p < .001$. (Panel B) Grand average waveforms derived from Fz while children heard task-irrelevant angry voices. The window used to compute average N2 amplitude is indicated by a horizontal line. Topographic maps for control (top) and abused (bottom) children are presented alongside the waveforms and show the average N2 amplitude for ignored angry voices.

SCR to their mothers' emotion expressions relative to expressions posed by unfamiliar adults, $t(15) = 2.85$, $p < .05$; whereas controls did not show a differential response to expressions posed by familiar versus unfamiliar adults, $t(11) = 1.58$, *ns*. To further explore the relationship between children's affective responses to stimuli and their attentional processing, we investigated the relationship between children's SCRs and their P3b and N2 amplitudes to angry faces. Abused children's SCRs to their mothers' expressions of anger correlated with P3b amplitude in response to their mothers' angry faces, $\rho(16) = .48$, $p < .05$. This relationship did not hold for control children, $\rho(12) = .33$, *ns*. Across groups, SCR and P3b amplitudes were not correlated for happiness or sadness. Similarly, SCR to angry faces (both familiar and unfamiliar) was associated with an increased N2 to anger for abused children, $\rho(16) = -.47$, $p < .07$; but not for control children, $\rho(12) = -.13$, *ns*. No relationship emerged between SCR and N2 for either happiness or sadness.

Emotion Processing and Anxiety

We next examined the interrelations between children's experiences of physical abuse, individual differences in symptomatology, and the attentional processing measures. Here, we treat individual differences in abuse experience as a continuous predictor of anxiety symptoms to create a more sensitive measure than a more traditional between-groups approach (Kosslyn et al., 2002; MacCallum, Zhang, Preacher, & Rucker, 2002). Our reasoning for including both analysis of group effects and individual differences in physical abuse was twofold. Traditional approaches to studying the effects of child abuse have characterized abuse as a dichotomous variable, largely because of reliance on legal reports as determinants of abuse, and we wanted to be consistent with this approach. However, the behaviors that define abuse are themselves continuous; thus, we wanted to determine whether the effect of various levels of abuse was continuous as well. Additionally, developing a greater mechanistic understanding of the effect of abuse requires that we take a more refined approach to understanding variations in both emotional experience and outcome. Indeed, zero-order correlations indicated associations between parent's own reports of their abusive behaviors toward their children and their children's reports of anxious symptoms, $r(27) = .48$, $p < .01$.

We next examined whether our cognitive processing measures mediated this association by further examining the relationship between abuse, child anxiety symptoms, and attentional processing of threat cues. The Clogg test (Clogg, Petkova, & Shihadeh, 1992) is a test of whether an intervening variable, or mediator, significantly changes the relationship between two variables (in this case, physical abuse and child symptomatology). This method has been shown to produce appropriate Type I error rates and greater power for detecting effects, relative to some of the other available methods for testing mediation, especially when using modest samples sizes (Baron & Kenny, 1986; MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002). After removing one multivariate outlier from the analysis, we found that more frequent and intense parent-reported abusive behaviors predicted increased P3b amplitude in children, $r(27) = .37$, $p < .05$; and children who exhibited larger P3b amplitudes when processing their mother's angry faces were also more likely to report experiencing symptoms of anxiety, $r(27) = .48$, $p < .05$. When the mediating influence of P3b amplitude was included in the regression model, the direct path from abuse experience to children's anxiety symptoms was reduced to $r'(27) = .35$, $p < .05$. The formal test reflecting the mediation by P3b amplitude of the relationship between children's abuse experience and anxiety symptoms was also significant, $t(26) = 2.05$, $p < .05$. Put another way, approximately 40% of the observed relationship between individual differences in abuse experience and anxiety in children was driven by enhanced attentional processing of their mothers' angry faces.

We also conducted tests using children's N2 amplitude as a mediator of the relationship between abuse experience and anxiety symptoms. Individual differences in abuse experience were related to N2 amplitude, $r(30) = -.41$, $p < .05$; however, N2 was unrelated to children's anxiety.

Control Analyses

To ensure that the results described earlier were not confounded by differences in stimulus quality between abusive and nonabusive mothers, we conducted a repeated measures ANOVA on the scores provided by adult raters for each facial expression, with status of mother (abusive, nonabusive) and emotion (angry, happy, sad) as within-participant factors. No interactions emerged between abuse group and facial emotion, $F(2, 56) = 0.33$, *ns*. Similarly, focused *t* tests did not reveal any group differences for the facial expressions. Identical analyses were conducted with raters' judgments of mothers' vocal expressions, and no interaction effects were observed, $F(2, 56) = 0.43$, *ns*, suggesting that all mothers were rated as producing similar quality facial and vocal expressions of emotion.

Discussion

The data obtained in Experiment 1 demonstrated that physically abused children showed enhanced P3b amplitude when directing their attention to their own mother's facial anger. The groups of abused and control children did not differ when attending to anger posed by unfamiliar adults or when attending to happy and sad facial expressions. Additionally, abused children displayed increased N2 amplitudes when presented with angry distractor cues, suggesting they expended greater effort inhibiting the involuntary processing of task-irrelevant anger. These ERP data suggest that, compared with control children, abused children exert more cognitive effort both to engage their attention toward salient anger cues and to withhold further processing of irrelevant but salient affective cues in the environment. Relative to controls, abused children showed larger SCRs to angry faces. Moreover, abused children's SCRs to anger expressed by their mothers correlated with their P3b amplitude in response to their mothers' angry faces. Finally, voluntary attention, as indexed by P3b to angry faces, mediated 40% of the relationship between physical abuse and anxious symptoms.

Experiment 2

Because relatively little work has focused on the processing of vocal (compared with facial) affect, Experiment 2 was designed to examine how abused children attend to vocal anger. This design also allowed us to examine children's involuntary processing of angry faces. On the basis of the results of Experiment 1, we predicted that abused children would show enhanced processing of their mother's angry voice and more evidence of distraction and inhibition, relative to control children, when presented with task-irrelevant angry faces.

Method

Participants

Twenty-eight children (14 physically abused, 14 control) participated in this experiment. Children were recruited and screened as described in Experiment 1; however, none of these children participated in Experiment 1. The demographics of the sample are given in Table 1.

Procedure

Procedures were identical to those used in Experiment 1, with the following exception: Children were instructed to attend to the *vocal* expression of emotion while ignoring the emotion in the face. A schematic of this task is presented in Figure 1.

ERP and SCR scoring. The following ERP components were of primary interest: P3b elicited in response to target voices (maximal at Pz, 650–850 ms posttarget) and N2 elicited in response to distractor nontarget faces (maximal at Fz, 300–500 ms poststimulus). After eliminating trials with overt response errors or excessive movement, the mean percentage of trials retained for averaging was 91% for congruent targets (control, $M = 92.8$, $SD = 3.0$; abused, $M = 90.4$, $SD = 2.5$), 90% for incongruent targets (control, $M = 90.7$, $SD = 2.9$; abused, $M = 89.2$, $SD = 3.3$), 87% for distractor nontargets (control, $M = 87.0$, $SD = 4.9$; abused, $M = 87.3$, $SD = 3.9$), and 88% for nondistractor nontarget trials (control, $M = 87.9$, $SD = 4.6$; abused, $M = 88.1$, $SD = 2.5$). Groups did not differ on the percentage of trials eliminated because of excessive artifact, all $ps > .2$.

Data analysis. Data were analyzed in the same manner used as in Experiment 1.

Results

Children's performance data are summarized in Table 4. As in Experiment 1, children responded faster to congruent trials than to incongruent trials, $F(1, 26) = 176.88$, $p < .001$; and were more accurate on congruent trials, compared with incongruent trials, $F(1, 26) = 64.14$, $p < .001$. No main effect of emotion was observed on reaction time, $F(2, 52) = 1.21$, *ns*.

Voluntary Attentional Processing of Emotion

Consistent with our first prediction, abused and control children's P3b responses differed across vocal presentations of emotion, $F(2, 52) = 6.06$, $p < .01$. Follow-up tests revealed that abused children showed a larger P3b to vocal anger relative to controls, $t(26) = 3.49$, $p < .01$; whereas the groups did not differ on happy, $t(26) = 1.36$, *ns*; or sad trials, $t(26) = 0.7$, *ns* (see Figure 4). Consistent with the P3b findings, abused children were most accurate on angry trials, followed by happy and sad trials, whereas control children were most accurate on happy trials, followed by sad and angry trials, $F(2, 52) = 3.47$, $p < .05$. Children were more accurate when responding to their own mother's vocal expressions, $F(1, 52) = 12.94$, $p < .001$; but P3b responses were similar in response to familiar and unfamiliar voices, $F(1, 52) < 1$.

Involuntary Attentional Processing of Emotion

Abused and control children showed similar behavioral performance in response to task-irrelevant angry faces. All children made more errors on distractor nontargets relative to nondistractor nontarget trials, $F(1, 26) = 58.66$, $p < .001$. The N2 peaked at 416 ms poststimulus and was maximal at frontal electrode site Fz ($M = -12.25$ μV, $SE = 0.88$) relative to Cz ($M = -11.10$ μV, $SE = 1.09$ μV) and Pz ($M = -3.43$ μV, $SE = 1.06$ μV), $F(2, 52) = 70.34$, $p < .001$; thus, the analyses reported here were performed only at the frontal site. However, the overall ANOVA did not reveal a Group × Emotion interaction or any main effects of emotion or poser familiarity on children's N2 amplitudes on distractor trials.

Attention Processing and Arousal

As in Experiment 1, we examined children's peripheral physiological responses to the affective stimuli. One control child was removed because of SCR scores 2 *SD*s above the group mean. Children showed larger SCRs to expressions of emotion posed by familiar adults relative to those of unfamiliar adults, $F(1, 25) = 7.59$, $p < .01$. A Group × Emotion × Familiarity interaction, $F(2, 50) = 5.61$, $p < .01$, indicated that, unlike abused children, control

Table 4
Means ± Standard Errors for Behavioral Performance Measures for Experiment 2

	Control children			Abused children		
Measure	Angry	Happy	Sad	Angry	Happy	Sad
Reaction time (in milliseconds)						
Congruent	958 ± 28	1000 ± 32	1054 ± 56	1008 ± 28	1059 ± 32	992 ± 56
Incongruent	1157 ± 38	1173 ± 32	1213 ± 50	1183 ± 38	1256 ± 32	1160 ± 50
% Hits						
Congruent	89.8 ± 1.4	87.3 ± 2.0	89.7 ± 1.6	90.7 ± 1.4	89.7 ± 2.0	88.1 ± 1.6
Incongruent	85.1 ± 1.3	82.3 ± 2.7	87.4 ± 1.7	83.7 ± 1.3	79.8 ± 2.7	84.2 ± 1.7
Distractors, % errors	14.7 ± 3.2	8.7 ± 2.6	14.8 ± 2.7	16.0 ± 3.2	17.6 ± 2.6	16.5 ± 2.7
Nontargets, % errors	8.4 ± 1.6	2.3 ± 1.4	5.5 ± 1.5	6.5 ± 1.6	8.5 ± 1.4	11.4 ± 1.5

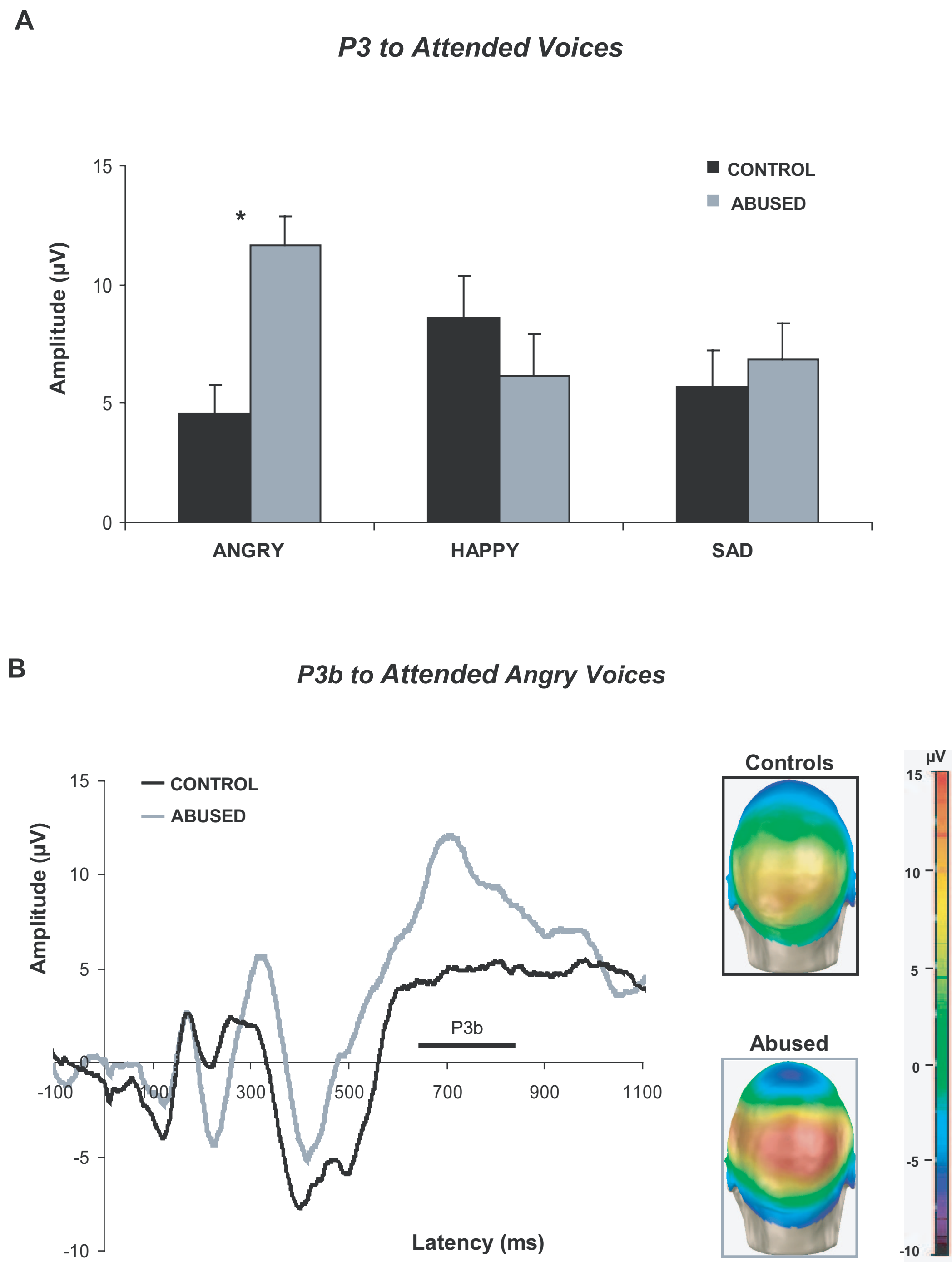

Figure 4. P3b (650–850 ms) to attended voices for Experiment 2. (Panel A) Average amplitude of the P3b to task-relevant voices at Pz. The interaction between group and emotion was significant, $F(2, 52) = 6.06$, $p < .01$. Asterisk indicates that abused children showed a larger P3b to angry voices compared with controls, $t(26) = 3.49$, $p < .01$. (Panel B) Grand average waveforms derived from Pz while children heard task-relevant angry voices. The window used to compute average P3b amplitude is indicated by a horizontal line. Topographic maps for control (top) and abused (bottom) children are presented next to the waveforms and show the average P3b amplitude for attended angry voices.

children were less aroused by their own mother's expressions of anger and more aroused by anger expressed by an unfamiliar adult, $t(13) = 3.53$, $p < .01$. Abused children showed a larger SCR to their mother's expressions of anger than did control children, $t(25) = 2.49$, $p < .05$. Groups did not differ on any other comparison, *p*s > .2. Correlational analyses did not reveal any significant relationships between children's SCRs and the amplitudes of either P3b to attended voices or N2 to unattended faces of any emotion.

Emotion Processing and Anxiety

One child in the physical abuse group was removed from the analysis of anxiety symptoms because of an anxiety score 3 *SD*s above the group mean. As in Experiment 1, higher levels of parent-reported abusive behaviors predicted greater child-reported anxiety, $r(27) = .37$, $p < .05$. More frequent and intense parent-reported abusive behaviors were related to children having higher P3b amplitudes when attending to their mother's vocal anger, $r(27) = .43$, $p < .05$. Additionally, children characterized by higher P3b amplitudes in response to their mother's voices also reported higher levels of anxiety symptoms, $r(27) = .57$, $p < .01$. When the mediating influence of P3b amplitude was included in the regression model, the direct path from abuse experience to children's anxiety symptoms was no longer significant, $r'(27) = .15$, *ns*. The formal test reflecting the mediation by P3b amplitude of the relationship between children's abuse experience and anxiety symptoms was also significant, $t(24) = 2.73$, $p < .05$. Put another way, approximately 77% of the observed relationship between abuse experience and children's anxiety was driven by enhanced attentional processing of their mothers' angry voices.

Control Analyses

We conducted a repeated measures ANOVA on adult raters' judgments of mothers facial and vocal expressions. Status of mother (abusive, nonabusive) and emotion (angry, happy, sad) were used as within-participant factors. No interactions emerged between group and emotion, $F(2, 40) = 0.24$, *ns*. Similarly, focused *t* tests did not reveal group differences for any of the facial expressions. We conducted identical analyses with raters' judgments of mothers' vocal expressions, and no interaction effects were observed, $F(2, 40) = 0.08$, *ns*.

Discussion

The results of Experiment 2 demonstrate that angry voices elicit a greater P3b in abused children relative to control children. The groups responded similarly to happy and sad voices. In addition, mediation analyses performed for these data produced results similar to those obtained in Experiment 1; namely, the positive relationship between abuse experience and children's anxiety symptoms was mediated by children's P3b amplitude to familiar vocal expressions of anger. Also consistent with results from Experiment 1, abused children showed a larger SCR to anger relative to other emotions and a larger SCR to anger expressed by their abusive mothers than did control children. However, directing children's attention to vocal emotion produced two effects that were inconsistent from those in Experiment 1. First, children appeared to process affect in familiar and unfamiliar voices similarly. Second, we had predicted that task-irrelevant facial anger would engage the attention of physically abused children, but this was not the case. These issues are discussed further later.

General Discussion

The two experiments reported here assessed children's attentional processing of facial and vocal emotion cues. We presented children with congruent and incongruent facial and vocal emotion expressions while directing children's attention toward either the visual (Experiment 1) or auditory (Experiment 2) modality. In general, we found that abused children (a) exhibited increased voluntary attention toward both facial and vocal anger cues, (b) were involuntarily drawn to vocal anger cues, and (c) were especially responsive to facial signals of anger from their own parent. These features of children's cognitive processing of emotion appear related to children's problems with anxiety.

Experiment 1 extends previous findings in demonstrating that selective attention is especially enhanced when abused children process their own mother's angry facial expressions. Because abused and control children did not differ in processing facial anger expressed by unfamiliar adults, it is possible that the salience of familiar angry faces may have suppressed children's processing of angry facial expressions posed by unfamiliar adults. In Experiment 2, P3b results suggest that abused children also devote more voluntary processing resources to the detection of anger conveyed in the voice. Children appeared to process vocal anger conveyed by familiar and unfamiliar adults similarly. There are several explanations that may account for this. One possibility is that vocal anger was salient enough to capture children's attention, regardless of the person conveying the information. In addition, if the identity of the speaker was detected after the emotional information was processed, the information conveyed by poser familiarity may not have been reflected in P3b amplitude. Although our behavioral data did not parallel the ERP findings, it is not uncommon for studies investigating the neural bases of cognitive operations to find dissociations between neural responses and behavioral performance (e.g., Bell, Willson, Wilman, Dave, & Silverstone, 2006; Sayala, Sala, & Courtney, 2006). Behavioral indices such as reaction time are under the influence of multiple processes and thus should not necessarily be expected to correspond directly to the measurement of more specific neural processes, such as those reflected in ERP (Hopfinger & Maxwell, 2005).

Both experiments also addressed children's processing of task-irrelevant emotional cues, which we take as reflecting an involuntary aspect of attention. In Experiment 1, the presence of task-irrelevant vocal anger (but not happiness or sadness) elicited a negative frontal ERP component, occurring at approximately 400 ms, that was larger in abused children than in controls. Because of its topography and the conditions under which it was (and was not) elicited in the present experiments, we interpret this component as reflecting evaluative and regulatory cognitive processes attributed to the N2. The N2 has been observed in other tasks that induce processing conflict and require inhibitory mechanisms to suppress response tendencies such as irrelevant and potentially distracting information (Johnstone, Pleffer, Barry, Clarke, & Smith, 2005;

Jonkman et al., 1999; Yeung & Cohen, 2006). Although our N2 emerged somewhat later than is typically seen, several studies have observed an N2 component at latencies as late as 400 ms, even in adults (Bartholow et al., 2005; Curtin & Fairchild, 2003; Jonkman et al., 1999; Liotti et al., 2000). It is also likely that the complexity of the stimuli used in the present experiments resulted in prolonged processing times for N2, as well as for P3b. We also observed differences in N2 latency in Experiment 1, such that N2 in response to vocal anger occurred almost 50 ms earlier in abused children than in controls.

The observation that auditory distractors elicited pronounced differences in N2 amplitude and latency suggests that vocal anger exerts a strong pull on attention for abused children, requiring the use of cognitive regulatory processes. The N2 component has typically been interpreted to reflect enhanced cognitive control (Bush, Luu, & Posner, 2000), and our results are consistent with this interpretation. It is likely that, as a consequence of greater processing of auditory anger cues, abused children must exert greater cognitive control to resolve conflicting signals and maintain their attention on the task. In contrast, we did not observe involuntary attention capture by facial anger cues in Experiment 2. An alternative explanation may be that children were simply not paying attention to the facial cues. This is unlikely, however, because we observed slowing of reaction times and decreases in accuracy on incongruent relative to congruent trials, suggesting that these stimuli were being processed. Another possibility is that task-irrelevant auditory cues exerted an enhanced effect on attention because of the dynamic nature of auditory stimuli relative to the static nature of posed facial expressions. Indeed, visual stimuli with characteristics that signal environmental change (e.g., moving stimuli, luminance changes, abrupt onset) receive attentional priority (Franconeri & Simons, 2003) and may represent a mechanism for alerting an organism to potentially significant events (Berti & Schröger, 2003; Sussman et al., 2003).

Abused children showed larger SCRs to anger than did controls, suggesting that abused children interpreted the anger expressions as particularly salient and arousing. In addition, children's SCRs to familiar expressions of anger were related to their P3b amplitude to those stimuli, suggesting a relationship between affective arousal and allocation of attention. Finally, across both experiments, the relationship between individual differences in children's abuse experience and self-reported anxiety symptoms was mediated by children's voluntary cognitive processing of anger, as reflected in P3b amplitude. This is consistent with previous research demonstrating a link between information-processing biases and anxiety in children (Lonigan et al., 2004) and adults (Fox, Russo, & Georgiou, 2005; Mogg, Philippot, & Bradley, 2004). However, the present study takes this notion one step further by suggesting that patterns of information processing may connect early traumatic experiences with risk for anxiety disorders. We recommend that future work investigate children with other types of traumatic histories to help further understand the manner in which these experiences contribute to risk for anxiety.

There are several limitations of the present experiments. First, we were unable to gather information regarding characteristics of abuse experience such as onset, duration, or severity. This information could help characterize specific features of a child's early experience that relate to risk for psychopathology. However, our results revealed significant group differences in spite of the potential heterogeneity of our abuse sample, reflecting the broad effects of physical abuse on children's development. Second, because we only showed children the face of one familiar adult (their mother), we are unable to completely separate the effects of familiarity and abuse on anger processing. However, our between-groups manipulation of abuse controls for the effect of familiarity on children's emotion processing. Thus, processing differences are most likely due to effects of abuse experience beyond those of familiarity. Finally, there is always the possibility that, when self-reporting on sensitive behaviors, individuals will report fewer negative behaviors or symptoms than are actually present. However, to the extent that mothers in these two studies underreported their abusive behaviors toward their children, the results presented here are likely to underestimate actual effects of child abuse and would bias results against the emergence of group differences.

In summary, these data suggest that atypical cognitive processing of emotion may link aberrant early experience with anxiety in children. Various aspects of neural circuitry could be targeted for investigation in terms of the mechanisms underlying these processes. For example, the prefrontally mediated anterior attentional system is thought to serve the functions of overcoming involuntary responses and resolving conflict produced by task-irrelevant but salient properties of target stimuli (Derryberry & Reed, 2001; González, Fuentes, Carranza, & Estévez, 2001; Posner & DiGirolamo, 1998). Our results suggest that this may be one of the brain systems affected by maltreatment. Indeed, source localization studies have indicated a generator for the N2 component of the ERP in the anterior cingulate cortex (Bekker, Kenemans, & Verbaten, 2005; Nieuwenhuis et al., 2003), which has been implicated in processes related to inhibition (Lavric, Pizzagalli, & Forstmeier, 2004), as well as signaling the presence of processing conflict (Botvinick, Braver, Barch, Carter, & Cohen, 2001). A growing body of evidence indicates that somatic states related to emotion are involved in cognition and learning (Bechara, Tranel, Damasio, & Damasio, 1996; Damasio, 1999; Lo & Repin, 2002). For example, individuals who show stronger somatic marking (larger SCRs) also show stronger learning performance (Carter & Pasqualini, 2004). Thus, autonomic arousal in response to threat may initially serve to bias attention toward such salient emotion cues. Over time, this may help abused children to learn about the predictive value of anger in a maltreating environment. However, the enhanced attentional processes that are adaptive in an abusive context may lead to maladaptive behaviors in more normative situations, with aberrant processing of threat cues increasing the child's risk for anxiety. In particular, the inability to flexibly regulate attention in the presence of threat cues may represent a mechanism by which plasticity in learning confers risk for maladaptation.

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