Neurophysiological Correlates of Children's Processing of Interparental Conflict Cues

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Abstract

The current study builds on the literature on child exposure to marital conflict by testing whether mother-reported marital conflict exposure predicts a child's P3 event-related potential (ERP) components generated in response to viewing quasi-marital conflict photos. We collected ERP data from 23 children (9 – 11 years of age) while presenting photos of actors pretending to be a couple depicting interpersonal anger, happiness, and neutrality. To elicit the P3 ERP, stimuli were presented using an oddball paradigm, with angry and happy photos presented on 20% of trials each and neutral photos presented on the remaining 60% of trials. Angry photos were the target in one block, and happy photos were the target in the other block. In the angry block, children from high-conflict homes had shorter reaction times on happy trials than on neutral trials, and children from low-conflict homes had shorter reaction times on angry trials than on happy trials. Also within the angry block, children generated a larger P3 on angry trials than on happy trials, regardless of exposure to conflict. Further, children from high-conflict homes generated larger P3s on angry trials and on happy trials compared with neutral trials, but children from low-conflict homes did not. Results are discussed in terms of implications for children's processing of displays of interpersonal emotion.

Key words: interparental conflict, children, event-related potential (ERP), P3, oddball paradigm

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Social experiences are central in children's socioemotional development, and by consensus, experiences with their parents' relationship are crucial, especially when that relationship is high in conflict. It is clear that interparental conflict predicts children's adjustment problems (Cummings & Davies, 2010), but less is known about some of the mechanisms underlying these associations (Cummings, Davies, & Campbell, 2000), especially neurophysiological mechanisms. Neurophysiology may serve as a window into children's processing of family-related stressors, which, ultimately, may comprise a key process in socioemotional development. The purpose of this study is to investigate neurophysiological correlates of children's responses to interparental conflict-related stimuli. Conflict between one's parents is a common stressor that could be associated with neural processing. We propose that children who see frequent and intense conflict would come to neurophysiologically process conflict stimuli differently than children who see fewer, better-resolved conflicts. Thus, in the current study, we examined whether differences in exposure to destructive interparental conflict are associated with differences in event-related potentials (ERPs) that could potentially be correlated with children's processing of interpersonal conflict cues.

Interparental Conflict and Child Adjustment

In recent years, increasing numbers of studies have sought mechanisms underlying associations between child adjustment and interparental conflict. Emotional security theory suggests that children's goals of establishing and maintaining a sense of security about their parents' relationship influences children's emotional reactions to interparental conflict, regulation of their exposure to conflict, and cognitive representations of their parents' conflict (Davies & Cummings, 2006). Children's cognitive representations of conflict, which reflect children's interpretations of the implications of parents' conflict for family well-being, are conceptualized as "radar systems for identifying interparental events" that may signal serious problems for the family (Davies & Cummings, 2006, p. 93). Moreover, representations reflecting emotional insecurity may lead to subsequent over-vigilance, with high sensitivity to signs of trouble in the interparental relationship (Davies, Sturge-Apple, Bascoe, & Cummings, 2014). Consistent with emotional security theory, videotaped depictions of simulated interparental conflict have been found to elicit negative emotional responses in children (Goeke-Morey, Cummings, Harold, & Shelton, 2003), and children's emotional security about their parents' relationship has been found to mediate associations between interparental conflict exposure and child adjustment (Davies, Harold, Goeke-Morey, & Cummings, 2002). Examining ERPs may allow us to tap into the neurophysiology that is relevant to such processes. To begin to fill this gap, in the current study, we examined associations between exposure to interparental conflict and an ERP component thought to reflect stimulus salience, the P3.

Children's appraisals of threat and self-blame regarding interparental conflict also serve as mechanisms underlying associations between interparental conflict and child adjustment (Fosco & Feinberg, 2014; Grych, Harold, & Miles, 2003). According to the cognitive contextual framework (Grych & Fincham, 1990), children's perceptions of threat regarding interparental conflict involve children's concerns that parents' conflict may cause harm to their parents or to themselves or escalate into more serious conflict, cause spillover of conflict into their own relationships with their parents, or lead to marital separation or divorce (Buehler, Lange, & Franck, 2007; Gerard, Buehler, Franck, & Anderson, 2005). Indeed, Gerard and colleagues (2005) found that children's perceptions of interparental conflict (e.g., intensity, hostility) predicted their perceptions of threat, which in turn predicted internalizing and externalizing problems. Further, in a comprehensive, longitudinal test, Buehler et al. (2007) found considerable support for elements of both emotional security theory and the cognitive-contextual framework, including these cognition-related elements.

Children's executive functioning has also been implicated in associations between family violence exposure and child outcomes. Jouriles and colleagues proposed a model for associations between family violence and child outcomes that includes several aspects of cognition, including executive functioning (Jouriles, McDonald, Mueller, & Grych, 2012). Supporting this model, Jouriles and colleagues (2008) found that parents' violence toward one another predicted poorer child performance on executive functioning tasks.

Previous studies have also examined components of the physiological stress response in conflict-adjustment links. For example, one study examined the roles of respiratory sinus arrhythmia (RSA), reflecting parasympathetic nervous system activity, and skin conductance, indexing sympathetic nervous system activity, in associations with delinquency (El-Sheikh, Hinnant, & Erath, 2010). For children with relatively low baseline RSA and RSA augmentation, or with high baseline skin conductance but low skin conductance reactivity, higher levels of interparental conflict predicted more delinquency.

In short, exposure to interparental conflict is clearly a salient social experience. It is associated with children's emotion, cognition, and behavior, and it interacts with the sympathetic and parasympathetic nervous systems to predict subsequent outcomes. Neurophysiological processes have been under-examined, however. ERPs are a measure of brain activity elicited by specific stimuli and task requirements. The P3 is a positive ERP component generated on experimental trials with infrequent attended target stimuli, with latencies in adults as early as 300 milliseconds for the auditory modality (Fabiani, Gratton, & Federmeier, 2007; Polich, 2007).

The P3 has been proposed to reflect stimulus discrimination and categorization processes. P3 amplitude is known to scale with stimulus probability, allocation of attentional resources, and use and storage of information in, memory (Polich, 2007; Key, Dove, & Maguire, 2005). The incoming target stimulus is likely maintained in working memory, so that an internal comparison can be made between the incoming target and the required response category (Polich, 2007). P3 latency is thought to reflect the time to evaluate the stimulus, and can vary as a function of stimulus modality and complexity, as well as task demands (Polich, 2007). The cognitive processes involved in P3 generation are likely to facilitate the identification of salient or meaningful events (Pollak, Cicchetti, Klorman, & Brumaghim, 1997). While a large portion of the literature on P3 relates to cognitive processes, larger P3 amplitudes can occur for stimuli with affective (relative to neutral) content (Johnston, Miller, & Burleson, 1986). Thus, we anticipated that children exposed to more negative family experiences might generate an even larger P3 to emotional stimuli than to neutral stimuli relative to other children in our laboratory environment.

The ‘oddball paradigm’ is frequently used to elicit the P3. In a standard oddball task, participants make a behavioral response to rare target stimuli presented among frequent non-targets, and the P3 is elicited to rare stimuli. However, in the three-stimulus oddball, a widely used variation on the standard oddball, two rare stimuli are presented, one of which is the task-relevant target and one of which is a non-target distractor. Here, we used a three-stimulus oddball for consistency with previous studies (e.g., Pollak et al., 1997).

Several previous studies have found associations between ERPs and experiences of severe early adversity, such as institutional care. Compared with control children, post-institutionalized children have been found to generate smaller P3 amplitudes on an inhibitory control task (McDermott, Westerlund, Zeanah, Nelson, & Fox, 2012). Several studies have also found associations between maltreatment and ERP components elicited to viewed facial expressions of emotion. In one such study, non-maltreated children generated equivalent P3 amplitudes regardless of whether they were instructed to respond to angry or happy faces, but abused children generated larger P3 amplitudes in the angry target condition than in the happy target condition (Pollak et al., 1997). In another study, abused children generated larger P3 amplitudes to angry faces than to sad and happy faces, but non-abused children did not (Shackman, Shackman, & Pollak, 2007). In the studies of maltreatment, the larger ERP amplitudes may reflect the emotional and social significance of the stimuli, and the importance for these children of being able to detect angry faces (Pollak et al., 1997).

Although witnessing interparental conflict is a less severe stressor than maltreatment, it is still a significant stressor, and it may shape brain development reflected in ERP activity. Yet, few studies have examined the neural correlates of children's processing of interparental conflict. We know of only one study to do so. Graham, Fisher, and Pfeifer (2013) used functional magnetic resonance imaging (fMRI) to examine sleeping infants' brain activation during the presentation of angry, happy, and neutral voices. Infants whose mothers reported more marital conflict showed more activation of brain regions that have been linked with stress and emotion processing, including parts of the anterior cingulate cortex and the hypothalamus. This study is an excellent starting point, and is crucial in documenting associations between exposure to interparental conflict and neurological activity, but many questions remain. Whereas fMRI is very well suited to addressing questions about specific brain regions showing activation in response to stimuli, ERP methods are very useful for addressing questions about the timing of activity in the brain. The P3 ERP was of particular interest in the current study because it is known to not only reflect cognitive processing of salient stimuli, but is also sensitive to stimuli with affective content. The primary purpose of the current study was to extend previous studies to examine exposure to marital conflict as a predictor of aberrant P3s generated in response to marital conflict cues. In the current study, we compared the P3s generated by children from homes with high levels of interparental conflict with those of children from low-conflict homes on a three-stimulus oddball task involving emotionally and socially significant stimuli, that is, photos of actors depicting interpersonal anger and happiness. Children commonly see their parents showing happiness and anger toward one another (Cummings, Goeke-Morey, & Papp, 2003), so the contextualization of social emotion within the setting of an interpersonal relationship has ecological validity. To our knowledge, previous studies have not examined whether individual differences in children's interparental conflict exposure help account for differences in the P3 during processing of interpersonal conflict cues.

Current Study

The present study builds on the emerging literature by considering children's ERP responses to facial emotions displayed by a couple as a function of the children's previous experience with marital conflict. Based on previous work by Pollak and his colleagues (e.g., Pollak et al, 1997), and our conceptualization that interparental conflict cues are more salient for children whose parents have higher levels of conflict, we hypothesized that children from high-conflict homes would generate larger P3 amplitudes in response to interparental conflict stimuli, compared with children from low-conflict homes, consistent with Pollak et al (1987). Specifically, using the two-target variant of the oddball paradigm we predicted that for negative task-relevant targets, in particular, P3s of children from homes with high levels of conflict would be larger relative to those from low-conflict homes. Further, the differentiation in P3 amplitude between negative non-target distractors should also be larger than those to other target stimulus categories. Similarly, as a result of the greater importance of quickly and accurately detecting signs of conflict for children from high-conflict homes, we also expected to find differences in behavioral performance associated with differences in exposure to interparental conflict. Specifically, we expected to find faster, more accurate responses among children from high-conflict homes than children from low-conflict homes.

Method

Participants

Participants were 24 children (11 females), ages 9 to 11 years (*M* = 10.54, *SD* = 0.89), and their mothers. This age range was selected so that the children would be old enough to sit relatively still while completing the ERP task, to minimize movement artifacts in the ERP data. At the same time, we wanted to restrict our age range and largely avoid the period of adolescence, in order to have relative homogeneity in developmental functioning, particularly given the small sample size. The sample was recruited from the community via flyers posted in public and via newspaper ads. The recruitment materials described the research as a study of family relationships, indicated eligibility criteria, and indicated the amount of monetary compensation. In order to be eligible to participate, children had to live with their biological parents, who had to be married to each other. Children also had to read at a 4th to 5th grade reading level or higher, have normal or corrected-to-normal vision and hearing, and not have any known neurological condition (such as epilepsy) nor any traumatic brain injury or head injury that included loss of consciousness. Twenty-two of the children were Caucasian and the other 2 were multi-racial. The median household income in the sample was $65,001 - $80,000, with about 20% of the sample falling in the range of $10,001 - $40,000, and nearly 46% of the sample having household incomes greater than $80,000.

Upon arriving at the lab, mothers and children were shown the stimulus presentation and data collection equipment, and then mothers provided written informed consent and children provided assent. Children were compensated $20 and mothers were compensated $80. The experimental protocol was approved by the Indiana University (Bloomington) Institutional Review Board and Human Subjects Committee.

Experimental Stimuli: Creation and Screening

We wanted to examine children's P3 responses to stimuli depicting interpersonal emotion, but commonly used stimulus sets depict individuals rather than couples, so we created and validated a novel set of stimuli. The initial stimulus pool consisted of 257 color photographs of two paid actors, a male and a female, recruited from the university population. The photos were taken by a professional photographer. In the photos, the actors posed as a couple and depicted a range of levels of interpersonal anger, happiness, and neutrality. The actors, who were both Caucasian, were positioned in front of a black background, and oriented partway toward each other, but with their faces in plain view from the front, and not obscured by their hair.

Stimulus screening was conducted with an independent sample of twenty 9- to 11-year-old children. As with the primary data collection, the experimental protocol was approved by the university's ethics committee, and mothers provided written informed consent and children provided assent. Children viewed the photos and classified each one as happy, angry, neutral, or indeterminate. These ratings allowed us to identify the most happy, angry, and neutral, from the perspectives of children in our target age range. The 34 photos classified by the most children as happy, the 34 photos most classified as angry, and the 102 photos most classified as neutral were selected for use in the current study (including 4 happy, 4 angry, and 12 neutral photos for practice trials). We created a flipped copy of each image, showing the actors on the opposite sides of the image from the original so that the actors' positions would not be a confound. The originals and flipped copies were randomly assigned to experimental blocks so that each actor appeared on each side of the screen an equal number of times for each condition in each block.

Procedures and Measures

Children were seated at a distance of approximately 60 inches from the computer screen, so that each picture occupied approximately 4° of visual angle horizontally (the longest dimension), to minimize the need for exploratory eye movements to view the stimuli. Children were given detailed instructions for completing the task. The images were presented using Presentation software (Neurobehavioral Systems, Inc., Berkeley, CA), in a three-stimulus oddball paradigm similar to that of Pollak et al. (1997), with 2 counterbalanced blocks of 150 trials each, plus 20 practice, 1 block with happy photos as the target, and 1 block with angry photos as the target. The orders of the blocks, and of photo presentation within the blocks, were randomized. Within each block, neutral photos were presented on 90 trials (60%), and angry and happy photos were each presented on 30 trials (20%). Photos were presented for 1500 ms each, with an interstimulus interval of 1000 to 2000 ms, during which time a fixation cross was presented in the middle of a black screen (sample stimuli are available from the first author). Children were told that they would "see some photos of some actors pretending to be a married couple. And in some of the photos they look like they're happy with each other and in some of the photos they look angry with each other, and some of the photos are in between." They were asked to press the spacebar on a keyboard resting on their laps when the target photo type (happy or angry) appeared, and to withhold responding when other photos appeared; these behavioral responses were used to calculate accuracy and reaction time.

Electrophysiological Recording and Processing

The electroencephalogram (EEG) was recorded continuously using a 128-channel Electrical Geodesics system (EGI Inc., Eugene, OR), with a sampling rate of 250 Hz and a low-pass filter of 100 Hz, and was referenced to the vertex electrode (with a midline frontocentral ground electrode). Electrode impedances were kept below 70 kΩ, per manufacturer's instructions. Using NetStation software (EGI Inc., Eugene, OR), recorded EEG data were filtered with a 0.3 - 40 Hz bandpass filter and segmented into 1700-ms epochs, which included a 200-ms pre-stimulus baseline.

EEG data were exported as binary files and further processing was completed using EEGLAB (Delorme & Makeig, 2004) operating in the MATLAB (Natick, MA) environment. This processing included visual inspection, an Independent Components Analysis (Makeig, Debener, Onton, & Delorme, 2004) to identify and remove eye blink artifacts (see Hoffmann & Falkenstein, 2008) which was run excluding bad channels, and the removal of trials with voltages exceeding ±200 μV. Subsequently, baseline correction was performed, bad channels were replaced using EEGLAB's spherical interpolation procedure, the data were re-referenced to an average reference, and incorrect behavioral trials were removed for the EEG dataset. By removing incorrect trials and trials with voltages exceeding ±200 μV after conducting ICA, we were able to preserve as many EEG trials as possible for ICA, which requires many data points.

Data from children with fewer than 10 correct go/no-go trials in a condition were omitted for that condition. One child's data were removed completely from the study because the child had fewer than 10 correct trials in more than one condition. Data were retained from 23 children (11 females, $M_{age} = 10.52$, $SD_{age} = 0.91$) for the angry and neutral conditions of the happy block, and from 22 children for the happy condition of the happy block and all 3 conditions of the angry block. Notably, we also reran the analyses using only data from children who had complete data for all conditions, and the results were the same. The mean percentage of channels retained was 95% (range: 91-100%); the mean percentage of trials retained was 81% (range: 44-99%).

Subsequent to data processing, a manufacturer-issued correction factor was applied, to adjust for effects of the hardware filter interacting with EEG data acquisition software, which was dependent on sampling rate. For our (default) sampling rate of 250 Hz, an 8-ms correction factor was applied (Electrical Geodesics, Inc., Nov 26, 2014). Notably, applying the correction factor shifts *all* ERP peak latencies; the corrected data were used for the analyses. The correction factor affects neither reaction times (which were measured in Presentation) nor ERP amplitudes.

The time window for identifying P3 ERP peak activity was identified through visual inspection of the scalp topographies of the grand averaged and individual subject ERP data, as well as being informed by typical time windows for this age range from existing studies. Specifically, viewing the grand-averaged ERP data averaged across conditions, we identified the beginning and ending time points of the third positive deflection as the P3. After verifying that these time points were consistent with those of other studies of children in this age range (Güler et al., 2012; Pollak et al., 1997; Shackman et al., 2007), we computed P3s separately for each condition in each subject. The P3 was computed as the average of the samples within the identified time window (420 – 712 ms post-stimulus), averaging across only parietal electrodes (see Figure 1). These electrodes were identified *a priori* based on previous studies with this age group (e.g., Güler et al, 2012). Peak latencies were identified as the time points associated with the maximum deflections within this window (see Figure 2 for topographic voltage map).

Interparental Conflict Questionnaire

During the lab visit, mothers completed the O’Leary-Porter Scale (OPS; Porter & O’Leary, 1980), a 10-item measure (including 1 unscored item) of children’s exposure to interparental conflict. OPS items are completed on a 5-point scale ranging from 1 (*never*) to 5 (*very often*). Sample items include "How often do you and/or your spouse display verbal hostility in front of your child?" and "What percentage of arguments would you say take place in front of your child?" The OPS is a widely used measure of marital conflict and has good psychometric properties (Porter & O'Leary, 1980). Cronbach's α in our sample was 0.80, and the skewness statistic was 0.425. One item inquires "How often is there a physical expression of hostility between you and your spouse in front of your child?"; 18 mothers (78%) responded "Never," 4 responded "Rarely," and 1 responded "Occasionally." These rates of violence are somewhat lower than in other samples (Child Trends, 2012). Overall conflict levels in our sample (M=18.70, SD=5.01) were similar to those of other samples; for example, Papp, Cummings, and Schermerhorn (2004) reported mean OPS scores of 18.77 (SD=4.57) and Porter and O'Leary (1980) reported mean OPS scores ranging from 18.30 (SD=5.82) to 23.69 (SD=7.91).

We split the sample at the median (18.89) into high- and low-conflict groups (Table 1). Dichotomizing reduces power to detect significant effects (Cohen, 1978), but it can also enhance interpretability and produce clearer results by showing differences between those scoring above vs below a specific score (e.g., the median). We chose this procedure to be consistent with Pollak et al. (1997), examining outcomes using a repeated measures general linear model (GLM) with a categorical predictor variable. As would be expected, the groups differed significantly from each other on OPS scores, $t(21)=-6.20$, $p < .001$.

Results

Behavioral Findings

Table 1 presents sample characteristics, as well as group means and standard deviations on accuracy and reaction time on the ERP task for both of the groups. We conducted a repeated measures analysis using a GLM with child age and sex as covariates, with trial type (angry, happy, neutral) as a within-subjects factor. We also conducted this repeated measures GLM with marital conflict exposure as a between-subjects variable. We found no main effects or interaction effects for children's accuracy in classifying photos as angry, happy, or neutral (i.e., pressing the spacebar for target photos only). However, for reaction time, there was a main effect of marital conflict exposure in the angry block, $F(1, 8) = 6.42$, $p < .05$, with shorter reaction times for the high-conflict group ($M = 1012.14$ ms, $SD = 78.76$) than for the low-conflict group ($M = 1156.65$ ms, $SD = 83.34$). This effect was qualified by a trial type X marital conflict group interaction, $F(1.55, 12.39) = 8.19$, $p < .01$. The contrast comparing angry and happy trials was significant, $F(1, 8) = 10.74$, $p < .05$, as was the contrast comparing neutral and happy trials, $F(1, 8) = 7.70$, $p < .05$. Follow-up *t* tests revealed a shorter reaction time for the low-conflict group on angry than on happy trials, $t(5) = -3.01$, $p < .05$, but no significant difference for the high-conflict group on angry compared with happy trials, $t(5) = 2.16$, $p = .08$ (see Table 1 for means and standard deviations). In addition, *t* tests revealed a shorter reaction time for the high-conflict group on happy than on neutral trials, $t(5) = 2.67$, $p < .05$, but no significant difference for the low-conflict group on happy, compared with neutral trials, $t(5) = -0.83$, $p = .45$.

ERP Analysis

Electrodes centered on the midline and located on the parietal scalp were selected *a priori* to measure the P3, based on previous studies. A topographic map confirmed that these areas had local amplitude maxima during the time window for the P3 responses (see Figure 2).

Trial type. To test for ERP amplitude differences for the trial types, we conducted a repeated measures analysis using a GLM with trial type (angry, happy, neutral) as a within-subjects variable, and with child age and sex as covariates. We report omnibus test results using the Greenhouse-Geisser correction for sphericity (Luck, 2005). For the P3 in the angry block (in which the task was to respond to angry photos), there was a main effect of trial type, $F(1.94, 33.01) = 3.57$, $p < .05$. The contrast in that block comparing angry and happy trials revealed a larger P3 on angry trials ($M = 3.22$ µV, $SD = 2.01$) than on happy trials ($M = 2.89$ µV, $SD = 1.80$), $F(1, 17) = 7.65$, $p < .05$. There was no main effect of trial type on the P3 in the happy block, nor were there any peak latency differences in either block.

Marital conflict. To compare the ERPs generated by children from high-conflict homes with those from low-conflict homes, we conducted a 3 (trial type: angry, neutral, happy) X 2 (group: high-conflict, low-conflict) repeated measures GLM, with trial type as a within-subjects factor and with group as a between-subjects factor, and with child age and sex as covariates. For the P3 in the angry block, there was a significant marital conflict X trial type interaction, $F(1.95, 31.21) = 3.65$, $p < .05$. The contrast of angry and neutral trials for this interaction was significant, $F(1, 16) = 4.71$, $p < .05$, as was the contrast comparing happy and neutral trials, $F(1, 16) = 6.44$, $p < .05$. Follow-up *t* tests revealed a larger P3 for children from high-conflict homes on angry trials ($M = 3.92$ µV, $SD = 3.23$) than on neutral trials ($M = 1.18$ µV, $SD = 1.01$), $t(10) = -3.11$, $p < .05$), but no significant difference for the low-conflict group between angry ($M = 3.25$ µV, $SD = 1.78$) and neutral trials ($M = 2.79$ µV, $SD = 1.61$), $t(9) = -0.73$, $p = .48$ (Figure 3). Similarly, there was a larger P3 for children from high-conflict homes on happy trials ($M = 3.19$ µV, $SD = 2.26$) than on neutral trials ($M = 1.08$ µV, $SD = 1.05$), $t(10) = -3.26$, $p < .01$, but no significant difference for the low-conflict group between happy ($M = 2.46$ µV, $SD = 0.98$) and neutral trials ($M = 2.79$ µV, $SD = 1.61$), $t(9) = 0.65$, $p = .53$ (Figures 4 and 5). There was no marital conflict X trial type interaction in the happy block, nor any peak latency differences in either block.

Post-hoc analyses. An important question in ERP research is whether attention influences information processing within an early stage following stimulus presentation, and can influence stimulus encoding. To address this question for our stimuli, we additionally examined the P1 and N1, both of which have been linked with attention processes (Key et al, 2005). Although the P1 and N1 both peak around 100 ms after the appearance of visual stimuli in adults, the P1 typically peaks over occipital regions, whereas the N1 is more broadly distributed (Mangun & Hillyard, 1991). Thus, we measured the P1 (62 – 217 ms) at occipital sites, selecting electrodes *a priori* based on previous studies (e.g., Henderson, Luke, Schmidt, & Richards, 2013). We measured the N1 (72 – 227 ms) at frontal sites (Figure 1), selected *a priori* based on Guler et al. (2012). We conducted GLM analyses of the P1 and N1 to determine whether our stimuli would produce differences in ERPs reflecting early stages of attentional processing. However, we found no main effects of trial type, nor any interaction effects between trial type and marital conflict exposure, for either the P1 or the N1.

In addition, we computed correlations to investigate whether reaction time and P3 amplitudes were correlated. There were no significant correlations between the P3 and reaction time for the sample as a whole. However, on happy trials in the angry block, larger P3 amplitudes were correlated with shorter reaction times for the high-conflict group ($r = -.88$, $p < .05$), but not for the low-conflict group ($r = .59$, $p > .10$). The correlations between the P3 and reaction times on angry and neutral trials were non-significant for both groups.

Discussion

This study builds on previous research on children's responses to marital conflict in a number of ways. It presents data using a novel set of photo stimuli depicting interpersonal anger and happiness. We found that, for the sample as a whole, children generated larger P3s on angry trials than on happy trials in the angry target block. This finding suggests that, regardless of history of exposure to interparental conflict, children discriminate between depictions of interpersonal anger and happiness, and that photos depicting anger may generally be more salient to children than photos depicting happiness, at least when the task is to identify angry photos. This result builds on previous findings that children show different emotional responses to different categories of interparental behavior, for example showing negative emotional responses to interparental hostility and positive emotional responses to interparental affection (Goeke-Morey et al., 2003). Given that the P3 is thought to reflect stimulus discrimination, the current results suggest that these differences may be related to processing differences at the neural level.

The current study also builds on previous research by examining associations between marital conflict exposure and the P3. Previous studies have documented that children's emotional (Davies et al., 2002), cognitive (Grych et al., 2003), and physiological responses to conflict (El-Sheikh et al., 2010) play important roles in marital conflict-child adjustment links. The current study is one of the first to examine the neural correlates of children's exposure to marital conflict. We found that children in the high-conflict group had larger P3s in the angry block on angry and happy trials than on neutral trials, but children in the low-conflict group did not. This effect was largely due to very small ERPs on neutral trials for children in the high-conflict group. The results suggest that for children from high-conflict homes, interpersonal emotion cues may be especially salient, particularly when they are being vigilant for anger cues. As with maltreatment (e.g., Pollak et al., 1997), it may be adaptive in some ways for these children to be proficient at discriminating emotion cues from other cues. That is, if emotion cues are more salient for these children, they might be better able to respond to signs of interparental conflict by avoiding the situation, for example. By the same token, signs of interparental happiness may suggest to children the availability of parental resources and support, which may be especially important in an environment that is generally low in such opportunities.

Notably, although there was little difference in behavioral, “go” reaction time on neutral trials compared with happy trials for children from low-conflict homes, children from high-conflict homes had much longer reaction times on neutral trials than on happy trials in the angry block. The fact that the high-conflict group showed smaller P3 amplitudes to neutral photos suggests that their larger reaction times were not due to the neutral photos being more salient to them. Instead, these children may have needed more time to distinguish neutral photos from the other photo types than their low-conflict counterparts. It is possible that they needed more time to classify photos they considered to be in between neutral and angry than to classify photos they considered to be in between neutral and happy, but we cannot make this determination based on these data. However, the high-conflict group did have somewhat longer reaction times on angry photos than on happy photos (although this difference was not statistically significant), consistent with this possibility. This potential explanation fits with conceptualizations from emotional security theory and the cognitive-contextual framework that children from high-conflict homes are more vigilant for signs of conflict (Davies et al., 2014), and have a greater tendency to perceive interparental interactions as threatening (Gerard et al., 2005).

Conceptualizing P3 amplitudes as reflecting stimulus salience and meaningfulness, the small P3s of children from high-conflict homes on neutral trials raises the intriguing question, *Why were neutral trials less salient than angry and happy trials for children from high-conflict homes?* One possible explanation is that they often see their parents interacting in a neutral way, but the emotions that are really important are the happy and angry ones. Notably, the happy and angry photos do not portray intense emotion; thus, these findings suggest children find low levels of non-neutral emotion especially salient. Moreover, these effects were found only in the angry target block. That is, when happy photos were the target, no differences were found between any of the trial types. This pattern may suggest that when children are being especially watchful for signs of anger, which may be analogous to situations in which parents have had a disagreement that they have not yet resolved, children may be more likely to discriminate signs of either happiness or anger than neutrality. Consistent with this possibility, children from high-conflict homes also had shorter reaction times on all trials types in the angry target block than children from low-conflict homes, which is consistent with the possibility of heightened vigilance in this block. In contrast, when there was no incentive to watch for signs of anger (as was the case in the happy block), children in the high-conflict group appeared to find signs of happiness and anger no more salient than signs of neutrality, and respond no faster than their low-conflict counterparts. This interpretation is to some extent at odds with our earlier interpretation that the shorter reaction times of children in the high-conflict group on happy trials than on neutral trials could be due to the potentially adaptive value of vigilance for conflict. It may also be that different mechanisms underlie reaction time and the P3 – that is, although children in the high-conflict group were slower to classify neutral trials than happy ones, neutral trials might not have been as salient to them as trials with emotion cues (either happy or angry ones).

Moreover, the high-conflict group had nearly equal P3s on angry and happy trials, whereas the low-conflict group had smaller amplitudes on happy trials than on angry trials. Children from high-conflict homes also had a negative correlation between the P3 and reaction times on happy trials in the angry block, meaning larger amplitudes were associated with shorter reaction times. This pattern of findings raises the possibility that children in high-conflict homes may have altered processing of interparental happiness cues. Perhaps for these children, seeing signs of happiness toward one another in the "parent" pictures was a sufficiently rare experience that it elicited a neurophysiological response similar to that elicited by interparental anger cues. Indeed, Gottman and Levenson (1999) found that a low ratio of positive to negative marital affect is associated with less marital well-being (see also Pasch & Bradbury, 1998). Moreover, our findings are consistent with those of a recent study by Warren and colleagues (2010), examining associations between adults' attachment security and brain activation during an emotion-word Stroop task using fMRI. Compared with neutral words, on trials with pleasant words, lower attachment security was associated with more activation in portions of left dorsolateral prefrontal cortex and anterior cingulate cortex, both areas that are associated with cognitive control processes. Thus, the pleasant words appeared to draw the attention of the low-security participants more than the unpleasant words. Warren et al (2010) suggested that having less security results in needing to exert more effort to tune out the distracting emotional content.

A similar process may help account for our findings. It may be that for children exposed to more marital conflict, cognitive processing resources are recruited just as much for happy photos as for angry ones. Notably, however, if the response to happy photos is increased because of the rareness of signs of interparental happiness for children from high-conflict homes, then it would be reasonable to expect the P3 to be larger for happy photos than for angry photos for these children, but this was not the case. Thus, we suspect that the similarity of the P3 to happy and angry photos for children in the high-conflict group is a function of both rareness and salience. That is, a possible explanation is that for these children, angry photos would elicit a larger P3 because of their salience, and happy photos would elicit a larger P3 because of their rareness, resulting in P3s being larger to both angry photos and happy photos relative to neutral photos. This potential explanation could also explain the longer reaction times on neutral trials than on either happy or angry trials (although significantly longer only on happy trials) and the lack of significant reaction time differences for angry trials vs happy trials. That is, perhaps the shorter reaction times of children from high-conflict homes on happy trials compared with neutral trials is a reflection of the rareness of the happy photos compared with the neutral ones, rather than an indication of more careful deliberation over neutral photos.

We were also interested in the possibility of differences in attentional processing of different stimulus categories. To address this, we conducted post-hoc tests of the P1 and N1, which are thought to reflect early attentional processes (Luck, Woodman, & Vogel, 2000). However, we found neither main effects nor interaction effects for either the P1 or the N1. Thus, it appears, at least for 9- to 11-year-olds, the brain differentiates these interpersonal conflict stimuli at a higher level than at the very early level of processing reflected by the P1 and N1.

This study has a number of limitations. The main limitation is the small sample size, although it is certainly comparable to those of other ERP studies with children in this age range. Notably, as opposed to models using multiple between-subjects factors, which would substantially reduce power relative to the models we conducted, interparental conflict group was the only between-subjects variable in any of our analyses. Regardless, a larger sample would allow more complex models of the relations among the variables. Future studies may also benefit from examining additional ERP components in this context, including the late positive potential, which has been associated with emotion regulation (Dennis & Hajcak, 2009).

Another limitation is the use of photos displaying interpersonal happiness, anger, and neutrality, as opposed to depictions of marital conflict situations that have more ecological validity. That is, our results might not generalize well to real-world interparental conflict situations. At the same time, our use of these photos is also a strength, because the stimuli were carefully created and selected so that the photos differed from one another primarily in terms of the emotion depicted, enabling us to rule out a variety of potential confounds. Additonally, the use of photographic stimuli allowed us to examine ERPs, which would not be typically elicited in an ecologically valid (dynamic) setting.

In addition, it is not yet known whether the neurophysiological correlates of children's processing of interpersonal conflict cues are associated with child adjustment outcomes. Given the theoretical and empirical basis for predicting such associations, and given the importance of identifying mechanisms underlying associations between interparental conflict and child adjustment, this is a crucial direction for future research. This is particularly important in light of the general lack of relations between ERP amplitudes and reaction times in our study. Further, interpretation of neurophysiological findings can be difficult when they are not illuminated by connections to adjustment variables. In particular, interpretation of the responses of children in the high-conflict group on neutral trials (large reaction times, small P3 amplitudes) could potentially be clarified by examining the associations of reaction times and P3s with adjustment.

Despite these limitations, the current study makes some important contributions to the literature. Building on previous research on children's exposure marital conflict, this is the first study we are aware of to test marital conflict exposure as a predictor of ERP responses generated to analogs of interparental emotion cues. The results suggest the neurophysiological processes may be one potential mechanism involved in children's responses to marital conflict exposure. This study demonstrates that, as with more severe stressors like maltreatment, moderate marital conflict predicts child behavioral and neurophysiological responses to analogs of interparental conflict cues, suggesting saliency processing mechanisms in association with family experience in children's processing stimuli portraying social emotions in a couple.

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Table 1. Sample Characteristics, Accuracy, and Reaction Time by Group

	Marital conflict					
	High (*n* = 13)			Low (*n* = 10)		
Males	7			5		
Females	6			5		
Mean age (*SD*)	10.29 (0.91)			10.86 (0.85)		
Accuracy % (*SD*)	84.81 (4.08)			86.39 (7.04)		
Marital conflict score (*SD*)	22.15 (3.39)			14.20 (2.53)		
RT all blocks (*SD*)	1074.78 (170.77)			1138.45 (75.05)		
	Angry trials	*Happy trials*	*Neutral trials*	*Angry trials*	*Happy trials*	*Neutral trials*
RT in angry block (*SD*)	991.11 (123.14)	865.76[a] (226.22)	1058.34[a] (133.74)	1070.75[b] (81.75)	1214.91[b] (147.64)	1197.64 (103.47)
RT in happy block (*SD*)	897.34 (517.90)	1114.02 (445.39)	1411.73 (406.25)	1073.92 (175.25)	977.74 (129.46)	1283.29 (192.05)

Note. Accuracy scores and reaction time are drawn from the photos task. RT = Reaction time in ms. Cells with the same superscript (a, b) differ significantly from one another.

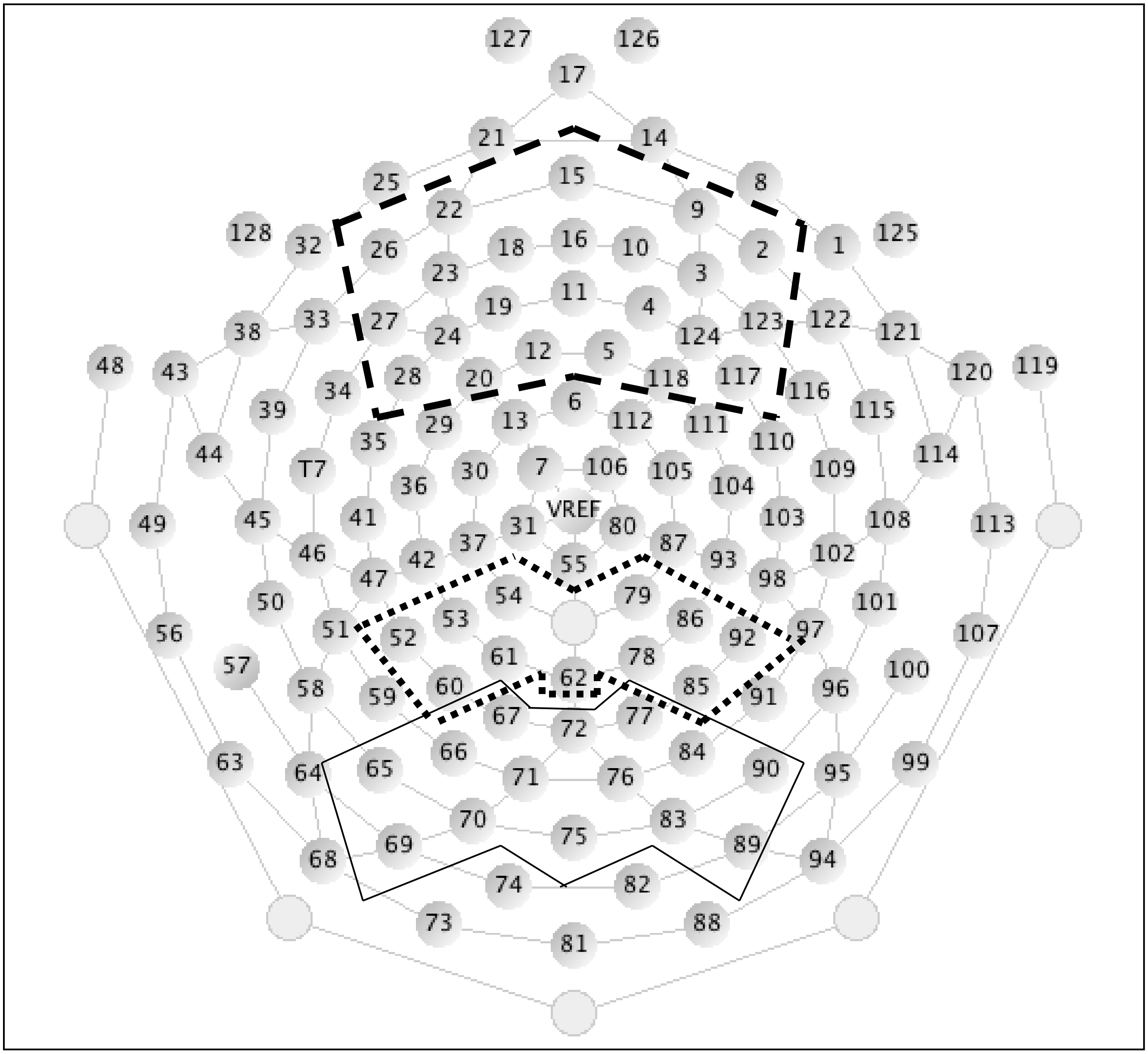

Figure 1. Layout of the EEG electrode net and locations of electrodes used for the P1, N1, and P3 analyses. The solid line denotes the occipital electrodes averaged to derive the P1 component, the dashed line denotes the frontal electrodes averaged to derive the N1 component, and the dotted line denotes the parietal electrodes averaged to derive the P3 component.

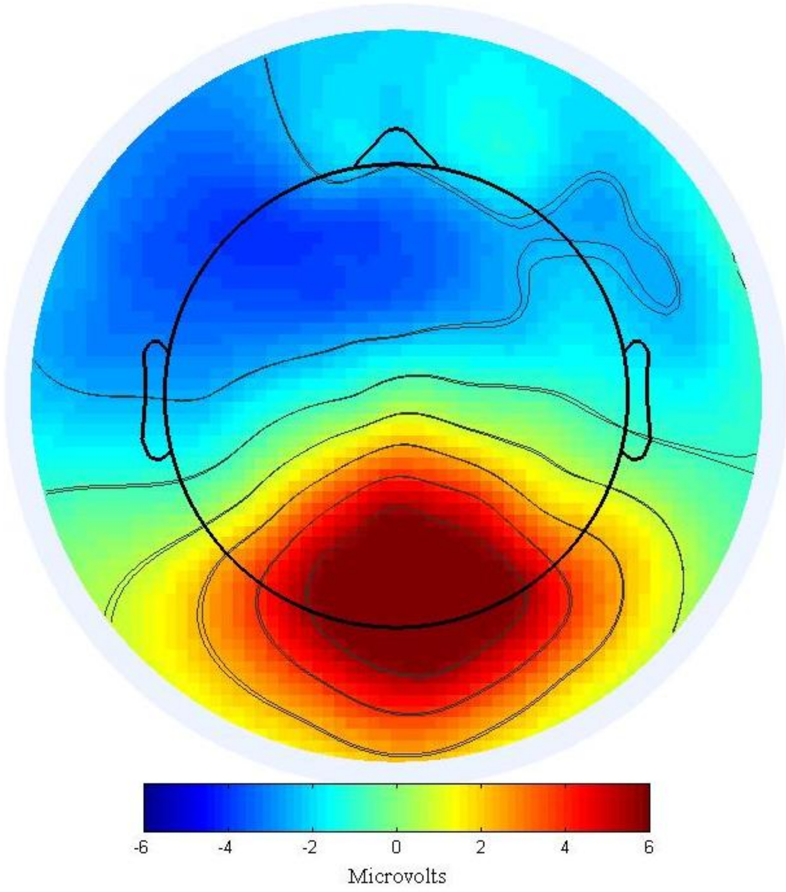

Figure 2. Topographic voltage map of P3 at the average peak latency across subjects and conditions (566 ms). Color scale is depicted in microvolts.

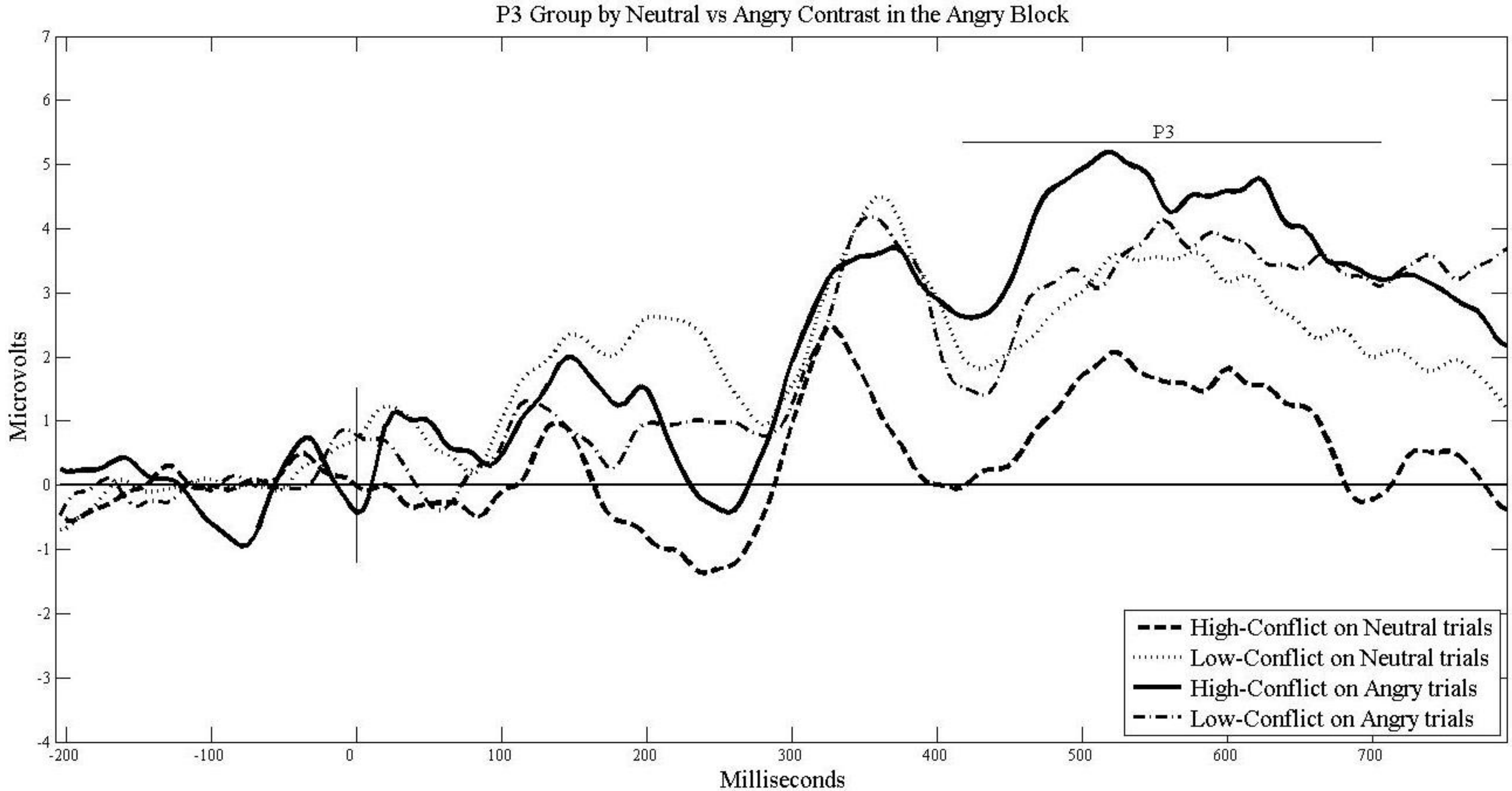

Figure 3. ERP activity elicited to neutral vs angry trials: Grand-average ERP waveforms depicting the marital conflict X trial type interaction effect on the P3 for the comparison of neutral and angry trials.

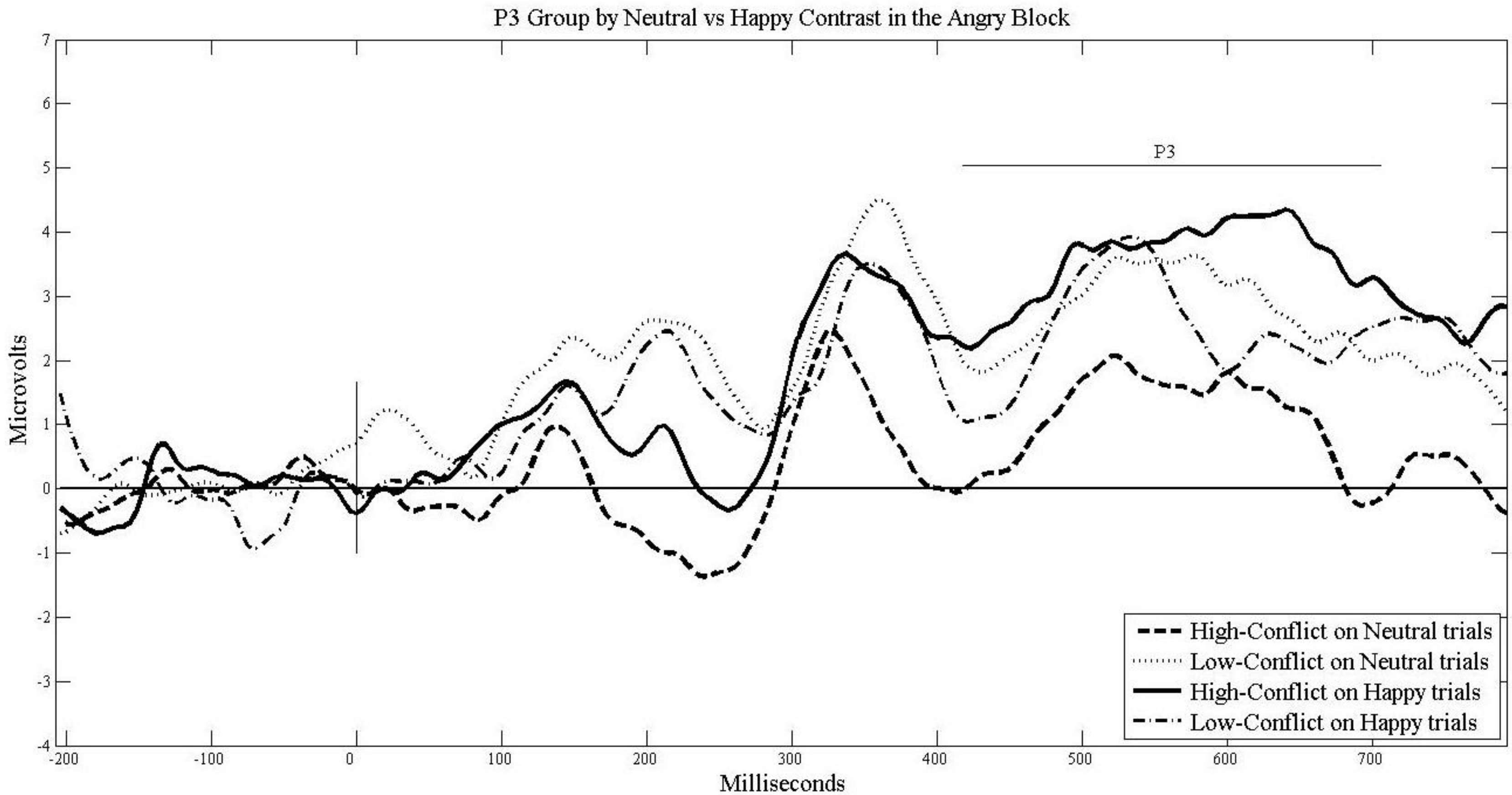

Figure 4. ERP activity elicited to neutral vs happy trials: Grand-average ERP waveforms depicting the marital conflict X trial type interaction effect on the P3 for the comparison of neutral and happy trials.

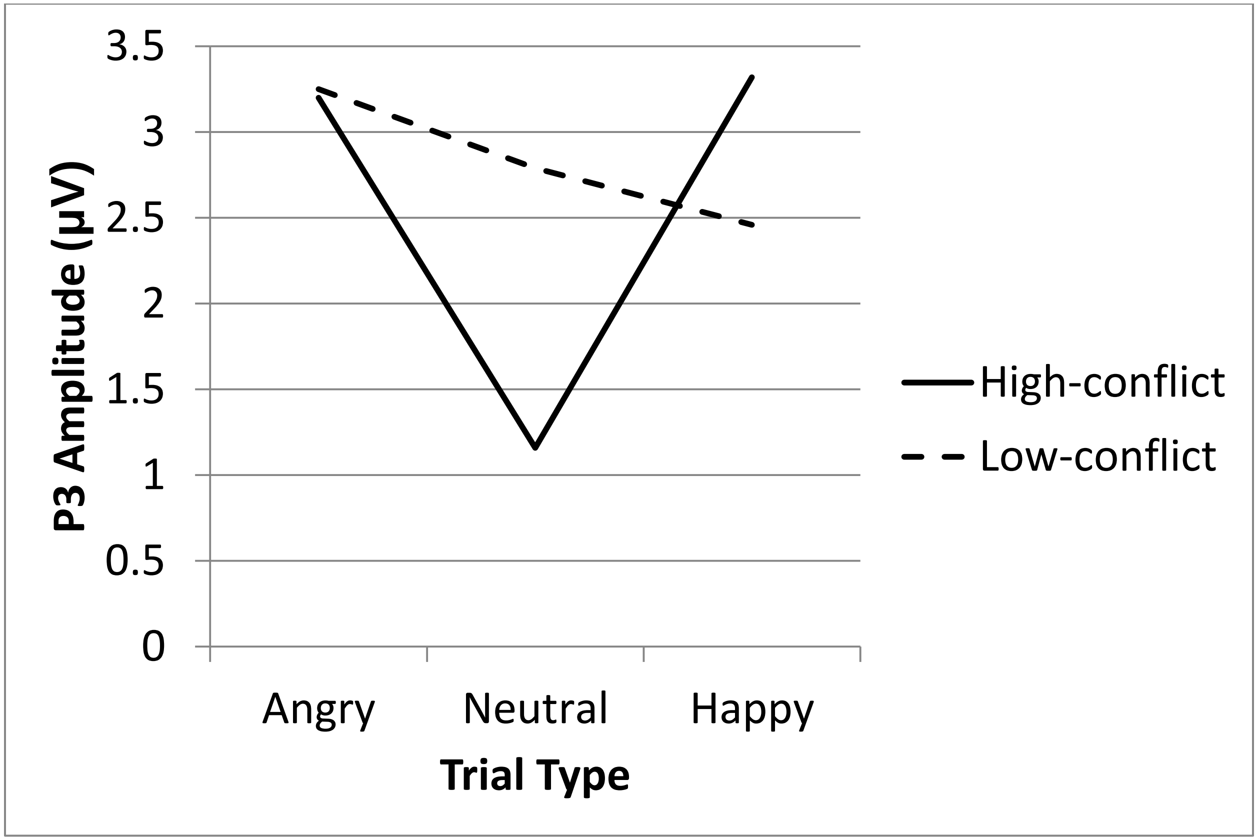

Figure 5. Mean P3 amplitudes on each trial type in the angry target block for the high- and low-conflict groups. Note that the means in the figure, which are from the GLM, differ slightly from those reported in the text, which are from the *t* tests, because one child who was excluded listwise from the GLM was included in the *t* tests, in which missing cases were omitted pairwise.