Children's Appraisals of Interparental Conflict Predict Event-related Potential Components

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Abstract

Interparental conflict and neural correlates of children's emotion processing were examined. Event-related potential (ERP) data were collected from 87 children (9-11 years old) with stimuli depicting interpersonal anger, happiness, and neutrality. Three ERP components were modulated by child-reported measures of conflict, reflecting a progression from early sensory attention to cognitive control to stimulus categorization. Negative conflict predicted larger N1 and N2 amplitudes on happy than on angry trials. Greater self-blame for conflict predicted larger N2 amplitudes across emotions and larger P3 amplitudes on angry than on neutral or happy trials. Results suggest conflict-related experiences shape processing of interpersonal emotion.

Keywords: event-related potential (ERP) components; interparental conflict; emotion processing; children

Children’s Appraisals of Interparental Conflict Predict Event-related Potential Components

Early rearing experiences alter developing neurobiology, including the development of emotion neurocircuitry (Callaghan & Tottenham, 2016). Evidence of such influence comes, in part, from studies showing associations of severe forms of early rearing adversity with event-related potential (ERP) components (Nelson, Westerlund, McDermott, Zeanah, & Fox, 2013; Pollak, Cicchetti, Klorman, & Brumaghim, 1997; J. E. Shackman, Shackman, & Pollak, 2007). Recently, studies have begun to examine associations with less severe forms of adverse family experiences. This work includes findings that moderate forms of family adversity, such as harsh parenting (Meyer et al., 2015), parental depression (Kujawa, Hajcak, Torpey, Kim, & Klein, 2012), and the combination of sub-optimal parenting and parental depression (Kujawa, Proudfit, Laptook, & Klein, 2015) are associated with ERP components reflecting such processes as reward responding and performance monitoring.

Among moderate forms of early adversity, children’s experiences with conflict between their parents, which play a key role in shaping development (Cummings & Davies, 2002; Davies & Martin, 2013), may be linked with neurocognitive processes as well. Such experiences can range from very positive to very negative conflict (Goeke-Morey, Cummings, Harold, & Shelton, 2003). Of particular interest in the current study, prior exposure to higher levels of negative interparental conflict (e.g., more frequent, intense, poorly resolved conflict) may shape children’s processing of salient events, such as emotion cues. That is, exposure to more negative interparental conflict may lead children to attend to and process environmental events in ways that help them guard against adverse outcomes (e.g., through avoidance behaviors, mobilization of resources to defend and engage, or other strategies, Davies, Hentges, & Sturge-Apple, 2015). Indeed, recent work has shown that children’s experiences with negative interparental conflict and violence are associated with alterations in children’s recognition of emotion (Raver, Blair, & Garrett-Peters, 2014) and their allocation of attention to emotion faces (Briggs-Gowan et al., 2015). Moreover, Lucas-Thompson, Dumitrache, and Sparks (2017) found that, in young adults, greater perceptions of threat regarding interparental conflict predicted allocation of less attention to stimuli depicting interpersonal happiness. Furthermore, self-blame also significantly predicted *increases* in allocation of attention to interpersonal anger after viewing simulated marital conflict displays (Lucas-Thompson, Dumitrache, et al., 2017).

Several cognitive subsystems are centrally involved in the processing of emotion cues, including early sensory attention, stimulus discrimination, cognitive control supporting selection of optimal behavioral responding, and working memory and stimulus categorization processes, and a number of ERP components are highly relevant to these cognitive subsystems. The P1 and N1, the first positive (P1) and negative (N1) deflections of the electroencephalogram (EEG) time-locked to stimulus onset, both reflect visual-spatial selective attention. The P1 peaks over occipital regions, and the N1 is more broadly distributed (Mangun & Hillyard, 1991). Whereas the P1 and N1 both reflect early attentional processing, they also differ from one another, in that the P1 is modulated by the subject's arousal state (Luck, 2014), and is enhanced by emotional relative to neutral stimuli (Stormark, Nordby, & Hugdahl, 1995), as well as by facial expressions of emotion (Eimer & Holmes, 2007). In contrast, the N1 reflects, in part, stimulus discrimination-related attentional processing (i.e., attentional processes while distinguishing between categories of stimuli) (Vogel & Luck, 2000). Children's attentional processing of emotion cues would be expected to be linked with children's experiences with interparental conflict, and both arousal-related attentional processes (P1) and stimulus discrimination attentional processes (N1) are likely closely related to children's cognitive appraisals of interparental conflict.

The N2 is a negative-polarity ERP that occurs around 200 - 350 ms post-stimulus onset in adults (Folstein & Van Petten, 2008). The N2 measured over frontocentral scalp has been linked most consistently with detection of novel stimuli and with cognitive control and inhibitory processes (Folstein & Van Petten, 2008). Recent work suggests that negative emotion and cognitive control are integrated within the anterior midcingulate cortex (A. J. Shackman, Salomons, et al., 2011). Information about potential threat cues is likely utilized in the anterior midcingulate cortex to guide the selection of behavior under conditions marked by uncertainty of the risk of punishment (A. J. Shackman, Salomons, et al., 2011). These conditions strengthen the need for cognitive control, leading to control behaviors intended to make a negative outcome less likely (Tolomeo et al., 2016). The N2 reflects efforts to detect salient information in the environment, such as signals of angry emotions, and to use that information to select behavior that will be optimally adaptive for the context (Cavanagh & Shackman, 2015). Thus, the N2 may be particularly sensitive to stimuli depicting the potential threat cue of interpersonal anger. This may be particularly true when task demands result in greater effort to detect anger cues, and especially for children who perceive higher levels of threat regarding conflict between their parents.

Measured at parietal electrodes, the P3 (also referred to as P3b) is thought to reflect stimulus discrimination and categorization processes, as well as allocation of attentional resources, and a larger P3 amplitude is generated by infrequent target stimuli (Key, Dove, & Maguire, 2005; Polich, 2007). Generation of a P3 requires an internal comparison between the incoming stimulus and the previous frequent stimulus, also producing context updating (see review by Polich, 2007). The last incoming sensory stimulus is likely maintained in working memory so that this comparison can be made. In addition, in order for the comparison to be successful, there must be an adequate allocation of attentional resources to the task. Additionally, the subject needs to continually maintain the response rule online (e.g., respond to stimuli of a particular category). Once the comparison is completed, the incoming target stimulus is stored in memory, which is likely what generates the P3 (Polich, 2007). Much of the literature on the P3 pertains to basic cognitive tasks, but the P3 has also been found to be generated by emotionally valenced stimuli compared with neutral stimuli (Johnston, Miller, & Burleson, 1986; Pollak et al., 1997). Thus, in summary, the P3 is thought to reflect stimulus discrimination and categorization processes, as well as allocation of attentional resources, and ultimately stimulus salience.

These same cognitive subsystems are likely integral to children's processing of emotion cues, including in the context of interparental conflict, and are likely linked with children's appraisals of conflict. Children form cognitive appraisals of the frequency, intensity, and degree to which interparental conflict is resolved, which correspond in magnitude to the severity of negative interparental conflict reported by parents (Grych, Seid, & Fincham, 1992). These appraisals are correlated with child adjustment problems, including internalizing and externalizing problems (Grych, Harold, & Miles, 2003). Moreover, children also form appraisals of the degree to which they perceive interparental conflict as a threat to family well-being, and the degree to which they blame themselves for their parents' conflicts. Whereas appraisals of self-blame consistently predict externalizing problems and sometimes predict internalizing problems as well, threat appraisals more consistently predict internalizing problems (Fosco & Grych, 2008; Grych et al., 2003). The goal of the current study was to examine associations of children's appraisals of interparental conflict with select ERP measures during children's processing of others' emotions. That is, we were interested in children's appraisals of interparental conflict as predictors of neurophysiological indices of early attention processing, cognitive control, and stimulus categorization while viewing images depicting simulated interpersonal emotion.

A few recent studies have examined associations between neurophysiology and children's experiences with interparental conflict. The first, a functional magnetic resonance imaging (fMRI) study, examined sleeping infants' brain activation while they were presented with angry, happy, and neutral voices (Graham, Fisher, & Pfeifer, 2013). Infants whose mothers reported more negative interparental conflict showed more activation in parts of the anterior cingulate cortex and the hypothalamus, brain regions linked with emotional reactivity and regulation. A second study showed that regions of the default mode network had stronger connectivity in infants whose parents' conflict was more negative (Graham, Pfeifer, Fisher, Carpenter, & Fair, 2015). The default mode network has been linked with both early life adversity and mental health problems. In addition, in an ERP study, while children viewed videotaped depictions of simulated interparental conflict, task-irrelevant auditory probes were presented and ERP components elicited by the probes were measured (Schermerhorn, Bates, Puce, & Molfese, 2017). Within this experimental paradigm, relatively smaller probe-evoked ERP amplitudes indicate relatively less diversion of information processing resources from the videos to the probes, suggesting allocation of greater information processing resources to the videos. Results of the study indicated that more frequent and intense interparental conflict was associated with allocating more information processing resources to simulated interparental conflict videos, indexed by smaller P1, P2, and N2 amplitudes to the probes. Moreover, smaller N2 amplitudes were associated with more externalizing problems. Lastly, in another ERP study, children who were exposed to more frequent and intense interparental conflict, based on mother report, had larger P3 amplitudes to images depicting interpersonal emotion (happy and angry) relative to interpersonal neutrality, but children from low-conflict homes did not (Schermerhorn, Bates, Puce, & Molfese, 2015).

These latter results provide initial evidence of associations between parent-reported interparental conflict and the P3 during processing of interpersonal emotion cues. The current study extends this work by examining children's reports of their cognitive appraisals of interparental conflict. Although parents' reports of interparental conflict frequency and intensity are consistently correlated with children's reports of these aspects of interparental conflict, parents' reports of conflict frequency and intensity are less consistently associated with children's reports of threat and self-blame regarding interparental conflict (Grych et al., 2003; Grych et al., 1992), and differences between parents' and children's reports may hinge on a variety of factors (Lucas-Thompson & George, 2017). Moreover, pertinent to the current investigation, children's reports are likely more closely linked to children's own neurophysiology than are parents' reports. In this study, we examined associations between children's appraisals of interparental conflict and children's neurophysiology in a larger sample than those of previous ERP studies of interparental conflict and examined the progression through the stages of cognitive processing reflected in the P1, N1, N2, and P3.

Whereas studies have shown associations between several of these components and exposure to severe adversity (e.g., Nelson et al., 2013; Pollak et al., 1997), ERP studies of less severe forms of adversity, such as parenting and parental depression, have largely focused on different ERP components. For example, previous work has found associations between harsh parenting and higher levels of performance monitoring, reflected in the error-related negativity (ERN) component (Meyer et al., 2015). Moreover, the combination of maternal depression and sub-optimal parenting predict reduced reward responsiveness, reflected in the feedback negativity (FN) (Kujawa et al., 2015). Thus, whereas these studies have been very informative about associations of less severe forms of adversity with such developmentally significant processes as performance monitoring, little is known about links with neurophysiological indices of early attention, cognitive control, and stimulus discrimination, which are also developmentally important cognitive processes.

Moreover, very little is known about associations between moderate levels of family adversity and children's processing of emotional displays. In one of the few studies to examine these associations, Kujawa et al. (2012) found that parental depression predicted less differentiation of the late positive potential (LPP), reflecting emotion processing, for emotional faces relative to neutral faces. Further, several ERP components, including the P3, suggested children whose mothers had a history of depression attended less to sad faces, compared with other children (Gibb, Pollak, Hajcak, & Owens, 2016).

Building on this work, the goal of the current study was to examine associations of children's appraisals of interparental conflict with select ERP components during children's processing of emotion. Measuring the P1, N1, N2, and P3 in this context enabled examination of cognitive subsystems that are especially likely to be associated with alterations in children's appraisals of interparental conflict. We tested two main hypotheses: 1) that appraisals of interparental conflict as more frequent, intense, and unresolved; appraisals of greater threat from conflict; and appraisals of greater self-blame for conflict would predict larger ERP amplitudes, across the stages of cognitive processing reflected in these ERP components, given associations between these appraisals and child functioning (Grych et al., 2003); and 2) that these same appraisals would predict larger ERP amplitudes for images of angry faces than for other facial expressions, given findings showing larger P3s related to angry stimuli in studies of maltreatment (Pollak et al., 1997) and interparental conflict (Schermerhorn et al., 2015).

Method

Participants

The sample for the current study was drawn from a larger study of emotional development involving 119 nine-to-eleven-year-old children and their mothers living in the northeastern United States. Inclusion criteria required that children live with their biological parents, who had to be married to each other, and that children had to read at a 4th to 5th-grade level or higher, have normal or corrected-to-normal vision and hearing, and not have any known neurological condition (such as epilepsy) or any traumatic brain injury or head injury that included loss of consciousness. In addition, a telephone screening was used to screen for, and exclude, families with a history of violence. Of the children in the larger study, data from 10 children were excluded from the current study because their mothers reported they were taking prescription medications for a medical, neurological, attentional, or behavioral disorder, data from 1 child were excluded because of a developmental delay reported by the mother during the lab visit, data from 1 child were excluded because of illness during the lab visit, and data from 1 child were excluded because of a neurological impairment reported by the mother during the lab visit. In addition, data from 5 participants were excluded because of poor performance on the ERP task (< 66.67% accuracy) and data from 14 participants were excluded due to significant artifacts (see EEG data section for details).

The final sample included 87 children (41 females, 45 males, 1 unspecified gender; *M* age = 10.67 years; *SD* = 0.81 years). Representative of the demographic characteristics of the area, 92% of children were Caucasian, 1% were American Indian/Alaska Native, and 7% were multiracial, and the majority of families were middle-class. Parents' mean length of marriage was 14.82 years (*SD* = 4.36 years).

Procedure and Measures

Experimental stimuli: Creation and screening. We used a validated stimulus set depicting displays of interpersonal emotion (Schermerhorn et al., 2015). The initial stimulus pool consisted of 257 color photographs, taken by a professional photographer, of two university theater students (one male, one female). In the photos, the actors, who were both Caucasian, posed as a couple and depicted a range of levels of interpersonal anger, happiness, and neutrality. The actors were positioned in front of a black background and were oriented partway toward each other, with their faces in view from the front. Stimulus screening was conducted with an independent sample of twenty 9- to 11-year-old children. The stimulus screening protocol was approved by the university's ethics committee, with mothers providing written informed consent and children providing written assent. For the stimulus screening study, children viewed the photos and categorized each as happy, angry, neutral, or indeterminate, with no time limit for responding. During this task, four pairs of labeled graphical emoticon images (one for each of the above categories) appeared on the bottom of the touch-screen monitor, and the photos of the actors were presented one at a time above the labeled emoticon images. An experimenter gave the children the following instructions: 'If the photo is happy, touch the image labeled "Happy." If the photo is angry, touch the image labeled "Angry." If the photo is in between happy and angry, touch the image labeled "Neutral (so-so)." If you can't tell what the photo is, touch the image labeled "Can't tell."'

These categorizations of the photos enabled identification of the photos most-classified as 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 classified by the most children as angry, and the 102 photos classified by the most children as neutral were selected for use in the current study (including 4 happy, 4 angry, and 12 neutral photos for practice trials). To ensure that the actors' positions would not be a confound, a flipped copy was created of each image, showing the actors on the opposite sides of the image from the original. The originals and flipped copies were randomly assigned to experimental blocks, so each actor appeared on each side of the screen an equal number of times for each trial type in each block.

EEG task. The task was presented using Presentation software (Neurobehavioral Systems, Inc.; Berkeley, CA) on a Hewlett Packard Compaq 4000 Pro SFF Business PC with a 24-inch ViewSonic V3D245 LED 120-Hz monitor. The stimuli were presented in a 2-block, 3-stimulus oddball paradigm, consistent with Pollak et al. (1997). Each trial began with the presentation of a white fixation cross presented in the middle of a black screen, followed by presentation of a photo. Neutral photos were presented on 60% of trials (90 trials/block), and happy and angry photos were each presented on 20% of trials (30 trials/block/emotion). Each block consisted of 150 trials (300 total trials for the task) plus 20 practice trials. The order of the blocks was counterbalanced, and the order of photo presentation within the blocks, and duration of the interstimulus interval (1000-2000 ms), were randomized. Duration of photo presentation was 1500 ms. In one block of the task, children were asked to press a button on a Logitech F310 game controller they held in their hands in response to angry photos and refrain from button-pressing in response to other photos (angry target block); in the other block, children were asked to button-press in response to happy photos only (happy target block). These responses were recorded and used to calculate accuracy and response time. The task design, requiring only infrequent motor responses (on only 20% of trials) and presenting non-neutral stimuli (i.e., angry and happy) on only 40% of trials, was intended to elicit neurophysiological processes related to detection of salient emotional information.

Children were seated approximately 60 inches from the computer screen, resulting in a visual angle of approximately 4.02° (horizontal) X 2.59° (vertical), to minimize the need for eye movements to view the stimuli. Prior to beginning the task, children were given detailed instructions for completing the task. An experimenter explained to the child 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.”

EEG data acquisition. The electroencephalogram (EEG) was recorded continuously using an Electrical Geodesics, Inc. (EGI; Eugene, OR) Net Amps EEG 300 system, with 128-channel HydroCel Geodesic Sensor Nets. Prior to beginning each block, electrode impedances were reduced below 70 kΩ, per manufacturer’s instructions. The EEG was recorded using NetStation acquisition software (Version 4.5.4, EGI), with a sampling rate of 250 Hz and a DC – 100 Hz bandpass filter. Data were referenced to the vertex electrode (with a midline frontocentral ground electrode).

Data were exported from the EGI software as binary files, and further processing was completed using EEGLAB v13.1.1 (Delorme and Makeig, 2004) operating in the MATLAB R2012b (MathWorks, Natick, MA) environment. This processing included filtering with a 0.3–40 Hz bandpass filter, and visual inspection to identify electrodes that had non-optimal scalp contact. A manufacturer-issued latency correction factor was applied, to adjust for effects of the Net Amps hardware's anti-aliasing filter interacting with the NetStation software, which was dependent on sampling rate (Electrical Geodesics, Inc., communication November 26, 2014). For our (default) sampling rate of 250 Hz, the event codes needed to be shifted positively by a correction factor of 8 ms. ERP amplitude data were not affected by this interaction. In addition, a photocell with audio/visual testing device (Electrical Geodesics, Inc.) was used to measure the timing delay of the stimulus presentation system (Luck, 2017), indicating an additional 12 ms correction was needed to further shift the event codes positively. The event codes were shifted offline, applying the total 20-ms correction needed. To identify and remove eyeblink artifacts, an independent components analysis (ICA; Makeig, Debener, Onton, & Delorme, 2004) was run on each file (see Hoffmann & Falkenstein, 2008) using runica, excluding bad channels, specifying the PCA option, and generating 32 components. Subsequently, using ERPLAB v6.1.3 (Lopez-Calderon and Luck, 2014) with EEGLAB v13.5.4b (Delorme and Makeig, 2004) and MATLAB R2015a (MathWorks, Natick, MA), the data were segmented into 1200-ms epochs, which included a 200-ms baseline, and baseline correction was performed using the pre-stimulus period. Data from channels with sub-optimal scalp contact were replaced using spherical spline interpolation, and the data were re-referenced to an average reference. Trials with voltages exceeding ±200 µV were removed using ERPLAB's simple voltage threshold function. Remaining trials were averaged together within trial type. Removing trials with voltages exceeding ±200 µV after conducting ICA enabled us to preserve as much of the recording as possible for ICA, which requires many data points. For the statistical analyses of the EEG data, only trials with correct behavioral responses were examined. Responses were excluded if they occurred less than 100 ms after stimulus onset, or more than 1500 ms after stimulus onset.

As noted earlier, data from 5 participants were excluded because of poor performance on the task (< 66.67% accuracy) and data from 14 participants were excluded due to significant artifacts. Specifically, regarding exclusion due to artifacts, data from participants with fewer than ten usable trials per trial type were not analyzed, resulting in the exclusion of data from 3 children without a sufficient number of angry trials in the angry block, 2 children with insufficient happy trials in the angry block, 6 children with insufficient neutral trials in the angry block, and 3 children with insufficient happy trials in the happy block. Thus, due to our criterion that participants were excluded if they had fewer than ten usable trials per trial type, ERP and behavioral analyses were based on data from 87 children. Included and excluded participants did not differ in age, gender, or interparental conflict scores (all ts < 1.52, ps > 0.13).

For the 87 children included in the analyses, across trial types within the angry target block, an average of 22.75 (*SD* = 14.12) trials per child were rejected due to artifacts; across trial types within the happy target block, an average of 24.84 (*SD* = 14.40) trials per child were rejected due to artifacts. The mean number of trials comprising ERPs in the angry target block was 20.97 for angry trials (SD = 4.98; range = 10–30), 25.03 for happy trials (SD = 3.62; range = 14–30), and 57.06 for neutral trials (SD = 15.67; range = 21–87). The mean number of trials comprising ERPs in the happy target block was 24.47 for angry trials (SD = 3.58; range = 16–30), 22.37 for happy trials (SD = 4.59; range = 12–30), and 70.95 for neutral trials (SD = 10.72; range = 44–90).

The time windows for measuring ERP amplitudes were identified through visual inspection of the EEG waveform morphologies and scalp topographic voltage maps of grand-averaged data, averaged across all participants, blocks, and trial types (Luck & Gaspelin, 2017). On the basis of previous studies with this age group (e.g., Gibb et al., 2016; Güler et al., 2012; Lamm et al., 2014; Thai, Taber-Thomas, & Pérez-Edgar, 2016), clusters of electrodes were identified *a priori* for the measurement of ERP amplitudes, and the selection of time windows was also informed by these studies. ERP amplitudes were computed as the mean voltage of the samples relative to baseline, in the following time windows relative to stimulus onset: P1 from 80-180 ms, N1 from 85-200 ms, N2 from 270-390 ms, and P3 from 440-720 ms (see Figures 1 – 3 for grand-averaged waveforms). The P1 was measured at occipital electrodes (70, 71, 75, 76, 83), the N1 and N2 were measured at frontocentral electrodes (5, 6, 11, 12, 16), and the P3 was measured at parietal electrodes (54, 61, 62, 78, 79) (see Figure 4 for topographic voltage maps).

Children's appraisals of interparental conflict. Children reported their appraisals of interparental conflict, threat, and self-blame regarding interparental conflict using the Children's Perceptions of Interparental Conflict Scale (CPIC; Grych et al., 1992). The 48-item CPIC is completed using a 3-point scale consisting of 0 (*false*), 1 (*sort of true*), and 2 (*true*), and higher scores reflect more conflict, threat, and self-blame. The Conflict Properties subscale is a 16-item measure of appraisals of the frequency, intensity, and resolution (reversed) of interparental conflict. It includes such items as "My parents get really mad when they argue." The 12-item Threat subscale assesses appraisals that interparental conflict could lead to worse problems (e.g., "When my parents argue I worry that they might get divorced."). The 9-item Self-Blame subscale assesses appraisals of self-blame for interparental conflict (e.g., "My parents blame me when they have arguments."). The CPIC is a widely used questionnaire that has demonstrated good psychometric properties (Grych et al., 1992). Cronbach's αs in this sample were 0.87 for Conflict Properties, 0.81 for Threat, and 0.73 for Self-Blame.

Model testing. To test the hypotheses regarding associations between children's appraisals of interparental conflict and ERP amplitudes, mixed models were computed in SPSS (IBM SPSS Statistics, Version 23.0.0.0). This analysis allowed the different trial types to be compared to one another (as in a repeated measures general linear model), while also allowing children's appraisals of interparental conflict to be handled as continuously scaled variables (a more powerful approach than using categorical/group variables). Based on preliminary model testing to identify the best-fitting model using criteria specified by Raftery (1995), the identity covariance structure was used. Each model included trial type (angry, happy, neutral) as a within-subjects factor, one CPIC score (Conflict Properties, Threat, and Self-blame; one CPIC score/model) as a between-subjects factor, and the CPIC score X trial type interaction, with ERP amplitudes as the dependent variables (one ERP component/model). Child age and gender were included as covariates in all models. Models were computed examining four ERP components (P1, N1, N2, P3), separately by block (angry target, happy target), separately for each appraisal type (conflict properties, threat, self-blame). Although there was some missing data (2 participants were missing the CPIC), analyses used the restricted maximum likelihood (REML) method to accommodate missing data. CPIC scores and child age were mean-centered, and gender was scaled with male gender set equal to 0 and female gender set to 1. Differences between trial types (e.g., angry vs neutral) and tests of simple slopes were evaluated only if the omnibus tests were significant ($p < .05$). Moreover, tests of first-order effects of trial type, first-order effects of children's appraisals, and interactions between the two were computed controlling for each other, making the tests more conservative and reducing the number of tests computed.

Given the study's hypotheses, reporting of the results focuses largely on results involving CPIC scores, although significant first-order effects of trial type are described as well. For models with significant results involving differences between trial types, because neutral trials provide a consistent point of comparison to both happy and angry trials in both target blocks, numerical results involving comparisons to neutral trials are presented in tables, and the valence of the results is described briefly in the text below. Numerical results that do not involve trial type differences (e.g., first-order effect of CPIC Conflict Properties), as well as numerical results involving comparisons between happy and angry trials (which are not presented in the tables because neutral trials are the reference condition), are reported only in the text below.

Results

Behavioral Results

Means and standard deviations for response time, accuracy data, and ERP component amplitudes on each trial with correct responses are presented in Table 1. Response times were faster for correct trials (M = 876.92, SD = 86.41) than for incorrect trials (M = 1006.84, SD = 136.90), $t(85) = -8.69$, $p < .0001$ (analysis omits one child who had no incorrect trials). Notably, many participants had zero or very few trials in which they made behavioral responses on happy trials in the angry target block, angry trials in the happy target block, or neutral trials in either block (all of which are incorrect responses). Children were less accurate on angry trials in the angry block (M = 84.29% correct, SD = 14.12) than they were on happy trials in the happy block (M = 91.46% correct, SD = 9.98), $t(86) = -4.74$, $p < .0001$. Bivariate correlations among CPIC scores, response times, accuracy, and ERP amplitudes in the angry target block on angry trials with correct responses and in the happy target block on happy trials with correct responses are presented in Table 2. CPIC Conflict Properties scores were significantly correlated with CPIC Threat and CPIC Self-blame, as expected, but Threat and Self-blame were not significantly correlated with one another. CPIC scores were generally not significantly correlated with response time, accuracy, and ERP amplitude data, but shorter response times were associated with less accuracy and with larger P3 amplitudes.

Electrophysiological Results

P1. All first-order effects and interaction effects involving trial type and the CPIC scores were non-significant in all models for the P1 for both target blocks (all *p*s > 0.13 for omnibus first-order and interaction tests of the primary variables).

N1. In the CPIC Conflict Properties model for the angry target block, there was a significant first-order trial type effect (Table 3). The table rows for angry and happy present the results for those two trial types relative to neutral trials (the reference trial type). For example, the row for happy trials (Estimate = -0.77) indicates that children had larger (more negative) N1 amplitudes on happy than on neutral trials and this difference was statistically significant. N1 amplitudes on angry and neutral trials did not differ significantly from one another. The contrast of happy and angry trials showed a non-significant trend for a larger N1 on happy than on angry trials, *t*(164) = -1.80, *p* = .07. Thus, for the sample as a whole, the N1 was larger on happy trials than on neutral trials in the angry target block. Relevant to our hypotheses, there was also a significant first-order effect of CPIC Conflict Properties in this model. To interpret this effect, a multiple linear regression of N1 on Conflict Properties was computed across trial type within the angry target block. This test indicated a non-significant trend for Conflict Properties to predict the N1 across trials within the angry target block, *b* = -0.08, *t*(80) = -1.85, *p* = .07; the model did not explain a significant proportion of the variance in N1 amplitudes, R^2 = 0.05, *F*(3, 80) = 1.39, *p* = .25. This result suggests that children with higher Conflict Properties scores tended to have larger N1 amplitudes across trial types when task demands involved responding to angry images, but the effect was not statistically significant.

In the happy target block, there was a significant CPIC Conflict Properties X trial type interaction effect on N1 amplitudes (Table 3). To probe the interaction, the simple slopes were evaluated for each trial type (Aiken & West, 1991). The difference between happy and angry slopes was significant, *t*(164) = -2.91, *p* = .004, indicating higher Conflict Properties scores predicted a larger (more negative) N1 on happy than on angry trials. No other simple slopes comparisons were significant. Thus, when happy images were the target trial type, children who reported more frequent, intense, unresolved interparental conflict had larger N1s on happy than on angry trials.

In the model for CPIC Threat in the angry target block, there was a significant first-order effect of trial type as above, *F*(2, 164) = 4.92, *p* = .008), with larger N1 amplitudes on happy than on neutral trials, *t*(164) = -3.12, *p* = .002). Similarly, in the model for CPIC Self-blame in the angry target block, there was a significant first-order effect of trial type, *F*(2, 164) = 4.91, *p* = 0.008), again with larger N1 amplitudes on happy than on neutral trials, *t*(164) = -3.12, *p* = .002). However, there were no other significant first-order or interaction effects in the tests of either CPIC Threat or Self-blame for either block.

N2. For Conflict Properties, in the angry target block, the first-order trial type effect observed for the N1 was found for the N2; the N2 was larger on happy than on neutral trials (see Table 4), and larger on happy than on angry trials, *t*(164) = -3.38, *p* = .0009). There were no other statistically significant effects in the angry block. However, in the happy target block, there was a significant Conflict Properties X trial type interaction effect on N2 amplitudes (Table 4). The difference between the happy and angry slopes was significant, *t*(164) = -2.57, *p* = .01, indicating higher Conflict Properties scores predicted larger (more negative) N2 amplitudes on happy than on angry trials. No other simple slopes comparisons were significant. This means that, as with the N1, when happy images were the target trial type, children who reported more frequent, intense, unresolved interparental conflict had larger N2s on happy than on angry trials.

For Self-blame, in the angry target block, there was a significant first-order trial type effect (Table 5); in addition to being larger on happy than on neutral trials, the N2 was larger on happy than on angry trials, *t*(164) = -3.35, *p* = .001). Further, there was a significant first-order effect of Self-blame. A multiple linear regression computed across trial types within the angry target block indicated that Self-blame significantly predicted the N2 across trials within the angry target block, *b* = -0.31, *t*(80) = -2.40, *p* = .02, and the model explained a significant proportion of the variance in N2 amplitudes, R^2 = 0.11, *F*(3, 80) = 3.26, *p* = .03. Thus, children with higher Self-blame scores had larger N2 amplitudes across trial types when task demands involved responding to angry images. There were no other significant effects for this model, and there were no significant effects in the Self-blame happy target block model.

In addition, in the model test of CPIC Threat in the angry target block, there was a significant first-order effect of trial type as above, *F*(2, 164) = 5.83, *p* = .004; in addition to the larger N2 on happy than on neutral trials, *t*(164) = -2.14, *p* = .03), the N2 was larger on happy than on angry trials, *t*(164) = -3.37, *p* = .0009). There were no other significant first-order or interaction effects in the tests of Threat in either block, although there was a non-significant trend for a Threat X trial type interaction in the angry target block, *F*(2, 164) = 2.80, *p* = .06.

P3. For Conflict Properties, there were significant first-order effects of trial type in both blocks, angry target block: *F*(2, 164) = 25.04, *p* < .0001; happy target block: *F*(2, 164) = 89.15, *p* < .0001. In the angry target block, P3 amplitudes were larger on angry than on neutral trials, *t*(164) = 7.05, *p* < .0001, larger on angry than on happy trials, *t*(164) = 4.03, *p* < .0001, and larger on happy than on neutral trials, *t*(164) = 3.02, *p* = .003. In contrast, in the happy target block, P3 amplitudes were larger on happy than on neutral trials, *t*(164) = 12.32, *p* < .0001, larger on happy than on angry trials, *t*(164) = 10.62, *p* < .0001, and marginally but non-significantly larger on angry than on neutral trials, *t*(164) = 1.70, *p* = .09. Thus, within each block, children had larger P3 amplitudes on trial types that matched the target type in that block (largest P3 on angry trials in the angry block; largest P3 on happy trials in the happy block). There were no other significant first-order or interaction effects in the tests of Conflict Properties in either block, although there was a non-significant trend for a Conflict Properties X trial type interaction in the happy target block, *F*(2, 164) = 2.82, *p* = .06.

For Threat, the pattern of results was similar, with significant first-order trial type effects in each block (both *p*s < .001), again with the largest P3s on angry trials in the angry target block (*p*s < .001), and the largest P3s on happy trials in the happy target block (*p*s < .001). There were no other significant first-order or interaction effects in the tests of Threat in either block, although there was a non-significant trend for a Threat X trial type interaction in the angry target block, *F*(2, 164) = 2.43, *p* = .09.

For CPIC Self-blame, there were significant first-order trial type effects in each block as shown in Table 6, again with the largest P3s on angry trials in the angry target block (*p*s < .001), and the largest P3s on happy trials in the happy target block (*p*s < .001). In addition, in the angry target block, there was a significant Self-blame X trial type interaction. The difference between the angry and neutral slopes was significant as shown in Table 6, indicating higher levels of Self-blame predicted larger P3 amplitudes on angry than on neutral trials. In addition, the difference between the angry and happy slopes was significant, *t*(164) = 1.98, *p* = .049, indicating higher levels of Self-blame predicted larger P3s on angry than on happy trials. Thus, when angry images were the target trial type, children who reported greater self-blame for their parents' conflicts had larger P3s on angry trials than on happy or neutral trials. The slopes for happy and neutral trials did not differ significantly from one another. There were no significant results in the happy target block, other than the trial type effect described above.

Discussion

The goal of the current study was to test for associations between children's appraisals of interparental conflict and specific neurophysiological measures. We examined children's appraisals of interparental conflict as predictors of neurophysiological indices of early attentional processing, cognitive control, and stimulus categorization while children viewed images depicting simulated interpersonal emotion. We hypothesized that children's appraisals of more negative interparental conflict, threat, and self-blame would predict larger P1, N1, N2, and P3 amplitudes across trial type, and in addition, that these appraisals would predict larger ERP amplitudes for angry images than for other emotional expressions. Our results partially supported our hypotheses. Specifically, when children were instructed to respond to angry images, greater self-blame for parents' conflicts predicted larger amplitudes of the N2 ERP component, and perceptions of interparental conflict as more frequent, intense, and unresolved tended to predict larger amplitudes of the N1 ERP component, consistent with hypotheses. In addition, when children were instructed to respond to angry images, greater self-blame predicted larger P3 amplitudes on angry trials than on either neutral or happy trials, again consistent with hypotheses. However, when children were instructed to respond to happy images, perceptions of more frequent, intense, unresolved conflict were associated with larger N1s and N2s on happy trials than on angry trials, inconsistent with hypotheses.

Overall, the results support the idea that children's appraisals of conflict are related to neurophysiological indices of early attentional processing, cognitive control, and stimulus categorization during emotion processing. Regarding the N1, which reflects early sensory attention, associations were found with CPIC Conflict Properties. Specifically, children's appraisals of their parents' conflicts as more frequent, intense, and unresolved predicted larger N1 amplitudes across trial types within the angry target block. Such appraisals also predicted larger N1s for happy images than for angry images within the happy target block. This is consistent with prior findings that interparental violence and appraisals of interparental conflict are associated with individual differences in allocation of attention to emotion faces on the dot-probe task (Briggs-Gowan et al., 2015), and in allocation of attention to stimuli depicting interpersonal emotion (Lucas-Thompson, Dumitrache, et al., 2017). One possible interpretation of this pattern is that exposure to conflict that is more negative may lead to subsequent recruitment of greater neural activation to support basic attentional processing of salient environmental stimuli. Prior experience with relatively negative conflict may shape neural systems toward greater attention toward, and detection of, sensory cues signaling the potential for conflict. The reverse direction of effects is also a clear possibility: pre-existing individual differences in attentional systems may lead to greater perceptions of parents' conflict as frequent, intense, and unresolved. Further work, informed by longitudinal data, is needed to investigate these possibilities.

The N2, reflecting cognitive control processes, showed a similar pattern of greater activation for happy images than for angry images in the happy target block for children who perceived more frequent, intense, unresolved interparental conflict. This result suggests greater cognitive control effort to support detection of, and response to, signs of happiness in conjunction with task demands to do so. In addition, children who blamed themselves more for conflict had larger N2 amplitudes across trial types within the angry target block, compared with other children. Recent work suggests the N2 is one of several ERP components that reflects anterior midcingulate cortex activity (Cavanagh & Shackman, 2015) utilizing information about potential threat cues to guide the selection of behavior under conditions of uncertainty (i.e., conditions in which there is potential for adverse events, but the likelihood of such events is not known) (A. J. Shackman, Salomons, et al., 2011). These conditions result in a greater need for cognitive control in the service of selecting an optimally adaptive behavioral response that will decrease the likelihood of occurrence of adverse events (Tolomeo et al., 2016). The N2 is thought to index these processes, making it particularly interesting that children who reported more self-blame for parents' conflicts showed larger N2 amplitudes to all trials specifically in the angry target block. That is, in the context of task demands to look for, and respond to, angry cues, children who had higher levels of self-blame also had higher levels of neurophysiological markers of cognitive control processes.

Regarding the P3, higher levels of self-blame predicted larger P3 amplitudes for angry images than for happy or neutral images in the angry target block, suggesting higher levels of working memory and categorization of emotion stimuli, specifically angry stimuli, in children who blamed themselves more for their parents' conflicts. Considering these results together with the N2 results, it may be that children who tend to blame themselves for interparental conflict devote greater cognitive control resources toward selecting adaptive behavioral responses, as reflected in the N2, because they feel more responsible for preventing more negative interparental sequelae. Similarly, these children may tend to exert greater effort toward stimulus discrimination to identify salient cues (e.g., anger signals), as reflected in the P3. An alternative possibility is that the process of routinely scanning the environment for potential threat (as reflected in the N2) and greater stimulus discrimination effort aimed at identifying potential negative cues (as reflected in the P3) may cause children to feel more responsible for preventing negative sequelae, resulting in more self-blame.

Notably, perceptions of conflict as frequent, intense, and unresolved were associated with individual differences in early and intermediate stages of cognitive processing, involving early sensory attention (N1) and cognitive control (N2). In contrast, children's self-blame was associated with individual differences in intermediate (N2) and later stages of cognitive processing (P3), reflecting working memory and stimulus categorization. Related to this, it is noteworthy that previous work has found stress to have very different effects at different stages of cognitive processing. For example, A. J. Shackman, Maxwell, McMenamin, Greischar, and Davidson (2011) found a lab stressor (threat of electric shocks) was associated with larger N1 amplitudes and smaller P3 amplitudes in adults during completion of an emotionally neutral task. Although the pattern of greater early processing and diminished later processing does not directly map onto the findings from the current study, key differences between lab stressors vs. significant family-related stress, as well as differences between children's developing neurobiology vs. the mature neurobiology of adults, and differences in task demands likely help account for these differences. More broadly, findings of the current study converge with those of previous studies in showing differences in associations of distressing experiences at different neurocognitive stages.

When children were directed to respond to *happy* images, greater perceptions of conflict as frequent, intense, and unresolved (Conflict Properties) predicted larger N1 and N2 amplitudes on *happy* trials than on angry trials. In contrast, when children were directed to respond to *angry* images, greater self-blame predicted larger P3 amplitudes on *angry* trials than on happy trials. In both cases, more negative conflict-related appraisals predicted greater sensitivity to trial types that were congruent with the target. That is, children whose appraisals reflect greater concern regarding interparental conflict may show greater sensitivity to cues in the environment that correspond to the signals they are searching for (e.g., greater sensitivity to signs of anger when being vigilant for anger). By the same token, these children may show greater sensitivity to signs of happiness when they are looking for signs of happiness. Relatedly, Davies, Sturge-Apple, Bascoe, and Cummings (2014) examined associations of childhood insecurity about the interparental relationship (i.e., more emotional distress, involvement in parents' conflicts, and negative internal representations of the interparental relationship) with functioning in adolescence. They found that, for adolescents who had had relatively high levels of insecurity about the interparental relationship in childhood, their levels of insecurity in adolescence were very sensitive to the level of negative interparental conflict in adolescence. Specifically, for adolescents who had been relatively insecure in childhood, high levels of negative interparental conflict in adolescence were associated with especially high insecurity in adolescence, but low levels of negative interparental conflict in adolescence were associated with especially low insecurity in adolescence. This pattern suggests that elevated interparental conflict may lead to a greater sensitivity to both negative and positive signals, which would be consistent with the finding in the current study that greater conflict-related appraisals were associated with greater neural responding to both angry and happy cues.

In the angry target block, across the sample as a whole, children had larger P3 amplitudes on angry trials compared with happy and neutral trials. Over and above this effect, children who blamed themselves for their parents' conflicts had a larger P3 in the angry block on angry trials than on happy and neutral trials. That is, even controlling for the pattern of larger P3 amplitudes across the sample on angry trials than on happy and neutral trials in the angry block, self-blame predicted an additional increase in P3s on angry trials relative to happy and neutral trials. Moreover, this self-blame X trial type interaction is partially consistent with findings from a previous study using these stimuli, in which greater parent-reported exposure to interparental conflict was associated with larger P3s for both types of emotion faces (angry and happy) compared with neutral faces (Schermerhorn et al., 2015). Thus, in both studies, higher levels of conflict-related variables were associated with larger P3 amplitudes on angry trials than on neutral trials. However, whereas in the current study, P3s were significantly larger on angry trials than on happy trials, in the Schermerhorn et al. (2015) study, P3s on angry and happy trials did not differ significantly from one another. These differences in results could be due to differences in the links of the P3 with parent-reported exposure, compared with children's self-blame for conflict. Although parent-reported conflict exposure and children's self-blame for conflict are conceptually related, they are also distinct constructs representing distinct aspects of family functioning. Another important possibility is that the differences could be a function of methodological differences, such as the current study's larger sample size. At the same time, recent work has also shown that poorer quality father-adolescent relationships and more stressful life events significantly predict children's appraisals of interparental conflict (specifically, CPIC conflict properties and threat scores), even when controlling for parents' reports of interparental conflict (Lucas-Thompson & George, 2017). Importantly, Lucas-Thompson and George's (2017) results suggest the possibility that children's appraisals of conflict may be driven just as much by the parent-child relationship and by stress as they are by interparental conflict. Thus, an important direction for future work is to examine the potential roles of these factors (parent-child relations, stress) in altering associations of children's appraisals of conflict with ERP components.

The absence of significant results for the P1 is noteworthy, particularly in light of the significant results for the N1. Recent work suggests that, whereas the N1 may reflect facilitation of processing of task-relevant stimuli, the P1 may reflect blocking of processing of task-irrelevant stimuli (Slagter, Prinssena, Reteig, & Mazaheri, 2016). Thus, P1 effects may be more identifiable in a task in which distractor stimuli are presented simultaneously with target stimuli. Moreover, the lack of significant findings for children's threat perceptions is also interesting, and it is consistent with results of a recent study examining stress physiology. Whereas that study showed that stress physiology (cortisol production) was associated with children's self-blame for parents' conflicts, stress physiology was not significantly associated with threat perceptions regarding interparental conflict (Lucas-Thompson, Lunkenheimer, & Dumitrache, 2017). The lack of significant cortisol-threat associations in the Lucas-Thompson et al. study, and the lack of ERP-threat associations in the current study lead to the question: *What sorts of mechanisms* ***would*** *be associated with children's threat perceptions regarding interparental conflict?* One possibility is that children's threat perceptions may lead children to be especially vigilant for cues signaling imminent interparental conflict. If threat is related to greater vigilance for potential negative outcomes, it may be closely connected to the ERN and FN ERP components, given associations of these components with sensitivity to errors and to feedback regarding potential loss (Cavanagh & Shackman, 2015). Links with threat appraisals may also emerge when examining attention bias, or allocation of attention toward or away from threat cues. If children's perceptions of threat regarding interparental conflict are associated with greater vigilance for potential negative cues, then measuring ERP components during an attention bias task, such as the dot-probe (e.g., Thai et al., 2016), may illuminate associations between neurophysiology and children's perceptions of threat regarding interparental conflict.

This study has a number of limitations. First, the study had a cross-sectional design, so conclusions cannot be drawn regarding the directionality of the associations between children's appraisals of conflict and their neurophysiology. That is, one possibility is that children's appraisals of conflict lead to alterations in neurophysiological indices of early sensory attention, cognitive control, and stimulus categorization during processing of interpersonal emotion cues. Alternatively, pre-existing individual differences in these neurophysiological indices may lead to differences in children's appraisals of their parents' conflicts. Moreover, other types of individual differences factors, such as temperament traits, may also contribute to such differences in appraisals. Temperament has been linked with various aspects of cognition, including cognitive control (e.g., Lamm et al., 2014), and may serve as a filter, altering children's perceptions of events, potentially including perception of interparental conflict. Further, genetic factors in parents may contribute to interparental conflict, and may be passed on to children, potentially contributing to a variety of child traits, including temperament and psychopathology. Such genetic factors may also contribute to the neural correlates of children's processing of emotion cues. Consistent with these possibilities, previous work has demonstrated that genetic factors contribute to both child externalizing problems and parents' conflict (Harden et al., 2007). However, even when genetic transmission is found, family experiences also exert an important influence on children in combination with genetic mechanisms (Dick et al., 2011). Thus, it is likely that the true nature of associations between children's appraisals of interparental conflict and the neural correlates of children's processing of interpersonal emotion cues is complex and reflects a transactional process involving multiple factors over the course of development.

Second, the sample had relatively low levels of racial, ethnic, and economic diversity, although it was representative of the geographic region where recruitment took place. The lack of diversity may limit the generalizability of the findings to a wider population. Third, the stimuli also lacked diversity, as they depicted only Caucasian actors. This may have introduced a confound in the current study on the basis of participants' race and ethnicity, as recognition of emotional expressions is less accurate when the perceiver and actor are not of the same racial and ethnic group (Elfenbein & Ambady, 2002). Future research should endeavor to recruit a more diverse sample and utilize stimuli that reflect greater diversity to reduce the influence of such potential confounds.

Fourth, a greater range of emotions portrayed by the stimulus set would enable more sophisticated tests of the sensitivity of neural systems to emotion cues. For example, interparental sadness may be a relatively commonly displayed emotion in homes with low marital satisfaction, making stimuli depicting interpersonal sadness a potentially ideal choice for future studies. Moreover, inclusion of stimuli depicting interpersonal fear would enable a broader range of tests, which could reveal links between children's experiences with interparental conflict and processing of an emotion category (i.e., fear) that is often found to be important in studies predicting key outcomes, such as anxiety (Reeb-Sutherland et al., 2015). Fifth, models were computed examining four ERP components (P1, N1, N2, P3), separately by block (angry target, happy target), separately for each appraisal type (conflict properties, threat, self-blame). Although this is a somewhat large number of models, because of the significance of identifying associations of appraisals with neurophysiological indices of multiple stages of cognition (early attention processing, cognitive control, and stimulus categorization), it was important to do so in order to identify which ERPs would show associations with conflict appraisals. The findings suggest associations of specific appraisals at multiple stages of cognition, a pattern that future studies will be able to build on in order to address more advanced questions, as well as endeavoring to replicate the current study's findings.

The current study adds to recent work examining associations between early adversity and neurophysiology (e.g., Kujawa et al., 2015; McDermott, Westerlund, Zeanah, Nelson, & Fox, 2012;

Meyer et al., 2015). We found associations between neurophysiological indices of multiple stages of cognition and children’s appraisals of interparental conflict. Children’s perceptions of conflict as frequent, intense, and unresolved were associated with individual differences in sensory attention and cognitive control processes. Children’s self-blame for conflict was associated with individual differences in cognitive control processes and stimulus categorization and working memory. In future work, these processes may shed light on key mechanisms in links between children’s exposure to interparental conflict and the development of psychopathology.

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Table 1.

Descriptive Statistics for Behavioral and ERP Amplitude Data for Trials with Correct Responses

	Angry Target Block			Happy Target Block		
	Angry Trials	Happy Trials	Neutral Trials	Angry Trials	Happy Trials	Neutral Trials
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Response Time (ms)	920.82 (99.78)				839.98 (95.28)	
Accuracy (% correct)	84.29 (14.12)	97.55 (4.62)	74.48 (19.12)	98.12 (3.36)	91.46 (9.98)	94.04 (7.33)
P1 Amplitude (µV)	8.46 (4.29)	9.04 (4.31)	8.42 (4.01)	8.01 (4.05)	8.26 (4.64)	8.36 (3.93)
N1 Amplitude (µV)	-4.87 (2.77)	-5.32 (2.46)	-4.60 (2.42)	-4.44 (2.81)	-4.83 (2.88)	-4.67 (2.29)
N2 Amplitude (µV)	-5.79 (3.10)	-6.78 (3.08)	-6.20 (2.64)	-5.84 (3.02)	-6.14 (3.06)	-6.38 (2.58)
P3 Amplitude (µV)	7.45 (4.14)	5.99 (3.68)	4.96 (2.59)	5.16 (3.46)	9.03 (4.81)	4.57 (2.76)

Note. ms = Milliseconds; µV = Microvolts; M = Mean; SD = Standard Deviation. Data are from trials with correct behavioral responses.

Table 2.

Bivariate Correlations for CPIC, Behavioral Data, and ERP Amplitudes for Target Trials with Correct Responses

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 CPIC CP	--													
2 CPIC TH	0.52***	--												
3 CPIC SB	0.27*	0.18	--											
4 Angry RT	-0.05	0.07	-0.13	--										
5 Happy RT	-0.11	0.08	-0.05	0.58***	--									
6 Angry Acc	0.00	-0.05	0.04	-0.51***	-0.39***	--								
7 Happy Acc	-0.14	-0.14	0.04	-0.25*	-0.46***	0.36***	--							
8 Angry P1	0.04	0.02	0.09	0.05	0.05	-0.17	0.08	--						
9 Happy P1	0.11	0.00	0.02	-0.11	-0.12	-0.18	0.01	0.64***	--					
10 Angry N1	-0.13	-0.14	-0.11	-0.07	-0.06	0.16	-0.02	-0.68***	-0.35***	--				
11 Happy N1	-0.17	-0.09	-0.12	0.09	0.09	0.07	-0.08	-0.55***	-0.72***	0.47***	--			
12 Angry N2	-0.07	0.13	-0.25*	0.04	-0.04	0.06	0.00	-0.34**	-0.11	0.60***	0.13	--		
13 Happy N2	-0.16	-0.03	-0.17	0.06	0.18	0.06	-0.03	-0.24*	-0.36***	0.27*	0.60***	0.34**	--	
14 Angry P3	0.05	0.04	0.11	-0.36***	-0.33**	0.10	0.19†	0.21†	0.27*	-0.06	-0.21†	0.15	-0.19†	--
15 Happy P3	0.22*	-0.01	0.07	-0.21*	-0.52***	0.03	0.21†	0.13	0.37***	-0.10	-0.40***	-0.10	-0.35***	0.64***

Note. CPIC = Children's Perceptions of Interparental Conflict scale; CP = Conflict Properties; TH = Threat; SB = Self-blame; RT = Response Time in Milliseconds Relative to Stimulus Onset; Acc = Accuracy (% correct); Angry = Angry Trials with Correct Responses in Angry Target Block; Happy =

Happy Trials with Correct Responses in Angry Target Block. ERP components are mean amplitudes in microvolts. †$p < 0.10$. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

Table 3.
Mixed Models Results for Associations between Conflict Properties and N1 Amplitudes

Predictor	*F*(df)	Estimate	Standard Error	*t* value (df)
Angry Target Block				
Intercept	466.17 (1, 80)***			
Trial Type	4.86 (2, 164)**			
Angry		-0.32	0.25	-1.30 (164)
Happy		-0.77	0.25	-3.11 (164)**
Neutral		0^a	0	
Conf Prop	5.07 (1, 80)*			
Conf Prop X Trial Rype	0.14 (2, 164)			
Conf Prop X Angry		0.02	0.04	0.51 (164)
Conf Prop X Happy		0.02	0.04	0.36 (164)
Conf Prop X Neutral		0^a	0	
Gender	1.31 (1, 80)			
Male		-0.53	0.47	-1.14 (80)
Female		0^a	0	
Age	0.06 (1, 80)			
Happy Target Block				
Intercept	344.69 (1, 80)***			
Trial Type	1.10 (2, 164)			
Angry		0.16	0.24	0.67 (164)
Happy		-0.19	0.24	-0.81 (164)
Neutral		0^a	0	

Conf Prop	0.67 (1, 80)			
Conf Prop X Trial Type	4.25 (2, 164)*			
Conf Prop X Angry		0.06	0.04	1.35 (164)
Conf Prop X Happy		-0.06	0.04	-1.56 (164)
Conf Prop X Neutral		0[a]	0	
Gender	0.01 (1, 80)			
Male		0.05	0.51	0.10 (80)
Female		0[a]	0	
Age	0.00 (1, 80)			

Note. [a] = These parameters are set to zero because neutral trial type and female gender are the reference categories. Conf Prop = CPIC Conflict Properties. †$p < 0.10$. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

Table 4.
Mixed Models Results for Associations between Conflict Properties and N2 Amplitudes

Predictor	*F*(df)	Estimate	Standard Error	*t* value (df)
		Angry Target Block		
Intercept	529.93 (1, 80)***			
Trial Type	5.83 (2, 164)**			
Angry		0.36	0.28	1.27 (164)
Happy		-0.60	0.28	-2.11 (164)*
Neutral		0^a	0	
Conf Prop	3.94 (1, 80)†			
Conf Prop X Trial Type	1.91 (2, 164)			
Conf Prop X Angry		0.10	0.05	1.93 (164)†
Conf Prop X Happy		0.03	0.05	0.67 (164)
Conf Prop X Neutral		0^a	0	
Gender	2.91 (1, 80)†			
Male		-0.93	0.55	-1.71 (80)†
Female		0^a	0	
Age	1.72 (1, 80)			
		Happy Target Block		
Intercept	544.80 (1, 80)***			
Trial Type	1.14 (2, 164)			
Angry		0.46	0.30	1.51 (164)
Happy		0.24	0.30	.79 (164)
Neutral		0^a	0	

Conf Prop	0.25 (1, 80)			
Conf Prop X Trial Type	3.30 (2, 164)*			
Conf Prop X Angry		0.07	0.05	1.35 (164)
Conf Prop X Happy		-0.07	0.05	-1.22 (164)
Conf Prop X Neutral		0^{a}	0	
Gender	0.00 (1, 80)			
Male		-0.03	0.53	-0.05 (80)
Female		0^{a}	0	
Age	3.63 (1, 80)†			

Note. ^{a} = These parameters are set to zero because neutral trial type and female gender are the reference categories. Conf Prop = CPIC Conflict Properties. †$p < 0.10$. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

Table 5.

Mixed Models Results for Associations between Self-Blame and N2 Amplitudes

Predictor	*F*(df)	Estimate	Standard Error	*t* value (df)
Angry Target Block				
Intercept	540.16 (1, 80)***			
Trial Type	5.74 (2, 164)**			
Angry		0.36	0.29	1.24 (164)
Happy		-0.60	0.29	-2.11 (164)*
Neutral		0^a	0	
Self-Blame	5.96 (1, 80)*			
Self-Blame X Trial Type	0.82 (2, 164)			
Self-Blame X Angry		-0.10	0.14	-0.70 (164)
Self-Blame X Happy		0.08	0.14	0.58 (164)
Self-Blame X Neutral		0^a	0	
Gender	3.65 (1, 80)†			
Male		-1.04	0.54	-1.91 (80)†
Female		0^a	0	
Age	1.17 (1, 80)			
Happy Target Block				
Intercept	554.71 (1, 80)***			
Trial Type	1.07 (2, 164)			
Angry		0.45	0.31	1.46 (164)
Happy		0.25	0.31	0.80 (164)
Neutral		0^a	0	

Self-Blame	1.86 (1, 80)			
Self-Blame X Trial Type	0.34 (2, 164)			
Self-Blame X Angry		0.04	0.15	0.29 (164)
Self-Blame X Happy		-0.08	0.15	-0.52 (164)
Self-Blame X Neutral		0[a]	0	
Gender	0.04 (1, 80)			
Male		-0.11	0.53	-0.20 (80)
Female		0[a]	0	
Age	3.28 (1, 80)†			

Note. [a] = These parameters are set to zero because neutral trial type and female gender are the reference categories. Self-Blame = CPIC Self-Blame. †$p < 0.10$. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

Table 6.
Mixed Models Results for Associations between Self-Blame and P3 Amplitudes

Predictor	*F*(df)	Estimate	Standard Error	*t* value (df)
		Angry Target Block		
Intercept	335.24 (1, 80)***			
Trial Type	25.78 (2, 164)***			
Angry		2.32	0.32	7.16 (164)***
Happy		0.99	0.32	3.07 (164)**
Neutral		0^a	0	
Self-Blame	0.00 (1, 80)			
Self-Blame X Trial Type	3.15 (2, 164)*			
Self-Blame X Angry		0.36	0.16	2.32 (164)*
Self-Blame X Happy		0.05	0.16	0.34 (164)
Self-Blame X Neutral		0^a	0	
Gender	1.24 (1, 80)			
Male		-0.74	0.66	-1.11 (80)
Female		0^a	0	
Age	0.18 (1, 80)			
		Happy Target Block		
Intercept	324.00 (1, 80)***			
Trial Type	86.22 (2, 164)***			
Angry		0.60	0.36	1.66 (164)†
Happy		4.40	0.36	12.11 (164)***
Neutral		0^a	0	

Self-Blame	0.33 (1, 80)			
Self-Blame X Trial Type	0.52 (2, 164)			
Self-Blame X Angry		0.17	0.18	0.96 (164)
Self-Blame X Happy		0.14	0.18	0.78 (164)
Self-Blame X Neutral		0[a]	0	
Gender	5.20 (1, 80)*			
Male		-1.58	0.69	-2.28 (80)*
Female		0[a]	0	
Age	0.09 (1, 80)			

Note. [a] = These parameters are set to zero because neutral trial type and female gender are the reference categories. Self-Blame = CPIC Self-Blame. †*p* < 0.10. **p* < 0.05. ***p* < 0.01. ****p* < 0.001.