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Kin Rejection: Social Signals, Neural Response and Perceived Distress During Social Exclusion

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Abstract

Across species, kin bond together to promote survival. We sought to understand the dyadic effect of exclusion by kin (as opposed to non-kin strangers) on brain activity of the mother and her child and their subjective distress. To this end, we probed mother-child relationships with a computerized ball-toss game Cyberball. When excluded by one another, rather than by a stranger, both mothers and children exhibited a significantly pronounced frontal P2. Moreover, upon kin-rejection versus stranger-rejection, both mothers and children showed incremented left frontal positive slow waves for rejection events. Children reported more distress upon exclusion than their own mothers. Similar to past work, relatively augmented negative frontal slow wave activity predicted greater self-reported ostracism distress. This effect, generalized to the P2, was limited to mother or child- rejection by kin, with comparable magnitude of effect across kin identity (mothers vs. children). For both mothers and children, the frontal P2 peak was significantly pronounced for kin-rejection versus stranger rejection. Taken together, our results document the rapid categorization of social signals as kin-relevant and the specificity of early and late neural markers for predicting felt ostracism.

The relationship between mother and child is a fundamental and defining human connection, profoundly impacting the biology and identity of both individuals (Bowlby, 1958; Francis, Szegda, Campbell, Martin, & Insel, 2003; Harlow & Suomi, 1971; Harlow & Zimmermann, 1958). For mothers, investment in the next generation is of obvious evolutionary value. For the child, the relationship with his/her mother is vital to survival and optimal growth—its disruption may jeopardize cognitive, emotional, and social development (Harlow & Zimmermann, 1958; Klann-Delius & Hofmeister, 1997; Main & Goldwyn, 1984). Children experiencing rejection by their parental figures often display impaired communicative, emotive, and cognitive skills (Benoit & Parker, 1994; Klann-Delius & Hofmeister, 1997; Malatesta, Culver, Tesman, & Shepard, 1989; Moss & St-Laurent, 2001; van, 1995; Ward & Carlson, 1995). Additionally, these children are more likely to become parents that exhibit the same behaviors with their offspring (Main & Goldwyn, 1984; Sullivan, Perry, Sloan,

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Kleinhaus, & Burtchen, 2011). Given the significant deleterious consequences of disruption of the mother-child relationship, there is a strong incentive for both mother and child to maintain the bond.

Broadly conceived, attachment theory provides a frame from which to view the putative evolutionary and psychological basis of the mother-child relationship (Bowlby, 1988). From this view, infants are pre-programmed to form attachments with others to promote survival (Bowlby, 1958). The ethological root of separation distress likely emerges from the survival benefit of close proximity to a caregiver (Bowlby, 1988). Research has leveraged the attachment concept to probe separation distress and understand how it relates to mother-child attachment (Ainsworth, Blehar, Waters, & Wall, 1978; Ainsworth & Wittig, 1969; Bowlby, Ainsworth, Boston, & Rosenbluth, 1956; Eisenberger, 2012; Flacking et al., 2012; Schaffer & Emerson, 1964; White et al., 2012). A large body of work documents how individual differences in young children's responses to separation and reunion with caregivers concurrently and prospectively tracks parent-child relationship quality and a broad range of psychosocial outcomes (See Thompson (2008), for a review).

Social Ostracism as a Probe of Attachment Processes

Social ostracism refers to the act of ignoring and excluding a person from the group (Williams, 2007). Consistent with the idea that attachment patterns generalize to new encounters, ostracism experiences with putative unfamiliar peers evoke neural responses that are associated with the quality of attachment (DeWall et al., 2012; Riem, Bakermans-Kranenburg, Huffmeijer, & van Ijzendoorn, 2013; White et al., 2012; White, Wu, Borelli, Mayes, & Crowley, 2013). In children, this type of exclusion is associated with poorer academic performance, dysregulated emotion, and loss of physical control (Kim, Koh, & Leventhal, 2005; Nesdale & Flesser, 2001; Schwartz, Gorman, Dodge, Pettit, & Bates, 2008). A number of investigators examining social exclusion draw connections between social pain and physical pain, acknowledging overlap at the conceptual or linguistic level (as revealed by common metaphorical descriptions – "*broken* hearts," "*hurt* feelings"), though accounts vary in terms of the extent to which the neuroanatomical substrates underlying these two experiences are distinct (Cacioppo et al., 2013; Eisenberger, 2006; Eisenberger, Gable, & Lieberman, 2007; Eisenberger, Lieberman, & Williams, 2003; Macdonald & Leary, 2005). Social pain is thought to have its roots in the survival value it confers to the individual as a dependent offspring and later as a member of a social group.

Much of the research examining social exclusion uses a standardized computerized task called Cyberball to probe the neural and behavioral effects of ostracism distress (Coyne, Gundersen, Nelson, & Stockdale, 2011; Crowley, Wu, Molfese, & Mayes, 2010; Salvy et al., 2011; Williams & Jarvis, 2006). In this task participants ostensibly connect with two or three players via the Internet to pass a virtual ball back and forth. Unbeknownst to the participant, their co-players are computer-based and move from *fair play,* where the ball is equally tossed among all players, to an *exclusion* phase, where the participant is left out of the game (i.e., the other two "players" pass the ball exclusively to one another). Studies employing fMRI during Cyberball reveal that the experiences of social exclusion engage neural circuitry relevant for the experience of distress and self-regulation (i.e., ventrolateral prefrontal cortex (PFC), medial PFC, dorsal anterior cingulate cortex (ACC), insula, posterior cingulate and medial orbitofrontal cortex (OFC)) during exclusion (Bolling et al., 2011; Eisenberger et al., 2003; Masten et al., 2009; Sebastian et al., 2011).

Cyberball has also been used to probe real time brain activity during social ostracism using event-related potentials (ERPs)(Crowley et al., 2009). To date, much of the work with ERPs and Cyberball focuses on frontal slow wave responses for rejection events. In particular, greater negative left frontal/central slow waves are associated with greater experienced distress (Crowley et al., 2009; Crowley et al., 2010; White et al., 2012). Importantly, a number of studies also implicate pronounced left-lateralized frontal slow waves in processing positive or appetitive stimuli and decreased anticipation of negative outcome (Cunningham, Espinet, DeYoung, & Zelazo, 2005; Gable & Harmon-Jones, 2010; Gable & Harmon-Jones, 2013; Graham & Cabeza, 2001; van de Laar, Licht, Franken, & Hendriks, 2004). Thus, the relatively more negative ERP slow waves for rejection events (during exclusion), which tend to be accompanied by less positive appraisal, may also reflect reduced approach motivation.

ERP studies tend to focus on one, and sometimes two brain potentials; for an interpersonal game, like Cyberball, these may include the N2 (expectancy violation) and the P300 (event saliency). Importantly, most if not all ERP work with Cyberball has involved play with unfamiliar peers. Adapting the Cyberball task to include familiar others (i.e., mother and child) could engage other attention-related components given the high saliency of the relationship and its ongoing reciprocal nature. One likely candidate is the frontal P2 response, which occurs early in the ERP waveform and has long been considered an incidence detector, thought to reflect selective attention and sensory processing of target arrays with simple (popout) stimulus features (Key, Dove, & Maguire, 2005; Luck & Hillyard, 1994; Mueller, Brehmer, von Oertzen, Li, & Lindenberger, 2008; Smith, Johnstone, & Barry, 2004). Thus, we might expect rejection by kin (mother or child) to preferentially engage the P2 as compared to rejection by an unfamiliar other.

While many published studies employ Cyberball to study exclusion by strangers (Bolling et al., 2011; Crowley et al., 2010; Eisenberger et al., 2003; Jamieson, Harkins, & Williams, 2010; Masten et al., 2009; C. L. Sebastian et al., 2011; C. Sebastian, Viding, Williams, & Blakemore, 2010; van Beest & Williams, 2006; White et al., 2012; White et al., 2013), to date the paradigm has not been used to probe processes within the mother-child relationship. Presuming the aforementioned evolutionary and interpersonal value of kin, we would expect responses for kin rejection to differ markedly from unfamiliar others.

While many have studied the behavioral impact of rejection on children in one form or another (e.g., Isabella, 1993), the effects of exclusion on mothers by their kin remains unknown. Available data collected through surveys of mothers points to associations between the effects of exclusion by child on maternal mood and the appearance of depressive symptoms (Eastwood et al., 2013). The paucity of available work here stands in contrast to the many clinical cases of a child who has either rejected one’s parents or refused to participate in reunion post-separation (Fidler & Bala, 2010; Friedlander & Walters, 2010).

Bowlby, along with the researchers who followed him, differentiated the "attachment system," which describes the child's bond with his/her primary caregivers, from the "caregiving system," which describes caregivers' affectionate bonds to their children (Bowlby, 1958; George & Solomon, 1996, 2008). Although there are important parallels between the attachment and caregiving system, the two systems are thought to serve different functions (George & Solomon, 2008). For instance, one of the central goals of the child within the parent-child attachment relationship relate to getting his/her physical and emotional needs met, whereas for the parent a central goal is providing for the child (George & Solomon, 2008). Put simply, the driving force in the parent-child relationship is to ensure that the parent meets the needs of the child. Thus, rejection within the dyad ought to affect mothers and children differently following from this essential difference in their relationship roles. In particular, rejection from the parent to the child should be more aversive than rejection from the child to the parent in that this behavior violates the child's central need in the relationship. In contrast, healthy parents should be able to tolerate rejection by the child with less distress than the child experiences upon receiving rejection by the parent. However, no work has examined this issue. Bringing together mothers' and children's responses to exclusion helps piece together the potentially unique psychological and neuronal effects of this primary social relationship.

Goals of the Current Study

Even in a relatively benign situation such as Cyberball, where a virtual ball is either thrown among all players (*fair play*) or not (*exclusion*), exclusion by kin may threaten strong biological and psychological bonds built since infancy for both mother and child. For this reason, we adapted the Cyberball paradigm to probe mother-child interaction in middle childhood. In our version of the game, mothers and children were both led to believe they were interacting with one another along with a stranger (Figure 1). Whereas in previous work, Cyberball involved a participant and two putative strangers, whose behavior and neural responses could be considered comparable, we distinguished between one player who was kin (mother or child) and a stranger.

Recognizing the nested nature of our design, with mother-child dyad as one unit of analysis, we approached our data from a hierarchical linear model framework. We expected that dyad (mother and child participants), would account for variability in our model. We have previously shown that neural frontal slow wave responses during exclusion from play by unfamiliar peers predict feelings of ostracism distress (Crowley et al., 2009; Crowley et al., 2010; White et al., 2012). Accordingly, we expected self-reported feelings of ostracism and ERP rejection-event slow waves to be associated in mothers and children. Secondly, we expected to see differences in the P2 peak; a greater amplitude P2 peak for kin rejection compared to stranger rejection would suggest greater attention engagement for that event for both mother and children in line with the proposed salience of kin-bonds over others. Thirdly, we hypothesized that the negative left frontal ERP slow waves would inversely predict greater distress for all participants. We also expected that rejection from kin (mother or child) would induce a more positive slow wave than rejection by a stranger, reflecting generally increased approach motivation upon signs of threat to this relationship. Finally, given the asymmetric relationship of the mother-child dyad (i.e., mothers aid their offspring’s survival, but not vice versa), and that mothers are likely more adept at emotion regulation, we expected children to be more distressed by exclusion than their mothers (George & Solomon, 2008).

Method

Participants

Twenty-one children (9 male, ages 9 to 12 years old, M_{age} = 11.048, SD_{age} = 1.071) were recruited along with their mothers (ages 40 to 52, M_{age} = 45.095, SD_{age} = 3.646) via mass mailings. Both mothers and children received $40 compensation for participating in the visit. Mothers provided written consent for themselves and permission for their children—children provided written assent. Yale University’s Human Investigation Committee approved the study protocol.

Procedure

Cyberball paradigm—Participants sat 60 cm from a 17 in LCD screen in a dimly lit sound attenuated room while participating in the game Cyberball. In this computerized game, participants must throw and receive a virtual ball, along with two pre-programmed players. Participants were led to believe the two other players in the game were real. In our mother-child version of Cyberball, children were told they were playing with a stranger child and their own mother—mothers were led to believe they were playing with a stranger mother and their own child. The game was divided into two phases: *fair play*, a series of trials where the ball is evenly thrown between all players, and *exclusion*, a series of trials where the ball is only thrown between the preprogrammed players.

The play screen was programmed such that each participant views his/her own glove at the bottom center and the other players’ gloves on the opposite sides at the top of the screen next to pictures of the other players. One of the pictures was the mother or child of the participant and the other picture was a demographic and sex-matched photo (of either another mother or child). In order to choose whom to pass to, the participant used their left and right index fingers on a response pad to throw the ball during play.

Authenticity of the game was enhanced with a Google™page with a “Cyberball” listing that was linked to a false “loading screen.” Participants were able to choose different gloves for play, different sound effects occurred for throws and catches, and balls thrown varied in trajectory. Before beginning the game, the experimenter vocally hinted at making sure that “additional players” were getting ready to play. The falsity of the game was revealed during a debriefing after completion of the experiment.

This adapted version of Cyberball had two conditions, 108 trials (throws) of *fair play* and 47 trials of *exclusion*. *Fair play* was further divided into 36 “my turn” events, where the participant received the ball from the other players, and 72 “not my turn” events, where the ball was thrown between the other players. The game was fixed with a waiting time to receive the ball, waiting 0, 1, 2 or 3 trials before receiving it again (frequency 12, 12, 10 and 2, respectively).

Immediately following *fair play* the game transitioned into an *exclusion phase*. In this condition there were 44 "rejection" events, where the ball was thrown between the other players, and 3 "my turn" events. This resulted in exclusion on 96% of the trials. For the purpose of analysis, the first five trials, the three "my turn" events, and following trial where the participant throws the ball were excluded. Thus only 36 trials of rejection-based events were ultimately examined for analysis.

Behavioral Measures of Ostracism—After the Cyberball session, participants filled out the Need Threat Scale to measure ostracism distress. This adapted 21-question version has been shown to be reliable and valid in past research (Crowley et al., 2010; Jamieson et al., 2010; C. Sebastian et al., 2010; van Beest & Williams, 2006). Feelings of distress, rated 1 ("Not at all") to 5 ("Extremely"), were gathered and final scores were rekeyed such that higher scores indicated with higher levels of distress.

EEG Recording and Preprocessing—Standard protocol was used to obtain a high-density EEG with a 128 Ag/AgCL electrode system (Electrical Geodesics Incorporated (EGI), Netstation v.4.2 software (EGI), and high impedance amplifiers (sampled at 250 Hz: 0.1 Hz high pass, 100 Hz low pass) acquired with a Cz reference. Impedances were all under 40k Ohms at the outset of the assessment. Stimulus presentation was conducted using E-prime v. 2.0 software (Psychology Software Tools, Inc.).

Post-collection processing followed standard procedures, including offline low pass filtering at 30 Hz and segmentation with a 100 ms baseline and 900 ms post-stimulus onset and re-referencing to an average reference. An artifact detection threshold was set at 200 μV, with an eye movement/blink threshold of 150 μV. Any channels/segments that did not fit these criteria were removed from further analysis. Ocular artifact removal (OAR) was implemented to correct eye movements/blinks for all participants (Gratton, Coles, & Donchin, 1983). We relied on an analogous channel cluster as used in our previous examination of frontal slow wave negativity and Cyberball (White et al., 2012). EGI Hydrocell net channels 19, 18, 21, 22, 23, 24, 25, 26, 27, 32, 33, 38 were used for these trials (Figure 1). For the purposes of analysis, the ERPs that correspond to any throws between the participant and one of the players during *fair play* were referred to as favor-based ERPs. Similarly, the ERPs that corresponded to throws between the other players during *exclusion* were referred to as rejection-based ERPs. We further distinguished between throws that involved kin (mother or child) or a stranger. A throw by the kin to the stranger (as opposed to the participant) during *exclusion* was considered a rejection-based ERP of kin. Conversely, a throw by the stranger to the kin (as opposed to the participant) during *exclusion* was considered a rejection-based ERP of stranger. For the purposes of this analysis, the number of events designated as "rejection events" was 36, 18 trials for kin rejection and 18 trials for stranger rejection. After signal processing, the numbers of trials available for averaging was comparable across conditions (Stranger Rejection: Mean, 15.10; SD, 2.93; range, 6-18; Kin Rejection: Mean, 15.55; SD, 2.86; Range 8-18).

Dyadic Analysis—Because the data were collected in terms of mother-child dyads, a hierarchical linear mixed model ANOVA was implemented to account for this level of analysis. Factors examined were role (2 levels: mother or child), identity (2 levels: stranger or kin), and condition (2 levels: *fair play* or *exclusion*); ostracism distress was added to the model as a covariate.

Results

Following our previous work, we examined the left frontal cortical region (White et al., 2012) (Figure 1). Figure 2 depicts current density spline maps for kin and stranger rejection. The frontal left-lateralized nature of the effects appears across all voltage maps. Figure 3 depicts ERP waveforms for the slow wave and P2 responses for stranger and kin. Rejection-based ERPs were examined with SPSS v.19 software (SPSS Inc., Chicago, Illinois, USA). As a preliminary analysis we examined associations between sex, age and our ERP measurements of interest (left slow wave, left frontal P2). Sex of the children was not related to any of the questionnaire scores or the ERP recordings, with all t values $t(19) < 1.674$ and all associated p values $p > 0.111$. Additionally, children's age was not related to any of the measures with all r values < 0.333 and associated p-values > 0.141.

Slow wave differences between stranger and kin

A linear mixed model ANOVA: role (mother or child) x identity (stranger or kin) x distress (score from 21 to 105) revealed a significant effect of identity for the slow wave (450-900 ms), $F(1, 31.698) = 37.972$, $p < 0.001$, as well as a identity x distress interaction, $F(1, 37.103) = 11.427$, $p = 0.002$.

In order to further understand the significant effect of identity, follow-up paired t-tests were conducted separately for mothers and children. Children showed significantly more negative rejection-based ERPs for strangers than for their mothers, $t(40)= -5.702$, $p < 0.001$ (means = −5.046 v. 3.083) (for a bar graph see Figure 4). Similarly, mothers showed a similar pattern of differences in the rejection-based ERPs between strangers and their children, $t(40)= -9.150$, $p < 0.001$ (means = −4.827 v. 4.186) (for a bar graph see Figure 4). Additionally, children exhibited greater self-reported scores of distress as compared to their mothers, $t(20)= 3.517$, $p = 0.002$ (means = 45.095 v. 32.428).

The interaction of identity x distress was analyzed post-hoc in two different ways. A simple bivariate correlation was conducted between slow wave and ostracism distress indicating there was a significant association for kin, $r = -0.481$, $p = 0.001$, but there was not a significant association for strangers, $r = 0.243$, $p = 0.121$ (for scatter plots see Figure 5). This analysis was followed by a partial correlation controlling for dyad (mother-child pair), still revealing a significant association for kin, $r = -0.409$, $p = 0.008$, but not for stranger, $r = 0.241$, $p = 0.129$.

P2 peak differences between stranger and kin

Analysis of the rejection-based P2 peak (100-300ms) followed the same approach as that for the slow wave (Figure 3). The same linear mixed model ANOVA: role (2) x identity (2) x distress revealed a significant effect of identity for the P2 peak $F(1, 35.285) = 28.007$, $p < 0.001$, as well as a identity x distress, $F(1, 42.928) = 8.700$, $p = 0.005$.

Since comparable interactions were observed as with the slow wave, analogous post-hoc tests were conducted. These revealed mothers showed more positive P2 peaks for kin as compared to strangers, $t(40)= 12.238$, $p < 0.001$ (means = 0.516 v. 5.969) (for a bar graph see Figure 4). A comparable pattern was seen in children, $t(40)= 8.638$, $p < 0.001$ (means = 1.239 v. 6.068) (for a bar graph see Figure 4).

Similar to the analysis of the slow wave, the P2 peak was analyzed for association with distress, with and without control for dyad membership. Bivariate correlations revealed a strong association for kin, $r = −0.410$, $p = 0.007$, and a non-significant association with distress for strangers, $r = 0.144$, $p = 0.362$ (for scatter plots see Figure 5). The partial correlation controlling for dyad yielded comparable results, a significant association for kin, $r = −0.409$, $p = 0.008$, but no association for stranger, $r = 0.146$, $p = 0.363$ (for scatter plots see Figure 5).

Given the negligible difference between the correlation for slow wave kin rejection and ostracism and the correlation between the P2 for kin rejection and ostracism (−0.48 vs. −0.41), it is possible that our effects are driven by a sustained response, beginning early at the time of the P2 that is superimposed on the slow wave. As an exploratory analysis, we examined the extent to which the P2 and the slow wave were distinct components by way of a principal component analysis with varimax rotation. One principal component factor, coinciding with the slow wave, covered 560 - 900 ms and accounted for 43.16% of the variance. Another principal component factor, spanning 112 - 396 ms, corresponded with the P2 response, accounting for 14.66% of the variance. This analysis suggests that the P2 and the slow wave may be considered distinct from a statistical variability perspective.

Discussion

We examined social exclusion in the context of mother-child dyads and the potential moderating role of this relationship on neural responding during social exclusion. Confirming our predictions, the magnitude of the left-frontal slow wave and the P2 increased in response to kin-rejection as compared to stranger-rejection. In addition, self-reported distress assessed post-exclusion was uniquely associated with neural response for kin-rejection as opposed to stranger-rejection, suggesting that when participants reported on felt exclusion this specifically reflected their responses to rejection by kin.

Ample evidence implicates the P2 in preferential processing and perception of salient stimuli (e.g., Luck & Hillyard, 1994) as well as incidence detection (Key et al., 2005). Against this backdrop, our findings here of augmented P2 upon kin rejection imply that rejection by kin, as opposed to strangers, engages more attentional resources and suggests that participants were generally more responsive to rejection events by their kin than by a stranger. More broadly, because the events in ERP Cyberball essentially reflect positions on the screen, where the player’s knowledge of the other social agent’s identity (mother, child or stranger) frames the meaning of the event, we believe we have tapped into a unique social signal reflecting preferential attention allocation to a “high salience” rejection event, one by kin.

Due to the temporal nature of the P2 and the discrepancies observed between kin and stranger-rejection, our results suggest that this event is processed rapidly, in less than a quarter of a second. Furthermore, greater distress was associated with a smaller P2 peak, in line with research showing a negative correlation with this peak and fear states (Lyby, Aslaksen, & Flaten, 2011; Sarlo & Munafo, 2010). While a large P2 peak may suggest greater responsiveness to external cues, the smaller P2 peak for more distressed participants could reflect greater disengagement from external events (throws) for these subjects or possibly greater avoidance. Relatedly, reduced P2 amplitudes have been observed in phobics responding to feared stimuli and also to reduced placebo responding among those with greater fear of pain (Lyby et al., 2011; Sarlo & Munafo, 2010).

Concerning our slow wave findings, previous work links left-lateralized slow waves to appetitive motivation and positive appraisals (e.g., Gable & Harmon-Jones, 2013). Compared to stranger-rejection, kin-rejection may therefore also prompt stronger tendencies to approach and regain proximity to kin given the high evolutionary premium put on this specific bond relative to encounters with strangers. Moreover, given the links of frontal slow wave activity to more positive appraisals and diminished ostracism distress (e.g., Crowley et al., 2010; White et al., 2012), kin may build on previous warm interactions with one another (as should be the overall trend in the healthy sample studied here) to anticipate a more conciliatory outcome in the face of current rejection.

Looking across the P2 and slow wave responses, we note that kin and stranger differences beginning at the P2 carry over as amplitude differences maintained across the slow wave. As well, the P2 and the slow wave for Kin rejection events relate similarly to felt ostracism. One possibility is that the P2 reflects a continuation of the slow wave effect. We conducted a PCA, which suggested at least at the level of statistical variability the P2 and slow wave are distinct. The common pattern of relation of the P2 and the slow wave with ostracism could just as easily reflect a cascade of processes such as attentional engagement (P2) followed by slow wave reactivity which could reflect a range of cognitive processes reflecting that may be more variable in time, such as appraisal and affect-regulation.

At the level of self-reported ostracism distress, our findings dovetail with classic work in the attachment literature, demonstrating that maternal departure elicits stronger negative affect than that of a stranger and that strangers cannot replace caregivers as key sources of comfort (Ainsworth et al., 1978; Ainsworth & Wittig, 1969). Yet, our results also showed that mothers and children responded similarly for rejection ERP events by kin and strangers during social exclusion—rejection by a stranger tended to induce a more negative frontal slow wave than did rejection by kin (Figure 3). Interestingly, both mothers and children showed relatively more positive slow wave rejection-based ERPs for interactions with each other as compared to interactions with a stranger (Figure 3). Likewise, maturation of cognitive capacity and coping skills may also partly account for the lower levels of distress in mothers versus children (Gullone, Hughes, King, & Tonge, 2010) as suggested by findings of age-related increases in neural activation of left-lateralized frontal areas during rejection (Gunther Moor, van Leijenhorst, Rombouts, Crone, & Van der Molen, 2010).

In terms of ERP-ostracism associations, since extant studies find that greater distress was associated with a more negative frontal slow wave for exclusion by strangers, we expected to observe this association here (Crowley et al., 2010; White et al., 2012). Instead, despite yielding more positive slow waves overall, only kin-based slow wave rejection events, and not stranger rejection events, were associated with ostracism distress (Figure 5). In interpreting these findings, it is important to note that while stranger and kin ERPs could be distinguished, ostracism distress was measured globally. Specifically, items on the Need Threat scale did not differentiate how the participant felt when excluded by a stranger versus how they felt when excluded by their kin. Because the participants demonstrated neural indicators of distress in response to the kin-initiated exclusion, we infer that the psychological reports of ostracism distress pertained to those kin-initiated exclusion events. The fact that self-reports only mapped onto neural responses to rejection by kin rather than strangers concords with our neural evidence of increased salience of kin-rejection (P2).

As expected, children reported greater levels of global distress after the game as compared to their mothers. This pattern may support the notion that mothers are less affected by rejection from their children than vice versa (George & Solomon, 2008). In other words, the observed differences in responding may be due to the differences in expectations mothers and children hold regarding their relationship with one another. Whereas children expect to receive care from their own mothers, mothers are less likely to look to their children for loving care and therefore ought to be less disturbed by rejecting behavior (George & Solomon, 2008). Our findings also meshes with parent-offspring conflict theory, in that offspring seek to maximize parental investment while parents need to balance their investment across all offspring as well as maintain their own fitness. Accordingly, ruptures to the mother-child bond may evoke greater levels of protest and distress from children than from parents (e.g., Barrett & Dunbar, 1994).

Importantly, we did not assess parent-child relationship quality or attachment status in this study, leaving open the question of the extent to which these variables might mitigate or accentuate the neural or self-report aspects of social exclusion by kin. The majority of research in the attachment field involves examining concurrent and prospective correlates of individual differences in attachment. Studies generally find that attachment security is associated with more optimal development and health among both children and adults (Bakermans-Kranenburg & van, 2009; De Wolff & van Ijzendoorn, 1997; Fonagy et al., 1996; Kobak, Cole, Ferenz-Gillies, Fleming, & Gamble, 1993; Roisman et al., 2007). Our study provides evidence that both mothers and children exhibit greater neural signs of distress in response to rejection from kin than from strangers. While we cannot speak to the impact of the attachment relationship, we propose that our findings open a new avenue for attachment research—that of exploring the role of individual differences in children’s and mother’s neural and subjective response to ostracism. As social beings, humans extrapolate from early experience to predict how future relational events will unfold (Bowlby, 1958). Therefore, we would expect that for children with extensive histories of rejection from caregivers (such as those with insecure or disorganized attachments), simulated ostracism may result in stronger neural reactions to distress as compared to the responses of children with relatively fewer experiences of rejection (such as those with secure attachments).

Importantly, we have framed this study from the perspective of mother-child attachment, but kin and strangers also differ on a second fundamental variable, familiarity. Studies of familiarity typically involve neural response to faces of familiar others (posterior P2) (Caharel et al., 2002; Webb et al., 2010). In our version of Cyberball, the face images remained on the screen for the entire game. Thus, the events that we focused on reflected rejection throws as "*actions*" by familiar others versus strangers rather than a physical representation of a person. Nonetheless, our effects may reflect social factors not directly specific to kin or to the mother-child relationship in particular, such as greater familiarity or a broadly construed ingroup versus outgroup bias. For instance in a pain perception study, P2 empathic responses were significantly reduced toward racial out-group faces compared to racial in-group faces (Sheng and Han, 2012). Notably, we observed *larger* P2 responses for rejection by kin compared to a stranger. From another perspective, while social exclusion by ingroup versus outgroup members gives rise to *elevated* self-reported distress and increased ACC activation (Bernstein, Sacco, Young, Hugenberg, & Cook, 2010; Krill & Platek, 2009), we documented a more positive frontal late slow wave for kin (associated with less distress) than for strangers (not associated with less distress). Also, in a related behavioral study, participants reported lower levels of need threat and self-reported distress when rejected by their romantic partner and a stranger than when rejected by two strangers (Capezza, Reed, Arriaga, & Williams, 2009 cited by Wesselmann & Williams, 2013). These studies, in combination with our findings, lead us surmise that rejection by individuals with whom we share an attachment may potentially yield specific effects beyond what might be accounted for by greater familiarity. Ultimately however, contrasting kin, familiar others and strangers as players in Cyberball probably reflects the most straightforward approach to disentangling potential familiarity and kin effects. As well, examining attachment quality variables with Cyberball (White, Wu, Borelli, Mayes, & Crowley, 2013; White et al., 2012) could provide support for a unique role of kin in response to social exclusion.

In light of our findings, there are some limitations worthy of note. The Need Threat scale that was used to evaluate ostracism includes general questions about distress that are not specific to the mother-child relationship. Implementation of specific questions to gauge the distress observed when excluded by one's mother or child may be beneficial for future studies. Similarly, our findings may not hold for other age groups. Especially in adolescence, normative distancing may occur within parent-child relationships (Kerns, 2008), potentially rendering rejection more common (and less salient).

From another vantage point, assessment of attachment related variables in mothers and children could also shed light on this issue if attachment security uniquely accounted for responding to rejection by kin. Finally, there is also a possibility that the deception employed in this study was not as effective for the mothers; in other words, they were aware that they were participating in a study and suspected they were not playing with their child over the computer. This could also account for the differential (lower) ostracism distress reported by mothers, although this point can be viewed against several other qualifying factors. First, ostracism distress and neural response were similarly associated across mothers and children. Second, and relatedly, the act of measuring ostracism distress is likely to make participants aware of the deception (the items communicate that exclusion was pre-ordained). Despite this possibility, felt distress still tracked neural response. Moreover, work that frames Cyberball as a hypothetical game (without deception) still yields similar patterns of felt ostracism (Crowley et al., 2009; Zadro, Williams, & Richardson, 2004).

This study is the first we know of to examine the effects of exclusion in both mothers and their child. We have shown that both mothers and children show similar and rapid neural responses (for social signals) to kin rejection events that similarly track ostracism distress, though more strongly for children. The similarities in neural responses among these kin members are consistent with an inherent value placed on relationships with kin versus those with others. Our findings represent a promising new area of inquiry for relationship research. This methodology could potentially be used to probe in other types of relationships in real time (e.g. friends, intimate partners) or potentially assesses aspects of relationship quality not accessible through questionnaires or behavioral observations. More broadly, with our ERP approach to Cyberball, a dynamic task superimposed on static events, we show that neural processing of naturalistic social signals can be studied in real time and is sensitive to specific information of agent identity at a very early processing stage. As such, our study has relevance for the pursuit of biomarkers and endophenotypes in psychiatry. This is, to our knowledge, the first “real-time” ERP social signal putatively acquired in the context of a real social relationship, where the neural response reflects differential perception of the action of one agent (kin) versus another (stranger). Thus our approach could be useful for studying social cognition in autism and other neurodevelopmental disorders.

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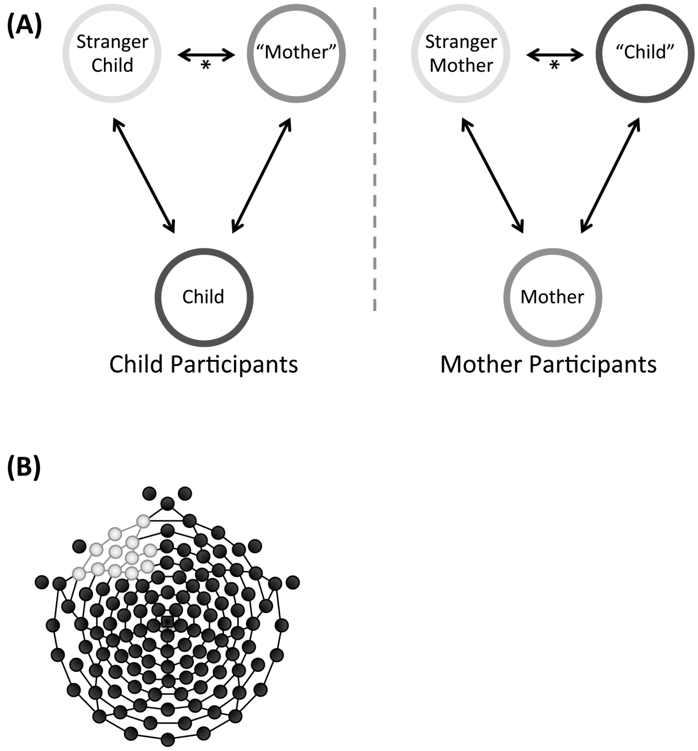

Figure 1.
Design of analysis parameters for mother-child Cyberball. **(A)** A schematic design of the Cyberball set-up for both child (left) and mother (right) participants. Children "played" the game against two computerized players, one of whom believed was their own mother. Mothers played in the same set-up, except they believed one of the players was their child. The game alternated between a condition of fair play, where the ball could be passed between all players (as indicated by all the arrows), and a condition of exclusion, where the ball was passed between the computerized players (as indicated by arrows marked *). **(B)** Frontal left electrodes, white, were chosen in examination of fair play and rejection-based ERPs.

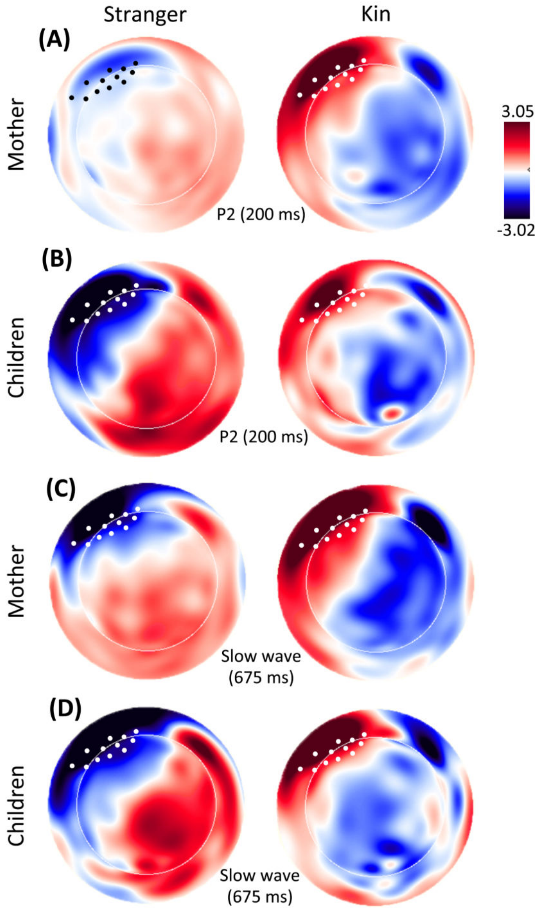

Figure 2.

Voltage maps of rejection-based ERPs during Cyberball with frontal left electrodes overlaid (black dots). (A) Mother P2 response at 200 ms for rejection-based ERPs for strangers (left) and kin (right). (B) Child P2 response at 200 ms for rejection-based ERPs for strangers. (C) Mother slow wave response at 675 ms for rejection-based ERPs for strangers (left) and kin (right). (B) Child slow wave response at 675 ms for rejection-based ERPs for strangers.

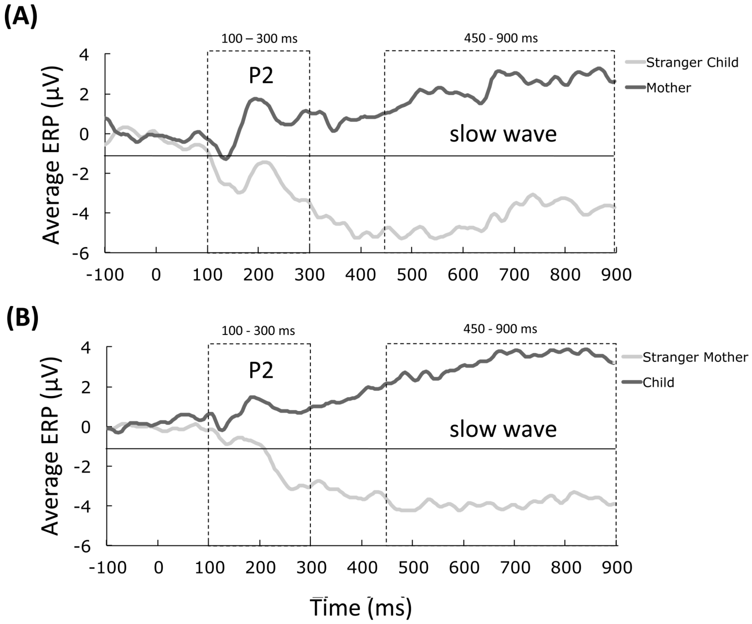

Figure 3.

Rejection-based ERPs of the P2 peak, 100 – 300 ms, and the slow wave, 450 – 900 ms, for both mother and children during Cyberball. **(A)** Rejection-based ERPs for the average frontal left electrodes for children playing with a stranger and their mother. **(B)** Rejection-based ERPs for the average frontal left electrodes for mothers playing with a stranger and their child.

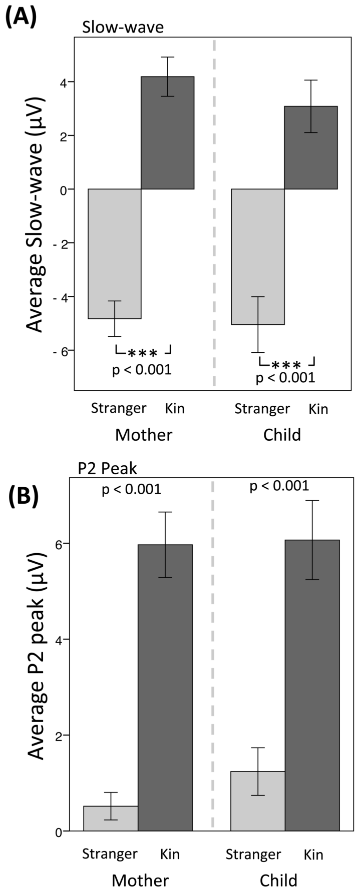

Figure 4.

Average slow wave amplitude (μV), 450-900 ms, and average P2 peak amplitude (μV), 100-300 ms, of rejection-based ERPs for mothers and children. **(A)** Both mothers and their children showed similar brain responses to rejection, with a significantly more positive slow wave for rejection-based ERPs from kin than strangers during exclusion (mothers: $t(40)= -9.150$, $p < 0.001$; children: $t(40)= -5.702$, $p < 0.001$). **(B)** Similarly, mothers and their children showed greater P2 peaks during rejection-based ERPs from kin than strangers during exclusion (mothers: $t(40)= 12.238$, $p < 0.001$; children: $t(40)= 8.638$, $p < 0.001$).

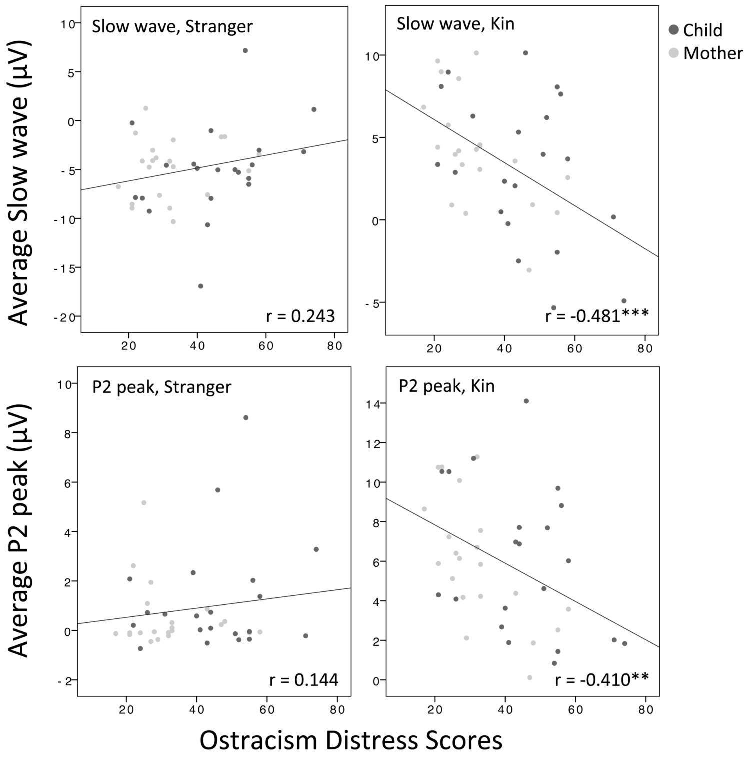

Figure 5.

Scatter plot of ostracism distress scores against average slow wave (top row) and P2 peak (bottom row) for rejection-based ERPs for strangers (left) and kin (right). There was no significant correlation for strangers (Slow wave: r = 0.243, $p = 0.121$; P2 peak: r = 0.144, $p = 0.362$). However there was a significant correlation for kin, where greater distress correlated with a more negative slow wave (r = −0.481, $p = 0.001$) and negative P2 peak (r = −0.410, $p = 0.007$).