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Neuroresponse To Social Exclusion By A Childhood Friend: An Erp Study

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Neuroresponse to Social Exclusion by a Childhood Friend: an ERP Study

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Abstract

We examined the role of friendship on the neural correlates of social exclusion in middle childhood with event-related potentials (ERPs) during a computer-simulated ball toss game, Cyberball. Experiencing fair play initially, children were then left out of the ball toss during an exclusion period. Forty children (ages 8-14) who played with a best friend and an unfamiliar peer were compared to forty-eight children (ages 8-14) who played with two unfamiliar peers. A slow wave (484-900ms post-stimulus) for both groups was evident in each of the conditions (favor, "not my turn," and rejection). Consistent with our previous middle childhood work, we found that the group playing with two unfamiliar peers showed a positive correlation between general self-reported ostracism distress and the amplitude of the rejection-related frontal slow wave. Specifically, a more negative slow wave predicted greater distress. Among the group playing with best friends, general ostracism distress was not associated with frontal slow wave activity. Importantly, a scale was designed for this study to account for differences in ostracism driven by a friend versus a stranger (Friendship Distress Questionnaire, FDQ). The rejection-related slow wave in the right frontal cortical region was associated with relationship stress on the FDQ. Higher friendship distress was associated with a more positive rejection-related slow wave. Findings suggest that constructs beyond those assessed by the Need Threat scale, such as trust and unfairness in a close relationship, could be relevant when studying the neural response to rejection, as well as illustrate the importance of considering ostracism's context (friend versus stranger).

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Introduction

Peer rejection

The phenomenon of peer rejection has been at the forefront of the lay news and has been studied extensively from the perspective of many disciplines, including psychology, sociology, education and anthropology. Peer exclusion is often linked to social hierarchy—broadly, whether or not the victims of peer rejection are liked by their peers.[1] Often there are child characteristics that make the child a likely target of exclusion or victimization; a child with aggressive or withdrawn behavior is more likely to be singled out for rejection.[2] However, this is a relationship that is very likely causal in both directions. It is also well-documented that children who are rejected by their peers are more likely to subsequently develop interpersonal difficulties and internalizing and externalizing problems. [3-6] Prognistically, however, peer exclusion foretells maladjustment independent of the victim's behaviors.[4,7]

Although child-specific and environment-specific characteristics likely mutually reinforce each other, there is evidence that the peer milieu may be the stronger force in the prediction of child maladjustment and externalizing and internalizing problems. A study by Ladd of predictive models of child psychological dysfunction found that an additive model that took into account both child factors (personal attributes) and environmental factors (degree of peer rejection) was most predictive of child maladjustment.[3]

The clear relationship between peer rejection and the development of internalizing mental health concerns, such as anxiety and depression, has been a subject of much interest.[1,3,6,8-11] For example, second through fourth grade girls classified as neglected via ratings from teachers and peers were found to be at higher risk for depression two years later.[6] Social withdrawal, a common precursor of internalizing problems is also linked to peer exclusion, with greater peer exclusion and victimization correlated with increasing social withdrawal over middle childhood and early adolescence.[12]

The association between peer rejection and externalizing problems is widely accepted in the literature, as well.[6,11,13-16] In general, children excluded by their peers are more likely to have externalizing behavioral problems such as aggression and other antisocial manifestations.[11] In a study of over a thousand children followed from ages 6-8 to 10-12, early peer rejection predicted increases in aggression.[13]

Much work has focused on the specific factors that might confer an increased risk of the development of aggressive behavior. A review by Leary et al. found that interpersonal rejection can be a determinant of aggression when the exclusion is a source of pain, frustration or threat to self-esteem and might be employed to manifest social influence, reestablish control or gain retribution.[15] Alarmingly, exclusion, or “weak social ties” to peers, was found to be a strong predictor of adolescent violence, according to The Surgeon General’s report on Youth Violence.[14] This correlation has burst into the public mind in notable national tragedies; social rejection has been implicated in school shootings, such as the Columbine High School tragedy in Colorado in 1999. More generally, in a case study of school shootings between 1995-2001, rejection was present in 13 of 15 incidents.[17]

A pivotal determinant in the development of internalizing and externalizing problems in response to exclusion is the concept of rejection sensitivity. Rejection sensitivity is defined as an individual's tendency to expect, perceive and react to rejection;[10] it is a measurable quantity that has been found to mediate the link between exclusion and consequent maladjustment.[10,11,18,19] A study of 9 to 11 year olds found that rejection sensitivity was associated with internalizing and externalizing problems after controlling for the effect of peer rejection.[11] Individual differences in children's appraisals of rejection predict subsequent development of psychological dysfunction.[11] If a child's perception is that she has been rejected, she may be sensitized to rejection in the future and develop anticipation of future exclusion.

Rejection sensitivity is an interpretation of a perceived rejection experience that affects behavior and development of maladjustment. Those with lower rejection sensitivity do not necessarily have less history of rejection but rather an attribution style that has been linked to less favorable psychological outcomes. The expectation of rejection influences processing of social situations. A study of fifth to seventh graders found that children classified as having angry rejection sensitivity, or to angrily expect rejection in interpersonal situations, showed increased distress after a condition of rejection of ambiguous intention.[10] Further, it was shown that children categorized as rejection-sensitive exhibited more aggressive behavior and interpersonal difficulties, as well as weakening academic performance.[10] In another study, anxious rejection sensitivity, or how anxiously individuals expected rejection, was predictive of increased social anxiety and withdrawal for middle school students.[19] There are many personal psychological variables affecting rejection sensitivity, as well. For example, degree of self-silencing, the extent to which one censors and represses needs and emotions, was shown to partially account for the association between rejection sensitivity and depression symptoms among dating adolescents.[20]

Higher perceived friendship quality, specifically that with a named best friend, has been found to play a role in buffering against development of psychological maladjustment. Friendship quality with a named best friend as well as perception of classmate support were shown to correlate with global self-worth in a study of shy children followed from early to middle childhood.[21] At an average age of 10 years old, children showed the effect of a close peer relationship correlating positively with global self worth, which in turn correlated negatively with shyness, loneliness and anxiety. In a study of third through fifth graders, low-accepted children (rated by their peers) reported lower quality best friendships than did better-accepted children.[22] A recent study of adolescents illustrated the potential of quality peer relationships in guarding against some of the internalizing problems of rejection. For those with unsupportive friendships, rejection sensitivity was associated with depressive symptoms.[23]

In addition, friendship quality has been linked to cognitive ability. A study following two adolescent cohorts over five years (from ages 12-16 and 16-20) found that those with lower perceived intimacy in best friendships had lower levels of and smaller increases in constructive problem solving.[24] In the literature, close friendships are linked to favorable outcomes and lessening of the ill effects of generic peer rejection. However, study designs prior to the present study have not, to our knowledge, involved rejection by an individual considered to be a best friend.

Ostracism

The impact of social exclusion on psychological adjustment during adolescence and middle childhood is understandable during this stage of high rejection sensitivity. During this time peers become most prominent in the social world and in shaping social behavior.[25] Children gradually become more concerned with others' opinions.[26] While the need for peer acceptance is paramount, being excluded, ignored or teased by peers is all the more poignant. One study comparing behavioral measures of adolescents to adults after a social exclusion task found adolescents' mood more negatively affected,[27] in alignment with self-report studies showing hypersensitivity to social rejection during this developmental time.[28]

In the social, psychological and neuroscience literature, stress elicited from exclusion is referred to as ostracism distress. This distress is widely considered to be secondary to a sense of threatened needs, which, when unmet, challenge the individual's ability to survive on some level. Whether it is banishment from community gatherings or group play, lack of inclusion or being barred from participation signifies lower social status that can cost an individual access to resources. Numerous studies show that even brief ostracism causes sadness and anger, reflexive reactions theorized as adaptive for survival.[29] Ostracism distress is often probed by the Need Threat Scale, which tests degree of distress along four fundamental need dimensions—control, self-esteem, belongingness, and meaningful existence.[30] Ostracism threatens control because it is a unilateral action, the individual does not choose to be excluded. It challenges self-esteem by affecting the value of self or the perception of not being liked. Ostracism challenges belongingness by separating the individual from the group. Lastly, it threatens meaningful existence by causing existential grief, as if the person does not matter or exist and, in radical cases, literally threatens life.[30]

In many studies of social exclusion, Cyberball is the tool used to create the ostracism condition preceding need threat assessment. Cyberball is a virtual ball-tossing game in which the participant is led to believe she is playing catch with two or three other players online, when in fact the other "players" are controlled by the computer program. The Cyberball paradigm induces brief ostracism by a period of "keep away;" for several minutes during the ball-toss, the other ostensible players exclude the participant from the game of catch. This method has consistently demonstrated the threatening of the fundamental needs on the Need Threat Scale.[31-34]

Interestingly, attempts by investigators to make the paradigm less meaningful or less distressing have not yet been successful at finding the minimum condition necessary to induce ostracism distress.[30] Despite being told they were playing with only the computer,[32,34] with despised KKK members[35] or on the condition of exclusion having monetary benefits and inclusion monetary costs,[36] participants still reported distress after playing Cyberball. These findings demonstrate the power of ostracism—its deep, aversive psychological impact regardless of mitigating circumstances.

This power makes sense in light of the theory that ostracism distress is adaptive. After being excluded, individuals generally act to secure their hindered needs.[29] Participants excluded during Cyberball are more likely to conform on a subsequent task, even when that means agreeing with obviously incorrect answers.[31] Ostracism has also been shown to motivate performance. In one study, ostracized participants performed better on a cognitive ability task when they were told it was an opportunity to raise their inclusionary status, an effect that was mediated by the need for belonging.[37] The desire to seek acceptance from a social group, or need to belong, seems to be an adaptive drive born out of the human inclination to form social bonds and to resist their termination.[38]

Felt ostracism distress, more generally categorized as “social pain,” drives behavioral responses to exclusion. Feeling pain from being excluded by a social affiliation prompts the individual to change strategies for more likely future acceptance. As reviewed in van Beest,[36] the ability to detect ostracism by registering it as painful drives adaptive coping responses—such as fight, flight or greater social insight and skill—which can increase the likelihood of being included in the future. Further, the experience of social pain promotes survival by creating distress when bonds of social attachment are disrupted.[32]

Ostracism research has made the case that social and physical pain share neural circuitry.[32,36,39-41] This overlap is appropriate from an evolutionary standpoint, as noted above, to assist social animals reacting to threats to inclusion[39] and encourage close social bonding.[32] Eisenberger argues that the attachment system made use of pain system mechanisms to prevent damaging outcomes of social separation.[32] The anterior cingulate cortex (ACC) seems to play a central role in this shared circuitry.[40]

Recent investigations have extended this theory to explore possible physiologic modulators of both physical and social pain. For example, one study demonstrated that physical pain suppression through daily acetaminophen use reduced self-report of social pain and neural responses to social rejection.[42] Another study found an increase in an inflammatory marker of stress (tumor necrosis factor-alpha (sTNFalphaRII)) correlated with increased activity in brain regions associated with social pain (dACC and anterior insula) during a rejection task.[43] These findings illustrate the importance of studying the neural substrates of social pain, as they may be closely intertwined with the physiology of the body and susceptibility to disease, including cardiovascular disease and depression.[43]

Neural correlates of social exclusion

The literature representing the current understanding of the neural substrates of ostracism distress—studies directed at localizing and characterizing the brain's response to social stress—comprises primarily works based in adult populations, but does lay an important general foundation of knowledge about the neural circuits involved in processing these insults. As reviewed by Crowley et al.,[44] regions that have been implicated in the processing of social rejection and distress include the dorsal anterior cingulate cortex (ACC),[32,45] subgenual/ventral ACC,[46,47] right ventrolateral PFC,[32,46] medial PFC [45,46] and insula.[32,45,46]

Seminal work by Eisenberger et al.[32] that first shed light on substrates involved in ostracism distress investigated the previously discussed theory that social and physical distress might share a common neurological apparatus. Comparing fMRI scans of regions found to be involved in processing of physical pain to scans during the Cyberball exclusion task, Eisenberger et al. found an overlap region of heavy involvement—the anterior cingulate cortex (ACC).[32] The ACC is hypothesized to act as an overarching conflict monitor, essentially a neural alarm system that is alerted when a neural stimulus is at odds with present goals.[48,49] The dorsal ACC mediates the affective component of distress resulting from physical pain rather than the sensory component of physical pain.[50,51] Earlier animal research has provided evidence suggesting that adaptive processes that would be expected to activate emotional, but not physical, pain can be interrupted by interference with the ACC. For example, surgical ablation of the ACC in hamster mothers disrupts behavior that keeps newborn pups close by, within radius of protection.[52] An analogous finding in humans is that mothers who hear the cries of their infants have marked activation of the ACC in response to that stress.[53]

These findings were supported by the work of Eisenberger et al.[32] who subjected volunteers to rejection using the Cyberball tool. Eisenberger et al. found that the ACC was more active during the experience of exclusion and was positively correlated with self-reported measure of subjective distress. Interestingly, the right ventral prefrontal cortex (RVPFC) was also activated during exclusion but its activity was negatively associated with self-reported distress; the conclusion of the investigators was that the RVPFC is an effective brake, likely acting to regulate the distress of social exclusion by disrupting the actions of the ACC.[32]

Further investigations have begun to parse out the fine differences between the neural responses of the adult brain versus the developing brain. Masten et al. replicated the Cyberball-fMRI study discussed above in 23 adolescents (12.4-13.6 years) and found the same results regarding the ACC and the RVPFC and confirmed the negative association of RVPFC activity with subjective distress.[46] This study, however, had other findings that were unique to adolescents. In addition to the above findings, it showed an association between higher activation of the insula and of the subgenual anterior cingulate cortex (subACC) and greater distress.[46] The subACC region, while not found to be differentially activated in adults exposed to the emotional distress of Cyberball, has been implicated in earlier studies of rejection experience in adults. Somerville et al. showed this region to be activated when subjects learned whether they were accepted or rejected.[47] In another study, Burklund et al., found that, on a more chronic basis, this subcortex is more highly activated in individuals who are lower in rejection sensitivity.[54] These findings implicate the subACC in interpreting possibly negative stimuli as less threatening.[46,54]

Sebastian et al. directly compared adolescent girls with adult women during a modified version of the Cyberball task and found that the adult subjects activated the ventrolateral prefrontal cortex (VLPFC) to a greater extent during exclusion than during inclusion, whereas the adolescent group showed the opposite pattern.[55] Because the right VLPFC was implicated by Eisenberger et al. in the regulation of distress during social exclusion,[32] some groups have hypothesized that this is a mechanistic explanation of the increased affective distress reported by adolescents versus adults subjected to exclusion stress.[56]

In another study by Sebastian et al., adolescents and adult females were subjected to a rejection-themed Stroop interference task in which they were asked to indicate the ink color used to write neutral-, rejection-, and acceptance-associated words.[57] The adults' VLPFCs were more highly activated by rejection-themed words, whereas the adolescents' were more activated by acceptance-based stimuli. Moreover, in the adolescents, the VLPFC was unable to distinguish between rejection-based and neutral words whereas in the adults it was.[57] These studies indicate, at the very least that the various prefrontal regulatory mechanisms responsible for the functions in question are dynamically changing between mid-adolescence and adulthood.[58]

fMRI-based investigations have greatly advanced our understanding of the processing of rejection in adults and, more recently, in adolescents, but they have limitations. As noted by Crowley et al., the blood-flow related signal change read by the fMRI apparatus occurs over a timeframe of 2 seconds or more.[44] Additionally, nearly all Cyberball-based fMRI studies have averaged signal over the entire exclusion block. These studies have provided a valuable starting point, but experience suggests that the nuanced perceptions that govern such intricate emotions as rejection and acceptance develop rapidly over small fractions of a second.[44] As such, a deeper understanding of these events may be provided by reading event-related brain potentials (ERPs). ERPs are unique EEG waveform "fingerprints" that can be reproducibly traced back to a given stimulus, and the natural timescale of ERPs has allowed a much finer temporal resolution than possible with other modalities.

A well-established ERP marker that is relevant in the study of affective response to rejection is the late positive potential (LPP).[44] This ERP is believed to reflect voluntary or facilitated attention to, or suppression of, emotional stimuli,[59,60] such as when a subject is asked to suppress the affective response to rejection.[61] This response is seen anywhere from 200 to 2000ms after a stimulus, usually in posterior midline cortical regions.[44] Initial studies performed by our group,[44,62] have validated the use of ERP analysis in investigating the rapidly occurring neural reactions to rejection. Findings suggest neural slow wave activity in frontal cortical regions tracks the level of expressed ostracism after Cyberball.

Trust

An understanding of the neuropsychological underpinnings of ostracism is a prerequisite for any analysis of the role of friendship state on exclusion, but is not alone sufficient. Unfairness in the context of a close friendship is a stress with several facets and likely engages psychological processes beyond those involved in the generic ostracism distress response discussed above. Such unfairness grossly comprises not only ostracism but also the distinct stress of breach of trust.

Trust, as a discrete concept in psychology and in the study of human behavior, is one with a long history and literature. It is defined as a "positive expectation in the face of uncertainty emerging from social relations,"[63] and is posited to be a vital lubricant in human interaction.[64] From a game theory standpoint, trust enables two individuals or parties to engage in cooperative behavior,[65] and on a societal level it has been shown to be associated with a more healthy, egalitarian and productive society.[64] Much of the understanding of the psychological mechanics of trust has been elucidated through "trust games," which investigate the behaviors surrounding reciprocity.

In such games, one party has a set amount of money and can choose to "trust" it to the other party. That amount is multiplied by a certain factor (as a return on a social investment), and then given to the other player; the recipient player can then choose how much, if any, of that money to return to the first player. Conceptually, the amount given is a measure of trust and the amount returned, a measure of reciprocity. From a rational perspective of self-interest, the optimal strategy would be for the recipient not to repay any money, and for the initial player, knowing this, not to trust it to the recipient in the first place.[66] Despite this, studies repeatedly show that behavior tends not to follow these predictions,[67] and in this discrepancy exists an entire field of study dedicated to the interplay between trust and reciprocity.

The applicability of this field of study and its accepted metric, trust games, to the analysis of the effect of friendship on exclusion is limited, however. Trust games are suited to the study of the development of mutually beneficial strategies between two unfamiliar individuals. In the dyad of a friendship, however, trust as it is defined—"positive expectation in the face of uncertainty"[63]—is preexistent. The distress in our best friend exclusion scenario is not equitable with the rational distresses of monetary loss, and a measure that addresses trust but ignores the emotional component of rejection has little utility.

Cyberball, as it has been previously used, has relied on the Need Threat scale. As discussed, this scale is an established psychological tool for the assessment of rejection. It has been validated primarily in the study of ostracism by strangers. Consequently, this is a measure that addresses rejection but ignores the component of trust inherent in close friendship.

Therefore, to address potential oversights in detecting feelings of distress caused by rejection by a known friend, as in our study, we propose using a questionnaire that instead evaluates feelings of betrayal and concern specific to that relationship. Such a tool might compliment instruments used in trust games and the Need Threat scale and allow parsing of likely differences between generic ostracism and friend-driven ostracism.

Hypotheses and specific aims

This study contributes to the neuroscience of ostracism distress, specifically the effect of friendship on social exclusion in middle childhood. Our specific aim was to investigate the impact of the experience of social exclusion by a friend during Cyberball. We contrasted the event-related potential brain responses and self-reported ostracism distress for a group who played Cyberball with their named best friend and an unfamiliar peer (the "best friend" group) to event-related potential brain responses and self-reported ostracism distress for a group who played with two unfamiliar peers (the "unfamiliar peer" group). This study is the first to focus on ERPs associated with social exclusion by a friend. Our findings extend work on social exclusion to the domain of friendship, beginning to elucidate its unique psychological processes and neural correlates. We chose to concentrate our analysis on the frontal cortical region, since frontal effects have been correlated with ostracism distress on both neuroimaging[32,45,46] and EEG.[44,62]

Our study hypotheses were as follows:

First, we hypothesized that the best friend group would show greater self-reported general ostracism distress on the Need Threat scale[36] following exclusion by a best friend and an unfamiliar peer than would participants who were excluded only by unfamiliar peers. Social exclusion elicits distress and correlates with brain response, a phenomenon that has been demonstrated in neuroimaging,[32,45-47] as well as ERP studies from our group.[44,62] However, to our knowledge, no work has examined social exclusion in the context of best friendships. Eisenberger et al. and others suggest that the physical and social pain systems share common neural circuitry.[32,41] They further argue that the experience of social pain exists to promote survival of mammalian species by creating distress when bonds of the social attachment are disrupted. By extension, we would expect ostracism by a close friend, which represents a close social bond, would be more distressing than being excluded by someone unfamiliar.

Second, we hypothesized that the aforementioned general ostracism distress would correlate with the amplitude of frontal slow wave rejection events for both groups. We examined this hypothesis separately for each group. Our previous work has related the degree of general ostracism distress measured on Need Threat scale immediately after the exclusion period to a more negative voltage frontal late slow wave ERP for rejection events;[44,62] we expect to again observe this association.

Third, focusing on the best friend group, we hypothesized that friendship distress (as assessed with a novel self-report scale created for this study) would correlate with the previously discussed general ostracism distress as assessed on the Need Threat scale. Recognizing that exclusion by a friend is likely emotionally and psychologically distinct from exclusion by a stranger, we devised the FDQ to address specific relational feelings, which could emerge from being ignored by a trusted peer. The FDQ was designed to reflect distress resulting from assumed unfair behavior exhibited by a best friend, eliciting feelings of betrayal and confusion. (See methods section for more explanation and Table 1 for scale items.)

Because Need Threat and FDQ are both assessing social distress, we expect the scales to be associated with one another.

Fourth, we hypothesized that friendship ostracism distress as measured on the FDQ would account for unique variance in the amplitude of the rejection-related frontal slow wave beyond that accounted for by general ostracism distress as measured on Need Threat. Since the FDQ acknowledges the additional insult of being betrayed by a friend, it should more strongly correlate with the slow wave brain response than the Need Threat correlates with brain response.

Methods

Statement of student involvement in procedures and data collection:

I was heavily involved in the design, implementation, as well as data collection of this study. My input into participant enrollment criteria, construction of an exclusion experience for best friend dyads, and creation of a novel scale to measure friend-driven ostracism distress helped direct the course of this work. Also, I, along with Max Greger-Moser, Postgraduate Research Associate, recruited participants via phone calls and enrolled them in the study. I gathered approximately 50% of the data by running EEG sessions and administering questionnaires to participants on weekend days during the winter of 2010-2011. The remainder of the data collection was performed by my thesis advisor, Michael Crowley, PhD, Associate Director, Developmental Electrophysiology Laboratory of the Yale Child Study Center (CSC), and by lab research associates of Yale CSC.

Participants

Forty participants (20 female) 8-14 years of age (mean =11.21, SD = 1.35) in the best friend group and forty-eight participants (25 female) 8-14 years of age (mean = 10.62, SD = 1.47) in the unfamiliar peer group participated for forty dollars compensation. Participants played Cyberball while electroencephalogram (EEG) was recorded and responded to questionnaires. Participants in the unfamiliar peer group and half of the participants in the best friend group were recruited via mass mailings. The other half of the participants in the best friend group were recruited by referral—potential participants were asked to recruit a same age, same sex child they considered "a best friend" to participate with them in the, "Best Friend Study," at the Yale Child Study Center. Children in the unfamiliar peer group also identified a comparable best friend when they completed the FQQ, discussed below. All participants and parents provided assent and consent, respectively, to participate in the study, which was approved by the Human Investigation Committee of Yale University School of Medicine.

Procedure

Behavioral measures

Prior to playing Cyberball, participants completed an abbreviated Friendship Quality Questionnaire (FQQ).[22] The FQQ is a 40-item questionnaire that assesses friendship quality. It is customized by indicating the respondent's best friend's name by entering it in the blank for each item. The six friendship characteristics assessed include, Companionship and Recreation ("___ and I always pick each other as partners"), Validation and Caring ("___ and I make each other feel important and special"), Help and Guidance ("when I'm having trouble figuring something out, I usually ask ___ for help and advice"), Intimate Exchange ("___ and I are always telling each other about our problems"), Conflict Resolution ("___ and I always make up easily when we have a fight") and Conflict and Betrayal (include "___ and I get mad at each other a lot"). The abbreviated version[68] used in this study has only 21 items. Responses range from 1 ("not at all true") to 5 ("really true"). A total Friendship Quality score, the average of items 2-21, was used in this study. Total score range was 1-5 with higher values signifying more positive friendship behaviors and relational style. (Conflict and Betrayal subscale items are reverse-scored.)

Immediately after playing Cyberball both groups responded to the Need Threat Scale[36] to assess social exclusion distress after the rejection condition. The Need Threat Scale is a 21-item questionnaire that has been shown to be reliable and valid as an indication of ostracism distress.[27,36,37] It has been used in neuroimaging research on the neural correlates of social exclusion, associating with fMRI activation.[32,46] We used a Need Threat Scale version revised for children.[44] Feelings of distress or threat were assessed along the four dimensions of fundamental psychological needs: belongingness ("I felt like I didn't fit in with the others"), self–esteem ("I felt unsure of myself"), meaningful existence ("I felt invisible") and control ("I felt powerful"), (reverse-scored). Feelings are rated on a 5-point scale from 1 ("Not at all") to 5 ("Extremely"). In our previous work, lower scores on the Need Threat scale indicated greater distress. For the purposes of the current investigation, however, we have rekeyed the scale such that higher total scores indicate greater distress.

After completing the Need Threat Scale, participants in the best friend group completed the Friendship Distress Questionnaire (FDQ), an 18-item survey designed for the present experiment to address the difference in feelings of being rejected by a close personal relation or best friend and being rejected by an unfamiliar peer. Questions were derived from a focus group of researchers who had administered the Cyberball task in the past. See Table 2 in results section for list of questionnaire items. Items were constructed to detect specific feelings of distress after being putatively excluded by a named best friend or trusted peer. Reactions related to thoughts and feelings of betrayal ("I felt my friend was sneaky"), revenge ("I wanted to get even with my friend") as well as relationship uncertainty ("I felt that our friendship was not as strong as I thought") were accounted for in its construction. Items were rated on a 5-point scale from 1 ("Not at all") to 5 ("Extremely").

EEG paradigm

Participants sat 60 cm away from a 17 in LCD screen in a dimly lit, sound attenuated room while undertaking the Cyberball Social Exclusion Task. Cyberball is a virtual ball toss game in which the participant plays catch with two virtual players. Participants are led to believe they are playing with real individuals over the internet. After a period of fair play in which all players throw to one other, the participant is suddenly excluded in a "rejection" period, in which the other two players only throw to each other. This interval of exclusion is distressing for participants as indicated by their responses on the Need Threat Scale.[29,44] Participants in the best friend group had a "reunion" phase after the exclusion block, in which they were included in another fair play session with the best friend and other player. In the debriefing session following the exclusion period and completion of questionnaires, participants and parents were informed that the game was preset and the other players were not real. No participants expressed regret at having participated.

During the game, the participant's glove, at the bottom center of the screen, received the ball when thrown from the other two players' gloves, above to the left and the right. (Figure 1) After receiving the ball, the participant chose to throw to the "player" either on the left or the right. To throw to another player, participants pressed their right or left index fingers on a response pad. In the case of the best friend group, the participant was told she was playing against her best friend and an unfamiliar peer who had been waiting to play

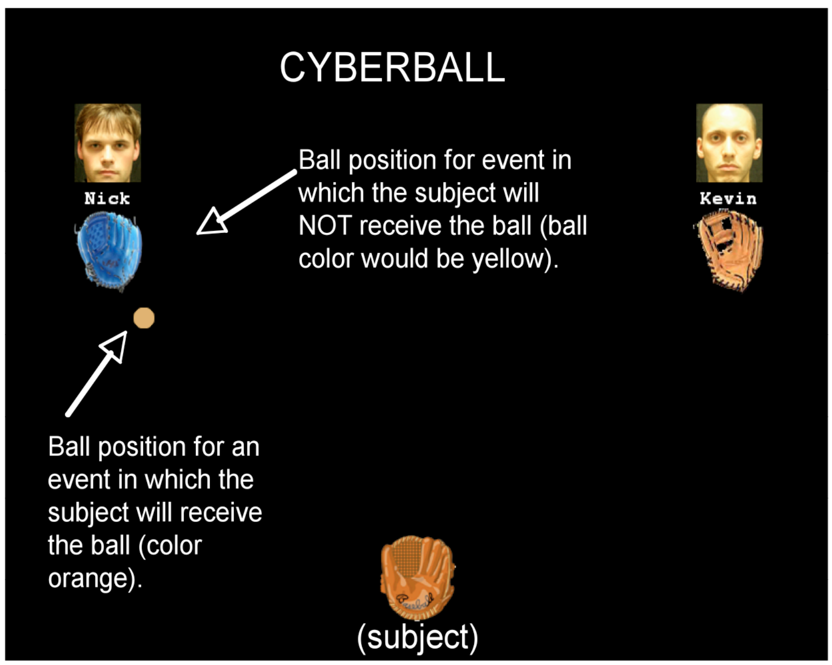

Figure 1. Cyberball screen shot. Participant's glove appears at bottom of screen. Photos and names of other "players" appear above their gloves. During a favor event, an orange ball is directed towards participant's glove. During a "not my turn" event during fair play or a rejection event during exclusion, a yellow ball is directed toward the other players' glove.

Cyberball over the internet. Participants in the best friend group had arrived at the Child Study with a previously identified and recruited best friend as part of a dyad. The best friend executed the Cyberball task simultaneously in another room while also undergoing EEG recording, ostensibly playing together with her best friend and an unfamiliar peer, though the game was preset. For the unfamiliar peer group, participants were told they were playing against two random children. The participants' ages, gender and ethnicity were identified and settings in the program ensured that the photos of the other "players" were similar in these categories. These photos were accessed from the Child Study Center's bank of photos for research purposes. All participants were led to believe with use of a camera that their photo would be displayed for other cyber players to see, although photos were only uploaded to the game in the case of the best friend group. These photos were similar in size, proportion, lighting and facial expression (neutral) to the photos drawn from the research bank.

To make the game appear live over the internet, participants saw a Google™ search page with listings for "Cyberball," one of which appeared to be selected, followed by a loading page that "launched" the game. The experimenter reinforced this idea of a live game by letting the participant overhear that the game was being "hooked up to play over the internet." Photos and names of the other "players" appeared next to their gloves. In the best friend group, the participant saw her best friend's photo and name next to one of the opponent gloves and a similar demographic player with another child's name next to the other glove. In the unfamiliar peer group, participants saw photos and names of two demographically similar but unfamiliar peers. In addition, elements were added to be appealing to children, including the opportunity to choose one of six different gloves to be theirs during the game, realistic sound effects for each throw and catch (swoosh, thump) and a randomly changing ball trajectory (straight, arc or sine wave).

Our version of Cyberball adapted for ERP analysis was composed of 155 trials (throws) across two blocks, a fair play block (108 trials) followed by an exclusion block (47 trials). During the fair play block, the participant received the ball from the cyber peers 36 times (favor events) and threw the ball to one of the peers 36 times. In the remaining 36 trials, players threw to one another and not to the participant ("not my turn" events). The number of trials through which the participant waited to receive the ball was prefixed, so that the participant waited 0, 1, 2 or 3 trials before receiving the ball again (frequency 12, 12, 10 and 2, respectively).

Without forewarning, fair play ended and the exclusion block began. This block of 47 trials was composed of 44 rejection events, when the ball was not thrown to the participant. Favor events (throws to the participant) occurred merely three times (trials 14, 25 and 39), which yielded exclusion 96% of the time. Thirty-six trials of the rejection events from this block were used in ERP analysis and compared to "not my turn" and favor events in the fair play block. The other eleven trials in the exclusion block—the first five trials, the three favor events, and the three thrown by the participant—were not used in the analysis.

Electrophysiological Recording and Preprocessing

Using standard procedures, a high-density EEG was recorded from 128 Ag/AgCL electrodes (Electrical Geodesics Incorporated (EGI)) with Netstation v.4.2 software (EGI) and high impedance amplifiers, sampled at 250 Hz (.1 Hz high pass, 100 Hz, low pass). All electrodes were reference to CZ for recording. Before beginning, all impedances were at or under 40k Ohms. The E-prime v.1.2 (Psychology Software Tools, Inc.) software package controlled the stimulus presentation.

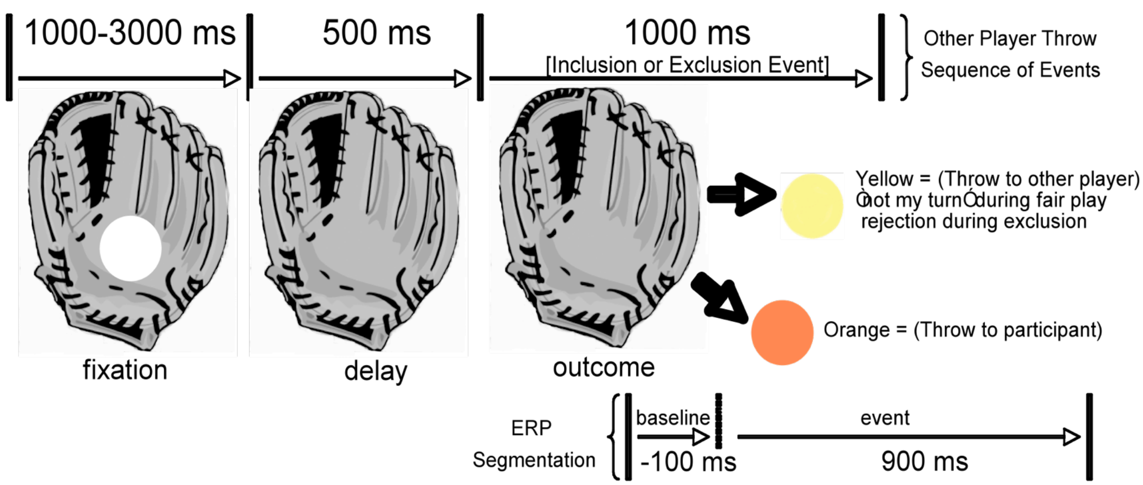

Figure 2. Schematic of a cyberplayer's glove and events. The ball arrives at one of the player's gloves, remains for a fixation period, disappears (delay), and reappears as an outcome event. Ball color and path indicate the type of event (yellow ball indicates a "not my turn" event during fair play and a rejection event during exclusion, orange ball indicates a favor event). ERPs are segmented on the outcome event.

Prior to segmentation, EEG data were low pass filtered at 30 Hz. ERPs were derived only when the ball reappeared after leaving the glove of the opponents/ cyberplayers, but before traveling on the screen (100 ms baseline, 900 ms post-stimulus onset). A schematic of a cyberplayer's glove and events is depicted in Figure 2. To determine EEG data artifact, a channel threshold of 200 μV and an eye movement/blink threshold of 150 µV was used. Any channel or trials marked bad because of artifact were removed from subsequent analyses. Channels were marked bad if 40% of the segments were bad, whereas trials were marked bad if there were eye movements/blinks or if there were more than 10 bad channels.

In addition to removing artifact with the above thresholds, each EEG trial was corrected for blinks and eye movements. Ocular artifact removal (OAR) was accomplished by the method developed by Gratton et al.[69] Within the unfamiliar peer group, 1 out of 48 subjects did not have enough trials for all the conditions and was rejected from the study. Within the best friend group, 3 out of 40 subjects did not have enough trials and were rejected from the study. Within accepted subjects of the groups, OAR was applied on 8 subjects and 15 subjects, respectively.

Artifact rejection was used to eliminate ERP's contaminated by movement and eye artifacts. For data to be included in the analysis, a total of no more than ten channels per event could be interpolated. Averaged data were baseline-corrected by subtracting the average microvolt value across the 100 ms prestimulus interval from the post-stimulus segment. After artifact rejection, the signal trial data were re-referenced from the vertex (Cz) to an average reference of all electrodes. The trial by trial data were then averaged separately for each of the 128 electrode sites and separately for the favor, "not my turn," and rejection conditions.

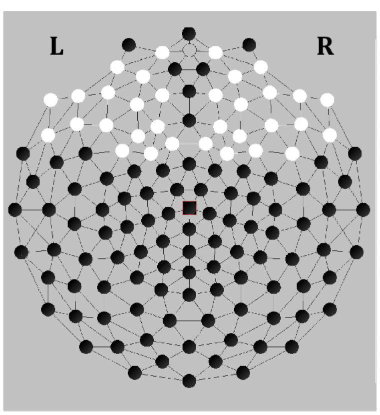

Figure 3. Scalp topography. 128 electrode Geodesic sensor layout. Electrode clusters used for left and right frontal ERP analyses highlighted in white.

As noted, our hypotheses focused on the frontal region, since our earlier ERP studies have found a frontal slow wave, which correlated with ostracism distress.[44,62] For our analysis, we used clusters of electrodes in the right and left frontal regions proposed by Mayes et al. to reflect neuroanatomical boundaries of the frontal cortices.[70] The electrodes included in the left frontal cluster for analysis were as follows: 12, 18, 19, 20, 21, 22, 23, 24 (F3), 25, 26, 27, 28, 32, 33, 34, 38, and 128. The electrodes included in the right frontal cluster were as follows: 1, 2, 3, 4, 5, 8, 9, 10, 14, 116, 117, 118, 121, 122, 123, 124 (F4), and 125. (Figure 3)

Results

Preliminary Analyses. As noted above in the results section, a few subjects were eliminated due to insufficient data, leaving 47 subjects and 37 subjects in the unfamiliar peer group and in the best friend group, respectively. After calculating initial correlations of the rejection-related slow wave with distress measures, an outlier analysis was performed. Data points greater than three standard deviations from the mean were eliminated and the correlations were recalculated. This technique yielded elimination of 3 subjects from the unfamiliar peer group (final N = 44) and 1 subject from the best friend group (final N = 36) for the best friend group. Correlations in our analyses reflected these final sample sizes.

Prior to examining study hypotheses, we first compared the groups in quality of a best friendship, as assessed by the FQQ, and explored the properties of the FDQ. We used a t-test to compare groups' scores on the FQQ. Mean scores on the FQQ for the unfamiliar peer group (mean = 78.56, SD =13.72) and the best friend group (mean = 83.03, SD = 9.88) were comparable, $t(81) = -1.339$, ns.

We further analyzed the groups to look for correlations between FQQ and ostracism distress. For the unfamiliar peer group, quality of a best friendship as measured on the FQQ correlated with general ostracism distress as assessed on the Need Threat Scale (N = 44, r = .38, p < .01). Thus, describing a best friendship as having higher quality (higher score) predicts greater

	Component		
	1	2	3
1. I felt like I wanted to get even with my friend.	.697	.182	-.030
2. I felt that I liked my friend less.	.907	.237	-.003
3. I felt like I changed how I thought about my friend.	.873	.219	-.146
4. I wondered why did my friend stop throwing me the ball.	.535	-.670	.263
5. I felt like I will trust this friend less in the future.	.894	.198	-.054
6. I felt like I didn't want to be friends with this person as much.	.724	.395	.022
7. I felt that my friend changed how he or she thought about me.	.876	-.097	.133
8. I was confused.	.700	-.411	.301
9. I thought, "some friend you are".	.746	-.371	-.231
10. I felt my friend was sneaky.	.819	.213	.241
11. I felt my friend was unfair.	.775	-.393	.101
12. I felt like my friend was teasing me.	.850	-.084	.067
13. I felt that our friendship was not as strong as I thought.	.840	.054	.063
14. I felt my friend dumped me for a new kid.	.837	-.199	.162
15. I might make fun of my friend for doing this.	.734	.047	-.569
16. I felt my friend was a cheater.	.891	.230	-.131
17. I thought I did something to annoy my friend.	.619	-.091	-.404
18. I'm not surprised my friend could do this.	.273	.558	.556

Table 1. Friendship Distress Questionnaire (FDQ) item list and Principal Component Analysis matrix.

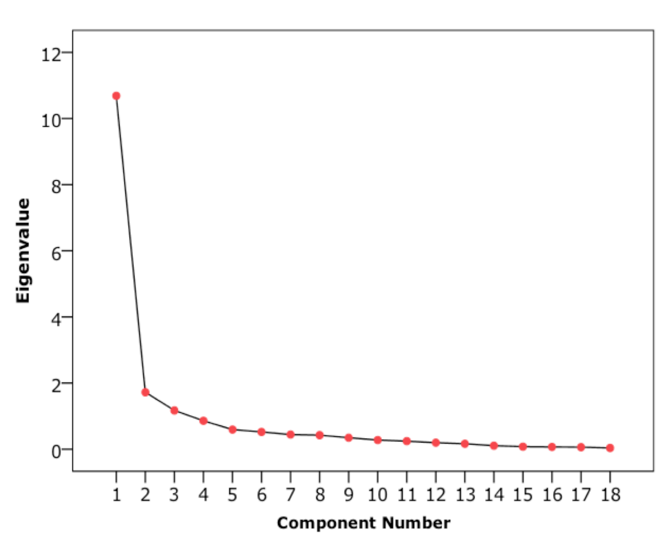

Figure 4. Scree Plot of FDQ PCA.

general ostracism distress when exclusion involves unfamiliar peers. For the best friend group (N = 36), quality of a best friendship did not correlate with general ostracism distress ($r = .044$, ns) or friendship ostracism distress as measured on the FDQ ($r = .009$, ns). Thus, friendship quality of a best friendship is unrelated to general ostracism distress and friendship ostracism distress when exclusion involves a close friend.

To explore properties of our novel scale, the FDQ, we first conducted a principal components analysis to examine the factor structure of the FDQ. (Table 1) This analysis revealed that 75.45% of the variance was accounted for by 3 factors, 59.37% for factor 1, 9.56% for factor 2 and 6.52% for factor 3. A majority of the variance was accounted for by a single factor, with only two items loading more strongly on factor 2 and no items loading more strongly on factor 3. As well, a scree plot of the factor eigenvalues indicated a marked change in slope after factor 1. (Figure 4) Thus we treated the FDQ as a single measure, using its total score for later analyses. This was in keeping with work on the Need Threat assessment of ostracism typically employed in research with Cyberball that uses a single measure reflecting a total score. To provide preliminary validity data for the FDQ we correlated it with the total score from the Need Threat Scale. We observed a strong association between the FDQ and the Need Threat Scale, $r = .61$, $p < .001$.

Next, we examined sex differences in general ostracism distress and friendship ostracism distress. Females and males did not significantly differ on general ostracism distress for the unfamiliar peer group ($t(45) = -.78$, ns) or the best friend group ($t(35) = 1.39$, ns). In the best friend group, males and females did not differ in their reports of friendship ostracism distress, ($t(35) = .19$, ns).

ERP Analysis. We used temporal principal component analysis (PCA) with a correlation matrix and varimax rotation to identify slow wave neural activity. We conducted a PCA on the frontal channels of EEG data (see Figure 3) for three conditions (favor, "not my turn," and rejection). Loadings higher than 0.4 were used to determine the time interval of each factor following Molfese et al.[71] The temporal PCA yielded four components accounting for 89.96% of the variance in the ERP signal. Temporal Factor 1 accounted for 40.12%, of the variance and consisted of a slow wave apparent in time interval 484-900 ms. Temporal Factor 2 accounted for 29.93% of the variance and appeared as a 252-680 ms time interval. Temporal Factor 3 accounted for 9.06% and appeared as a 168-360 ms time interval. Temporal Factor 4 accounted for 7.43% of the variance and appeared as a 4-220 ms time interval. Temporal Factor 5 accounted for 3.04% of the variance but did not yield a significant time interval.

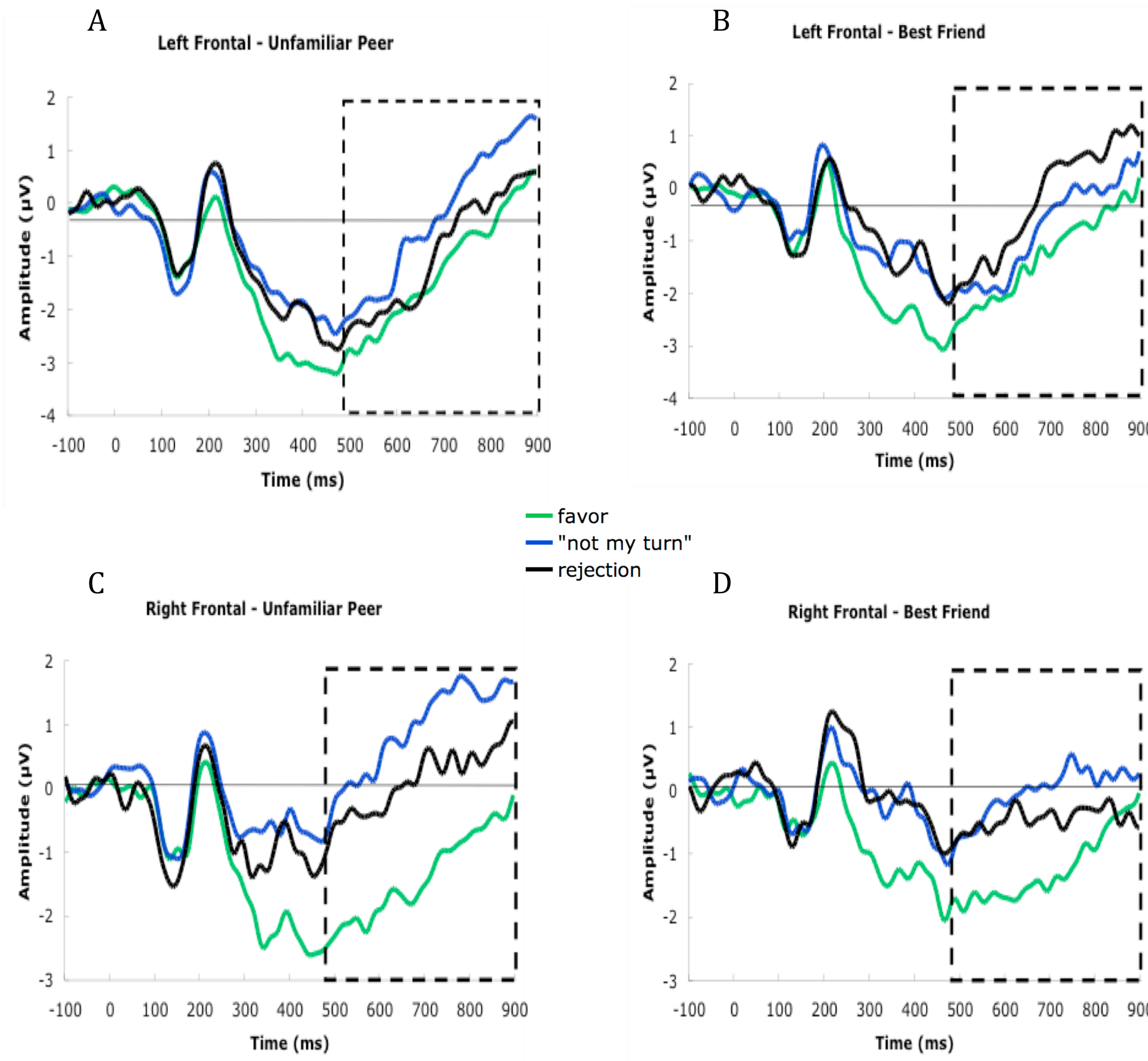

Figure 5. Average ERP waveforms for favor (green), "not my turn" (blue), and rejection (black) events (temporal PCA window 484-900 ms, dotted box) (A) at left frontal for unfamiliar peer (B) at left frontal for best friend, (C) at right frontal for unfamiliar peer, and (D) at right frontal for best friend.

We made no specific predictions about differential neural response to Cyberball events but conducted repeated measures of ANOVA in an exploratory fashion. A repeated measures ANOVA: condition(3) x hemisphere(2) x group(2) revealed a significant condition effect, $F(2, 164) = 7.10$, $p = .001$, Partial Eta Squared = .08, Observed Power = .93. A pairwise comparison indicated that favor (mean = -1.39 µV, SE = .22) had a more negative slow wave than rejection (mean = -.45 μV, SE = .26), mean difference = -.94 μV, SE = .35, $p < .05$. Favor (mean = -1.39 μV, SE = .22) also had a more negative slow wave than "not my turn" (mean = -.12 μV, SE = .24), mean difference = -1.27 μV, SE = .34, $p = .001$. (Figure 5) However rejection and "not my turn" were not different, mean difference = .33 μV, SE = .36, ns. No other significant effects, including group effects, were observed. (All Fs < 1.5, ns.)

Primary Analyses. We address hypotheses one through four in the following section. We were interested in only two correlations in the unfamiliar peer group (rejection-related slow wave in right and left frontal regions with general ostracism distress) and four correlations in the best friend group (rejection-related slow wave in right and left frontal regions with both general ostracism distress and friendship ostracism distress). Thus we kept the overall error rate below $p = .05$ with a Bonferonni correction separately for the unfamiliar peer group and for the best friend group. We included the other analyses and correlations for a post-hoc examination of our data.

First we hypothesized that social exclusion by a close friend would lead to greater feelings of general ostracism for the best friend group compared to the unfamiliar peer group. An independent sample t-test revealed that the groups were comparable in terms of general ostracism distress, $t(82) = -.266$, ns.

Second, we hypothesized that post-exclusion ostracism distress would predict a more negative voltage frontal slow wave. Pearson correlation analysis revealed that general ostracism distress correlated with a right frontal slow wave for the unfamiliar peer group, $r = -.425$, $p < .005$, but not for a left frontal slow wave, r = -.010, ns. (See Table 2 and Figure 6.) Providing discriminant validity for the ostracism effect specific to rejection events, no other ERP slow waves were associated with general ostracism distress for the unfamiliar peer group. For the best friend group, general ostracism distress was not significantly related to the rejection-related frontal slow wave for either of the right frontal or the left frontal regions, r = .244 and .248, respectively.

	Unfamiliar Peer Group N = 47	Best Friend Group N = 37	
	General Ostracism Distress	**General Ostracism Distress**	**Friendship Ostracism Distress**
Left Frontal Slow Wave			
rejection	-.010	.248	.282
favor	.139	.314	.093
“not my turn”	.036	.089	-.027
Right Frontal Slow Wave			
rejection	**-.425****	.244	**.498****
Favor	.088	-.122	-.004
“not my turn”	.139	-.048	-.101

Table 2. Pearson correlations between mean ERP slow wave voltages (left frontal /right frontal) for favor, “not my turn,” and rejection events and general ostracism distress (unfamiliar peer group) and general ostracism distress/friendship ostracism distress (best friend groups).

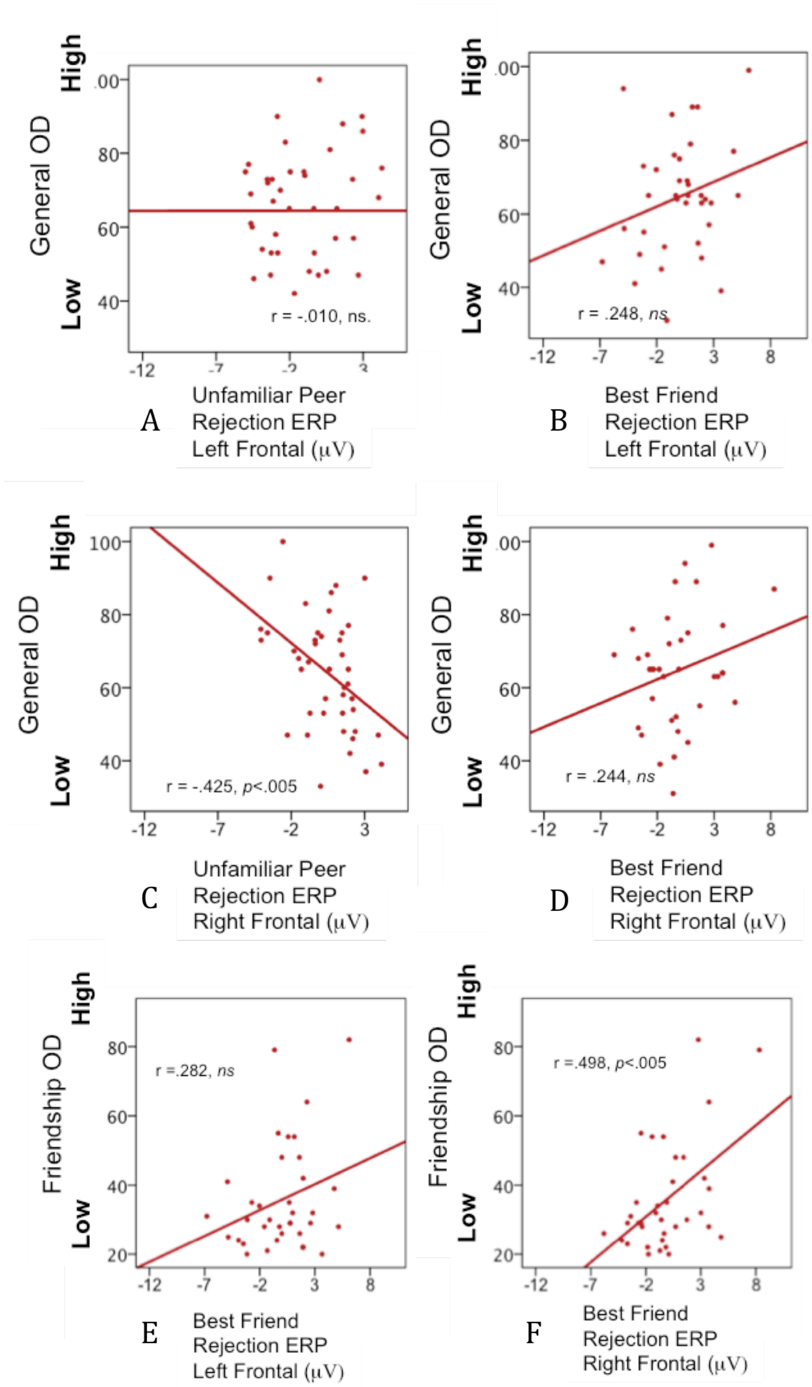

Figure 6. Scatter plots for ostracism distress and rejection ERPs. General ostracism distress (OD) and mean slow wave data for rejection events for unfamiliar peer and best friend groups (A) at left frontal region for unfamiliar peer, (B) at left frontal region for best friend, (C) at right frontal region for unfamiliar peer, and (D) at right frontal region for best friend. Friendship ostracism distress (OD) and mean slow wave data for rejection events for best friend group (E) at left frontal region and (F) at right frontal region.

Our third hypothesis examined the convergent validity of the FDQ, which aimed to indicate friendship-specific ostracism distress. We expected this newly developed measure to be correlated with general ostracism distress, as measured by the Need Threat Scale. Friendship ostracism distress and general ostracism distress were significantly correlated, $r = .613$, $p < .001$.

Our fourth hypothesis examined the specificity of friendship ostracism distress in predicting neural response to rejection in the best friend group. We examined the correlation between friendship ostracism distress and frontal slow wave neural activity. Despite our findings from hypothesis 1 showing that general ostracism distress did not significantly track neural response to rejection for the slow wave for the best friend group, for friendship ostracism distress we observed a correlation with a right frontal slow wave, $r = .498$, $p < .01$, but not for a left frontal slow wave, $r = .282$, ns. Providing discriminant validity for the friendship ostracism effect specific to rejection events, no other ERP slow waves were associated with friendship ostracism distress for the best friend group.

Discussion

The aim of this study was to examine the neuropsychological correlates of exclusion by a best friend. Our finding that friendship ostracism distress correlated with a slow wave for the best friend group is an interesting corollary to our findings from earlier studies[44,62] that neural responses to rejection events reflect individual differences in perceived general ostracism distress. We will review hypotheses and findings in detail below.

We first posited that self-report of general ostracism distress as assessed by the Need Threat scale would be greater for the subjects in the best friend group compared to those in the unfamiliar peer group. However, somewhat surprisingly, we did not observe a significant difference in general distress between these two groups. However, these data must necessarily be weighed against common experience; it is intuitive that being excluded by a friend is different from being excluded by an unknown peer. Friendship carries with it an implicit expectation of fairness as well as an informal social bond. As such, we conclude that psychological factors bearing on the type of relationship and the meaning of exclusion within the relationship also bear consideration.

Our second hypothesis was that the self-reported general ostracism distress score would correlate with the amplitude of a frontal wave. As noted in the methods section, we initially examined the entire 1000-millisecond period and identified five separate factors, and then based further analysis on Factor 1, which accounted for the plurality of the variance seen in the average of all events. This empirically derived temporal factor was defined as the time period between 484 and 900 ms, typically referred to as a slow wave. Similar slow waves have been characteristic of distress-based ERP research in the past. Frontal negative slow waves have been observed in automatic affective responses to threatening stimuli, such as frightening images[72] and electric shocks.[73] Our group previously studied adults playing Cyberball and identified an ERP between 580 and 900 ms in the left prefrontal and medial frontal cortical regions[62] that correlated closely general ostracism distress.

Further, our group followed this adult study with a middle childhood study and found a slow wave from 500 to 900 ms in the medial-frontal regions.[44]

We interpreted our factors in the context of a known, well-accepted ERP in the literature, the late positive potential (LPP). The LPP, however, has been described in the literature as being a slow wave between 200 and 1000 milliseconds, a time period that would be compatible with our Factor 1. As an ERP hypothesized to be a response to attention to emotional stimuli,[59,60] it is also clearly a candidate to be implicated in the neural response to friend rejection. It is tempting to relate our slow wave with the LPP, but this may be premature, as rejection represents a distinct stimulus compared to those used to elicit the LPP in other work and therefore likely involves different neural generators. Further research may allow us to isolate variables that lead to these similar waves and conclude if they are kindred patterns.

Statistical analysis of the slow wave to test our second hypothesis revealed that its amplitude correlated with general ostracism distress [36] solely for rejection events in the right frontal cortical region for the unfamiliar peer group; (Table 2) event and region characteristics for the slow wave did not reach statistical significance in the best friend group. For the unfamiliar peer group, greater distress was associated with a more negative voltage slow wave. (Figure 6C) As well as observing similar timing of slow wave neural response associated with rejection events in this study compared to our previous studies, the correlation of the frontal slow wave and general ostracism distress was also alike in magnitude at $r = -.43$, compared to .47 in our other middle childhood study[44] and $r = .62$ in our adult study.[62] (NB: As mentioned in the methods section, the Need Threat Scale was recoded in this study to make higher values connote greater general ostracism distress. This recoding accounts for the opposite directionality of the correlation in this study compared to our previous studies.) The finding that neural correlate features in children responding to rejection would parallel that of adults is logical given that children as early as middle childhood readily perceive psychosocial distance regarding sociometric status and popularity;[74] therefore, we would expect this developmental continuity.[44]

Compared to our findings in our earlier studies,[44,62] factor 1 found in the present study has been consistent in terms of its timing and magnitude of correlation with general ostracism distress but has varied in topography. The frontal slow wave in the present study appeared in the right frontal region, compared to left and medially for our adult study[62] and medially in our other child study.[44] For our participants in the unfamiliar peer group, we used a larger sample which encompassed our previous study, possibly directing statistical significance towards the topographic right. Hemispheric differences are present in early infancy, and specialization continues throughout development.[71]

For adults, left lateralization of frontal effects associated with exclusion distress has been seen in other studies, including an imaging study that demonstrated increased left inferior frontal activation among lower rejection-sensitive individuals[45] and an EEG study that found increased left frontal cortical activity associated with increased anger in response to ostracism.[75] The frontal cortical lateralization effect has also been observed in a study of evaluative processing, with a larger amplitude LPP associated with the right prefrontal region for negative stimuli, while that in the left prefrontal region is associated with positive stimuli.[76]

Prefrontal activation, in general, has been correlated with emotion regulation;[77] thus, the difference in adults' neural response topography from children's might denote the temperance of the social exclusion experience. In our last middle childhood exclusion study we posited that that the difference observed in child and adult scalp topography for rejection events might reflect developmental changes in frontal lobes.[44] It makes sense that the rejection experience of middle childhood and adolescence would be neurologically distinct during a time characterized by increased emotional reactivity and ongoing brain development.[78] For example, adolescents undergoing an exclusion experience playing Cyberball were shown to have greater activation in the subgenual ACC associated with greater distress, compared to that associated with less distress in adults.[46] Thus, there are likely many changes to rejection processing as social cognition matures.

Interestingly, in the best friend group we did not find a correlation between the rejection-related slow wave and general ostracism distress. Friendship in the literature has been found to be protective in guarding against general ostracism distress and the long-term detrimental effects of peer rejection. At least one of these studies has used Cyberball to induce general ostracism distress. In this investigation, which demonstrates the longevity of this protective effect of friendship, adolescents deemed to have higher quality friendships—gauged by the amount of time spent with friends outside of school—had less activation in brain regions involved in processing of social exclusion (dACC and anterior cingulate) two years after the quality of friendship assessment.[79] A few studies have begun to clarify the direct impact of friendship quality on rejection sensitivity and psychological adjustment, specifically in findings of higher quality friendships associated with less likely development of internalizing[79,80] and externalizing[81] problems.

Higher quality friendships among the best friend group do not appear to explain the lack of correlation between general ostracism distress and the rejection-related slow wave in the best friend group. We have assessed the variable of friendship quality by measuring the quality of a best friendship as measured on the FQQ.[22] The results on FQQ were comparable across groups. Moreover, friendship quality was associated with experienced distress only in the unfamiliar peer group. We posit that this lack of correlation (or inability to reject the null hypothesis concerning the best friend group for hypothesis 2) supports the possibility of a unique neural correlate for rejection manifested by a best friend as opposed to a stranger.

Another interesting finding from our FQQ analysis was the correlation between the Need Threat Scale and the FQQ in the unfamiliar peer group. The more the participant valued a close friendship or highly rated it in quality, the more upset she was when left out by unfamiliar peers. This further supports work by Eisenberger et al., which posits that social pain is adaptive and plays a role in affiliative bonding.[32]

Our third hypothesis was that the scales measuring general ostracism distress and friendship ostracism distress, assessed using the Need Threat scale and the FDQ, respectively, would correlate with each other. Since both these scales were targeting the social and interpersonal stress of exclusion, it is reasonable that they would be found to correlate.

The fourth and final hypothesis we put forward at the beginning of this project was that friendship ostracism distress (measured by our novel FDQ scale) would correlate more strongly with the amplitude of the rejection-related slow wave than general ostracism distress (measured by the Need Threat scale) for the best friend group. This hypothesis was supported by our data. Referring to Table 2, we can see that in the right frontal lobe, the general ostracism distress scale was not significantly correlated with the ERP slow wave for the best friend group, whereas the FDQ scale scores were, reflecting a relatively strong effect. Since the Need Threat and FDQ tools correlated with each other while the FDQ solely correlated with the rejection-related slow wave for the best friend group, we believe this provides discriminant validity for the FDQ as measuring something different than the Need Threat and specific to social exclusion by a best friend. Furthermore, the PCA of the FDQ items yielded one considerably significant component for 17 out of 18 items, which we think represents friendship-related distress. (Table 1)

Referring to the ERP voltage vs. ostracism distress score plots in Figure 6, greater friendship ostracism distress was associated with a more positive voltage rejection-related slow wave. This finding differs from the directionality of the slow wave voltage found to correlate with general ostracism distress for the unfamiliar peer group, for which higher general ostracism distress was associated with a more negative voltage slow wave and was consistent with our earlier general ostracism distress-slow wave correlations.[44,62] This flip in directionality found for our novel study manipulation (participants' neural response to exclusion by a close friend and their distress measured on the FDQ) supports the possibility that we are observing a distinct neural correlate.

We speculate that exclusion by a peer engages different processes than exclusion by a random agemate. While both the Need Threat and FDQ assess distress, the psychological processes they assess are distinct, conceptually as well as statistically. 62% of the variance in friendship ostracism distress cannot be accounted for by general ostracism distress. We conducted a partial correlation analysis, as well. The simple correlation between friendship ostracism distress and right frontal rejection was .496. After controlling for general ostracism distress this relationship remained nearly unchanged, $r = .453$. We believe this difference supports the hypothesis of a neural correlate unique to our study manipulation of being excluded by a best friend.

In colloquial terms, these data recapitulate what everyday experience would strongly suggest and what Eisenberger[32] and Panksepp[41] put forth as adaptive for maintenance of close social bonds —rejection involving a close friend feels psychologically and emotionally discrete from that involving strangers. It indeed makes sense that it would be accompanied by a distinct neural correlate to aid in perceiving this difference. The Need Threat is a tool that calculates a score based on four subscales: belongingness, meaningful existence, control, and self-esteem. Since

Need Threat does not significantly correlate with the rejection-related slow wave for best friends while the FDQ does, we can surmise that there are additional, emotional and psychological processes which are partially distinct from those that reflect the Need Threat Assessment. We propose this may account for why our first hypothesis was not supported.

Conclusions

As a complete work, our study paints an important, though preliminary, picture of the neural correlates of best friend rejection, and supports the need for a novel tool to measure this stress. The essence of this difference highlights importance of context in the study of ostracism. We make a clear case for considering the source of the rejection and there are doubtlessly many other contextual variables that influence the subtleties of rejection response.

We believe that our research begins to fill a gap in the literature. The intersection between middle childhood research and friendship research is not, and should not be, an esoteric academic field. The importance of friendship formation at this developmental time is bountifully described in child psychiatry. For example, high quality childhood friendships have been shown to diminish the link between childhood sexual abuse in childhood and adulthood anxiety.[82] In a second example, behavioral problems in early school were correlated with increased middle childhood peer rejection and lower friendedness, which, in turn, correlated with higher adolescent internalizing problems.[83] In a third example, children defined as having externalizing or comorbid (both internalizing and externalizing) behaviors were more involved in a deviant peer group and observed in increased levels of deviancy training.[84] In a final example mentioned here, of the many in the literature, having a greater percentage of friends using alcohol predicted statistical mediators, including depression, which predicted suicidal behavior.[85]

Accordingly, we feel that the dearth of information about the neural response to best friend rejection represents an important need in this field. We hope that these findings do not simply languish on a page as an academic footnote. Rather, we see this line of research as having very real consequences in clinical psychiatry. Ultimately we desire that the study of variable response to exclusion will allow for a more nuanced understanding. Games such as Cyberball have yielded an important body of work, but children rarely experience social exclusion from unfamiliar peers. Indeed, it may be how a child responds to social exclusion within the context of a significant social relation that is more prognostic of a pathological response to rejection.

We hope that moving the dialogue about social exclusion and ostracism to specific interpersonal relationships will inform interventions aimed at peer rejection and victimization as well as informal parenting and mentoring of kids in navigating their social worlds. Many of the items on our novel FDQ scale—for example, "I felt our friendship was not as strong as I thought"—could easily become topics for cognitive based therapy to weaken the link between stimulus (inferred rejection) and response (the conclusion of a weak friendship), or opportunities for clinicians to help children learn resiliency or rebuild childhood relationships when they go awry.

Limitations and future directions

It is important to call attention to the limitations of this study and to the avenues of future research that these open. I will attempt to organize these in chronological order, starting with subject enrollment.

First, we had initially planned to include only 8 through 12-year old subjects to isolate issues unique to middle childhood but encountered difficulty enrolling enough subjects of this age. Enrolling 13 and 14 year olds allowed us to meet our goal number of subjects but probably added an unwelcome confounding element. This six-year age span represents a tremendous range in terms of social cognition skills and mentalization abilities and includes a major transition from the dominant social influence being parents to peers. Accordingly, an examination of greater numbers of children within narrower age cohorts is needed for a more comprehensive developmental perspective in neural response to social exclusion.

A separate enrollment issue involves the possibility of a sampling bias. We noted early on the possibility that the way we recruited subjects for the best friend group and for the unfamiliar peer group—with the former group told to bring a best friend if they could recruit one—might lead to self-selection in that group of children more likely to have close friends. As a control for this, we administered the FQQ to assess for differences between groups. Although we did not find a significant difference between FQQ scores between subject groups, there may differences in baseline social behavior between these groups that were too subtle for detection by this scale.

In addition to revising enrollment criteria, important changes could include components of experimental design. For example, numerous studies have found differences between sexes in their friendship relations.[86-88] Although we found no significant difference between groups' genders and their general and friendship distress scores, we may be statistically underpowered to detect such differences.

While we were able to identify important differences between study groups with the data collection performed, changes in collection could provide cleaner raw data in future studies, maximizing the signal to noise ratio. In this initial investigation, for example, we pooled all the rejection trials made by the best friend with those made by an unfamiliar peer during the exclusion period. Thus the game actually comprises two distinct rejection events: the best friend throwing to the unfamiliar peer, which constitutes best friend ostracism, but also the unfamiliar peer throwing to the best friend, which does not. Analyzing only the former would provide a cleaner data sample.

It is also plausible that the duration of the Cyberball task and, specifically, the exclusion period, contributes to heterogeneity of ERP findings. Common sense seems to indicate that the emotional insult of being excluded in this manner likely peaks at some point. The first few times the subject is excluded might reasonably be accredited to random chance or the friend trying to reach out to the unknown party, which is why we removed the first few rejection events in the exclusion period from analysis; only after a pattern has emerged would a subject likely begin to process his or her friend's actions as being exclusionary. On the other hand, it might also be suspected that by the end of the several minutes of the exclusion period, the stimulus of rejection has undergone extinction or that the subject has simply lost interest in the game. Although we tried to maintain the participant's attention to the ball toss by having three favor events during exclusion, it is likely that there is an ideal time period over which the data collected would most purely represent the stimulus of best friend rejection. There may be a role for combining investigative modalities in identifying this time period. As noted earlier, fMRI lacks the sub-second resolution to be an ideal modality in identifying the detailed neural mechanics of rejection processing, but it may be suited to grossly identifying this time period of enriched signal.

Employment of neuroimaging in general would be informative in further studies of best friend rejection. It would be enriching to know whether or not our finding of a distinct neural correlate of ostracism distress of being excluded by a close peer relation would be corroborated by fMRI studies with similar designs. Again, fMRI does not provide the temporal resolution of EEG and our unique neural correlate was identified in a window under 500 ms. However, with enhanced contextual salience of exclusion by a close relation, it is conceivable that an alteration in brain structures involved or in their degree of activation might be revealed via neuroimaging techniques.

Regarding the behavioral measures assessing distress after Cyberball, one tool is widely accepted while the other is novel. The Need Threat scale,[36] as noted, has been deemed valid and reliable based on studies of general ostracism distress, including those accompanied by neuroimaging and electrophysiology techniques. On the other hand, FDQ has solely been applied in the present study. It was designed to address the relational stress of rejection by someone considered to be a friend as opposed to someone unfamiliar. Our finding that the FDQ correlates with the rejection-related slow wave for best friends while the Need Threat does not suggests that this novel scale is assessing at least one partially distinct construct. Thus, the FDQ, or a similar tool, might be valuable to the study of social exclusion in assessing rejection by a close personal relation. However, before wider application, the FDQ must be administered to many more subjects for validation and identification of subscales.

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