Final Report to the Bial Foundation Bursaries for Scientific Research 2011:
When Rejection Hurts: Probing the Neural Basis of Childhood
Social Exclusion with a Dense-array EEG

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Recently social neuroscientists have begun to examine the neural correlates of social exclusion with a simple interactive game called Cyberball (Williams & Jarvis, 2006). In this game, a participant makes and receives throws from two other cyber players during a "fair play" portion of the game. Then seamlessly, the other players only throw to one another leaving the participant out of the game. This exclusion experience is mildly distressing to people. Eisenberger et al. (2003) observe that the degree of social distress to exclusion on the Cyberball task is linearly related to fMRI BOLD signal in some neural circuitry common to physical pain (Eisenberger, Jarcho, Lieberman, & Naliboff, 2006; Eisenberger & Lieberman, 2004; Panksepp, 2003). Building on these ideas, we set out to study social exclusion in middle childhood with event-related potentials (ERPs). With the support of the Bial Foundation we have completed 7 manuscripts to date (citations follow the end of this manuscript). refs In 2012, we expect to complete an additional 4 manuscripts based on our data sets. As proposed in the initial grant application, two main studies (Study 1 and Study 2) were conducted examining neural activity with event-related potentials (ERPs) in middle childhood during the Cyberball game. Study 1 adapted the ERP method for examining social exclusion among unfamiliar peers. This study was published in *Social Neuroscience* in 2011. Study 2 examined social rejection in the context of a best friendship. These studies are described in more detail below, after a brief synopsis of our other programmatic work.

During the funding period and through support from the Bial Foundation, several important collaborations based on the Cyberball paradigm emerged. I will not go into detail describing the findings as the published manuscripts have already been submitted to the Foundation. First, with autism expert, Kevin Pelphrey, Ph.D. of the Child Study Center, we began neuroimaging work with the version of Cyberball that I developed. I had approached Dr. Pelphrey with the idea of developing a game similar to Cyberball, called Cybershape. This was to be a game to contrast with Cyberball in which the visual aspect of the game is similar to Cyberball, but players intermittently do not follow the rules. My interest in developing Cybershape was to examine a well known but understudied aspect of autism, the difficulty these individuals have with changes in routine. This work served as the master's thesis of Danielle Bolling at the Center (*Neuroimage*) followed by a replication study in autism spectrum disorders published in *Developmental Cognitive Neuroscience*. Finally, we completed a third study on the development of the neural systems that respond to social exclusion, published in *Developmental Science*. Once available, the reprint of this manuscript will be provided to the Bial Foundation. At the same time, James McPartland, Ph.D. approached me about doing and ERP study in autism with Cyberball. We used participants from Study 1 as a control group for the ERP study, which was also published in *Developmental Cognitive Neuroscience*. Lastly, I have a growing interest in attachment research, which grew out of collaboration with Jessica Borelli, Ph.D. and Linda Mayes, M.D. Dr. Borelli assessed 97 children on the Child Attachment Interview while she was at Yale. Three years later, Lars White, M.S. brought a subset of these children back into the laboratory, those with a secure attachment style and those with an insecure-dismissing attachment style. We assessed these children on the ERP version of Cyberball developed through the support of the Bial Foundation. We found a very interesting pattern of results. In addition to replicating the findings of our previous *Social Neuroscience*, we observed a dissociation of experienced ostracism and neural response, specifically for the insecure-dismissing group. The abstract from this project flows the descriptions of Study 1 and Study2. Once the reprint is available, this will be submitted to the Bial Foundation.

**Study 1: Social exclusion in middle childhood: rejection events, slow-wave neural activity, and ostracism distress**

We saw approximately fifty children in the first developmental study. The data for the first thirty-three male and female children, ages 8-12 years, were published in *Social Neuroscience*. Experiencing fair play initially, children were ultimately excluded by the other players. We focused specifically on "not my turn" events within fair play and rejection events within social exclusion (Figure 1). Dense-array ERPs revealed condition differences ("not my turn" vs. rejection) in slow-wave activity (500-900 ms) for the medial frontal cortical region and the posterior occipital parietal region (Figure 2). Time dependent associations between exclusion events and self-reported distress about the rejection/exclusion experience were also evident for slow wave neural activity (Figure 3). Greater distress was associated with a more negative frontal slow wave and a larger late positive potential (LPP), with children of high and low levels of distress showing markedly different patterns of cortical neural activity (Figure 4). Source modeling with GeoSource software suggested that slow wave neural activity during rejection events was reflected in cortical regions previously identified in functional imaging studies of ostracism, including subgenual cortex, ventral anterior cingulate cortex and insula (Figure 5).

**Study 2: Neuroresponse to Social Exclusion by a Childhood Friend: an ERP Study**

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 their 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 (see Figure 5 for frontal ERPs). 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 (see Table 2). 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). This project served as the basis for a Yale Medical School thesis for Jessica L. Crawford, M.D. We are in the process of preparing a manuscript based on these findings.

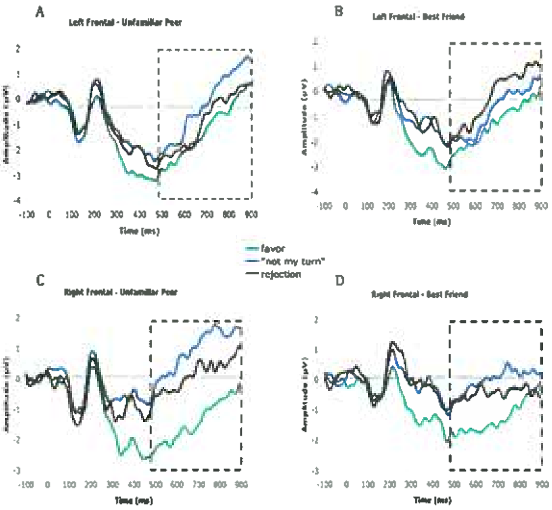


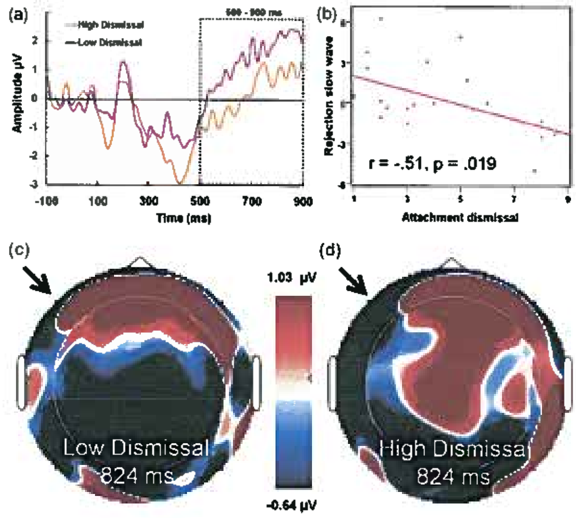

**Figure 5.** Average ERP waveforms for favor (green), "not my turn" (blue), and rejection (black) events (temporal PCA window 484-900 ms, dotted box) (A) at left frontal for unfamiliar peer (B) at left frontal for best friend, (C) at right frontal for unfamiliar peer, and (D) at right frontal for best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

| | 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).

***In press* findings on attachment and social exclusion**

Attachment representations are thought to provide a cognitive-affective template, guiding the way individuals interact with unfamiliar social partners. To shed new light on the underlying mechanisms, we employed the Cyberball social exclusion paradigm to study the temporal dynamics of experienced rejection events among young adolescents. We tested whether event-related potentials (ERPs) sampled during exclusion by unfamiliar peers, differentiate insecure-dismissing from securely attached youth, as indexed by the Child Attachment Interview. Thirteen secure and 10 dismissing 11 to 15-year-olds were ostensibly connected with two peers via the internet to play a computer-simulated ball-toss game. Peers, who were actually computer-generated, were programmed to distribute the ball evenly (inclusion), but eventually exclude the participant (rejection). Afterwards children rated their distress. As in previous studies, higher distress was related to a more negative slow wave (500-900ms) during rejection, a waveform implicated in negative anticipation and appraisal. Though attachment groups were comparable in frontal ERPs and self-reported distress, an attachment-related dismissal dimension was also associated with a more negative left frontal slow wave during rejection, suggesting that high dismissal potentially involves greater expectations of further rejection (Figure right). As expected, dismissal and subjective self-reports of distress were uncorrelated. Yet, a novel approach to combining the neural index and self-reports of rejection to measure their dissociation revealed that higher dismissal predicted underreporting of distress relative to ERPs. Our findings suggest that both anticipatory and evaluative aspects of working models generalize to peer contexts in early adolescence.




**Manuscripts to date with support of the Bial Foundation:**

Bolling, D. Z., Pitskel, N. B., Deen, B., **Crowley, M. J.**, Mayes, L. C., & Pelphrey, K. A. (in press, 2011). Development of Neural Systems for Processing Social Exclusion from Childhood to Adolescence. *Developmental Science.*

Bolling, D. Z., Pitskel, N. B., Deen, B., **Crowley, M. J.**, McPartland, J. C., Kaiser, M. D., et al. (2011). Enhanced Neural Responses to Rule Violation in Children with Autism: A Comparison to Social Exclusion. *Developmental Cognitive Neuroscience*, 1(3), 280-294.

Bolling, D. Z., Pitskel, N. B., Deen, B., **Crowley, M. J.**, McPartland, J. C., Mayes, L. C., et al. (2011). Dissociable brain mechanisms for processing social exclusion and rule violation. *Neuroimage*, 54(3), 2462-2471.

**Crowley, M. J.**, Wu, J., McCarty, E. R., David, D. H., Bailey, C. A., & Mayes, L. C. (2009). Exclusion and micro-rejection: event-related potential response predicts mitigated distress. *NeuroReport*, 20(17), 1518-1522.

**Crowley, M. J.**, Wu, J., Molfese, P. J., & Mayes, L. C. (2011). Social exclusion in middle childhood: rejection events, slow-wave neural activity, and ostracism distress. *Social Neuroscience*, 5(5-6), 483-495.

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White, L. O., Wu, J., Borelli, J. L., Rutherford, H. J. V., David, D. H., Kim-Cohen, J., Mayes, L.C. & **Crowley, M.J.** (in press, 2011). Attachment dismissal predicts frontal slow-wave ERPs during rejection by unfamiliar peers. *Emotion.*