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Attachment Dismissal Predicts Frontal Slow-Wave ERPs During Rejection by Unfamiliar Peers

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Attachment representations are thought to provide a cognitive affective template, guiding the way individuals interact with unfamiliar social partners. To examine the neural correlates of this process, we sampled event-related potentials (ERPs) during exclusion by unfamiliar peers to 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 computerized ball-toss game. Actually, peers were computer generated, first distributing the ball evenly, but eventually excluding participants. Afterward children rated their distress. As in previous studies, distress was related to a negative left frontal slow wave (500 900ms) during rejection, a waveform implicated in negative appraisals and less approach motivation. Though attachment classifications were comparable in frontal ERPs and distress, an attachment-related dismissal dimension predicted a negative left frontal slow wave during rejection, suggesting that high dismissal potentially involves elevated anticipation of rejection. As expected, dismissal and self-reported distress were uncorrelated. Yet, a new approach to quantifying the dissociation between self-reports and rejection-related ERPs revealed that dismissal predicted underreporting of distress relative to ERPs. Our findings imply that evaluations and regulatory strategies linked to attachment generalize to distressing social contexts in early adolescence.

Keywords: attachment, event-related potential, social exclusion, social neuroscience, adolescence

At the heart of attachment theory lies the notion that early affectional ties with primary caregivers lay the foundation for subsequent relationships (Bowlby, 1969, 1973, 1980; Bretherton, 1985; Bretherton & Munholland, 2008; Owens et al., 1995). This continuity across relationships is thought to stem from repeated interactions with caregivers giving rise to mental representations or internal working models (IWMs). IWMs are thought to initially guide behaviors with caregivers themselves, but "increasingly become a property of the child himself" (Bowlby, 1988, p. 127), acting as *cognitive–affective filters* (Laible & Thompson, 1998)

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through which children appraise and form expectations about themselves, the world, and others in relationships (Bowlby, 1973; Bretherton, 1985).

In order to study working models as distinct from the attachment bond per se, scholars propose examining these processes when the caregiver is absent (Sroufe, Egeland, Carlson, & Collins, 2005). To this end, studies focus on the influence of IWMs on new social encounters. Links have emerged between IWMs and cooperative behaviors with unknown same-sex strangers in adulthood (Roisman, 2006) and interactions of children with adult strangers or new peers (Main & Weston, 1981; Pastor, 1981; Troy & Sroufe, 1987). Evidence implies that social exchanges involving negative affect are especially powerful for differentiating among attachment classifications (Feeney, Cassidy, & Ramos-Marcuse, 2008). In these instances, IWMs are assumed to operate much like a self-fulfilling prophecy (e.g., Ainsworth, 1990). *Securely attached* individuals learn to anticipate (and elicit) support from others owing to similar past experiences with caregivers. Conversely, *insecure children*, whose parents are thought to be on average less sensitive and responsive to bids for comfort (Ainsworth, Blehar, Waters, & Wall, 1978; De Wolff & van Ijzendoorn, 1997), may develop corresponding beliefs of others as less supportive during distress and themselves as "essentially unwantable" (Bowlby, 1973, p. 204). Yet, few studies examine the psychological processes thought to underlie this extrapolation of attachment patterns to new social encounters.

Neural measures may offer a promising avenue to explore the cognitive–affective process of generalization of working models. However, the study of the neural bases of individual differences in attachment is still in its infancy (see Coan, 2008). Only a handful of studies compare neural activity between attachment classifications (Gillath, Bunge, Shaver, Wendelken, & Mikulincer, 2005; Zilber, Goldstein, & Mikulincer, 2007), with many reporting activation of reward and approach-related circuitry (e.g., left frontal activity) to social interactions or stimuli in secure relative to insecure subjects (e.g., Dawson et al., 2001).

To date, most neuroimaging studies focus on the attachment dyad or nonrelational tasks, leaving open the question of how attachment patterns generalize to new encounters. To shed light on this issue, we studied neural correlates of working models during exchanges with unknown peers using event-related potentials (ERPs). Given the rising salience of peer contexts for adolescents (e.g., Larson & Richards, 1991)—to the point where peer interactions may at this stage be a correlate of attachment security over and above parent–child exchanges (Allen, 2008)—we felt a young adolescent sample was well-suited to explore this area.

We employed a novel adaptation of a virtual ball-toss game ("Cyberball"; Williams, Cheung, & Choi, 2000) to electroencephalography (EEG) where participants ostensibly play with two peers online, who initially include, but later exclude the participant (Crowley, Wu, McCarty, et al., 2009). Part of the appeal of using ERPs in this context is their high temporal resolution which helps to unpack the moment-to-moment modulations of neural activity that follow the equally rapid shifts in social exchanges. This method has enabled comparisons of neural responses to rejection events during exclusion with highly transient events matching rejection in their outward appearance, but occurring during inclusion when peers do not throw to participants ("not my turn" events). Comparison of these events permits the isolation of neural activity related to feelings of rejection from its mere perceptual corollaries (Crowley, Wu, Molfese, & Mayes, 2010). In the present study, the ERP version of Cyberball therefore allowed us to test the assumption that variation in attachment patterns comes to the fore mainly under socially distressing conditions (e.g., Ainsworth, 1990), such as peer rejection.

Regarding the neural pattern of activity, rejection in Cyberball has elicited a positive-going slow wave between 500 and 900 ms at left frontal sites in young adults (Crowley, Wu, McCarty, et al., 2009) and frontocentral sites in children of ages 8–12 years (Crowley et al., 2010). Also, Crowley et al. (2010) found attenuated frontal slow-wave activity during rejection as compared with inclusion "not my turn" trials. More negative frontal slow waves also emerge when cues signal an aversive outcome is about to follow (Baas, Kenemans, Böcker, & Verbaten, 2002; Crowley, Wu, Bailey, & Mayes, 2009; Regan & Howard, 1995). Thus, Crowley et al.'s (2010) findings imply that children come to expect being ejected from the Cyberball game (aversive outcome) as rejection events accumulate during exclusion.

In a similar vein, a more negative frontal slow wave during rejection has been found to predict increased distress on self-reports following Cyberball (Crowley, Wu, McCarty, et al., 2009; Crowley et al., 2010). Supporting such links to appraisal, slow waves in frontal regions are also linked to evaluative processes in affective tasks (e.g., Flaisch, Häcker, Renner, & Schupp, 2011). Thus, positive or appetitive stimuli evoke greater, especially left-lateralized frontal slow waves (e.g., Cunningham, Espinet, DeYoung, & Zelazo, 2005; Gable & Harmon-Jones, 2010; Graham & Cabeza, 2001), in line with left-hemispheric specialization for approach (Davidson, 1998). Lower (left) frontal late slow-wave activity during rejection may thus also reflect a less positive appraisal (i.e., "They will not pass the ball to me").

Due to the key function of working models to evaluate and anticipate others' behavior (Bretherton & Munholland, 2008), we deemed frontal late slow-wave ERPs during new peer encounters as potentially susceptible to effects of attachment. We focused on the two most frequent interview-derived attachment patterns, that is, secure and insecure–dismissing status (Shmueli-Goetz, Target, Fonagy, & Datta, 2008; van Ijzendoorn & Bakermans-Kranenburg, 1996). We also considered the core dimensions underlying these classifications (coherence, dismissal, idealization) due to potential gains in sensitivity vis-à-vis categories in assessing secure versus dismissing status and physiological markers (Roisman, Fraley, & Belsky, 2007; Rifkin-Graboi, 2008). Insecure–dismissing status is thought to involve excessive self-reliance, positive distortions (*idealization*) or downplaying and claiming not to remember (*dismissal*) attachment episodes, with the putative aim of blocking out vulnerability to preserve a positive sense of self despite a rejecting caregiver (Hesse, 2008). Secure status is characterized by *coherence*, the ability to retrieve and reflect on relevant memories of attachment episodes.

We hypothesized that as compared with securely attached children, more insecure and dismissing children would show a lower magnitude of frontal slow waves during rejection, a pattern we have found to reflect greater distress in previous work (Crowley, Wu, McCarty, et al., 2009; Crowley et al., 2010). Consistent with findings from other modalities (Dawson et al., 2001), we predicted that differences would be maximal in a left-lateralized frontal region, suggesting less positive appraisal and approach motivation linked to dismissing attachment.

From the perspective that one function of working models is to scaffold the cognitive–affective strategies that children develop in reaction to unresponsive or rejecting caregiving, we also sought to examine the characteristic denial of vulnerability in dismissing attachment. Thus, dismissing adults typically provide ostensibly positive or emotionally neutral responses on the Adult Attachment Interview (AAI; George, Kaplan, & Main, 1996). Yet, this comes coupled with *greater* physiological arousal relative to secure adults (e.g., Dozier & Kobak, 1992). Analogous findings exist in dismissing versus secure children and adults, revealing elevated physiological distress although self-reports or external behaviors disagree (e.g., Beijersbergen, Bakermans–Kranenburg, IJzendoorn, & Juffer, 2008; Borelli et al., 2010; Spangler & Grossmann, 1993). In an attempt to extend prior findings, we studied neural activity and self-reports of rejection and formed a measure of dissociation between these indices. We hypothesized that higher levels of dismissing attachment would predict self-reports of lower distress *relative* to the frontal slow-wave response to peer rejection.

Method

Participants

Participants were drawn at random from a subset of a sample comprised of 97 children investigated 3 years prior to the current study (Time 1) when the sample was age 8–12 years (mean age = 10.01 years; see Borelli et al., 2010, for more details). The subset was selected based on (a) the age range of interest (11–15 years) and (b) secure and insecure–dismissing attachment classifications as indexed by the Child Attachment Interview (CAI; Shmueli-Goetz, Target, Datta, & Fonagy, 2004) administered at Time 1 (see below). They were initially recruited from the New Haven catchment area via mass mailing, flyers, and Internet postings. Sixty-four of 73 children originally classified as secure or dismissing fell into the age range of interest (11–15 years). This subset was initially contacted via mail, then email, at which point four participants declined. An additional five participants had moved, yielding a pool of 55 participants. Thirteen secure (six boys; seven girls) and 10 dismissing (nine boys; one girl) youth children with a mean age of 12.86 years (standard deviation [*SD*] = 1.30; range = 11.25–15.66) were recruited at random from this pool via telephone (91.3% Caucasian, 8.7% biracial children) without reference to any further variables. On average, the cohort had high socioeconomic status (SES), receiving a score of 54.84 (range: 38.5–66.0) on the Hollingshead Four Factor Index (Hollingshead, 1975). The majority of parents were classed as major professionals (56.5%), followed by minor professionals (34.8%) and skilled workers (8.7%).

Procedure

During the first visit, participants were administered the CAI (Borelli, 2007; Borelli et al., 2010). For the present EEG study, participants returned 3 years later and consent as well as assent forms were collected again, from parents and minors, respectively. Once the EEG net was applied children were administered the Cyberball paradigm immediately followed by the ostracism distress measure. Following this, participants were given another ERP task and completed two further questionnaires not included in the present analyses. After removing the EEG net, children and parents were debriefed and received $40 and $10 for their participation, respectively. This research was approved by the Human Investigation Committee at the Yale School of Medicine.

Apparatus

Visual stimuli (Cyberball task and questionnaires) were presented on a 17-inch cathode ray tube (CRT) monitor, with participants seated 33 in. away. A response pad with four buttons was used to respond during the Cyberball task. Questionnaires were entered into E-prime (Schneider, Eschman, & Zuccolotto, 2002) and prerecorded (in a neutral female voice) to rule out variance in performance due to reading abilities and facilitate similar interpretation of each item across participants. Responses to questions were made using a universal serial bus (USB) mouse.

The EEGs were recorded using Net Station 4.2 from a 128 channel dense-array EGI Geodesic Sensor Net 200. The geodesic net comprises 128 sponge sensors organized in geodesic form, possessing an elastomer tension structure. Electrodes were arranged across the scalp with standard interelectrode distance of 2.7 cm. The vertex (Cz) electrode served as a reference, and, prior to data analysis, recordings were rereferenced to the average reference. EEG was recorded at 250 Hz and filtered at 0.1–100 Hz (time constant = 1 s). Impedances were checked at the beginning of the experimental session and were kept below 40 kilo-Ohms.

Data were preprocessed implementing a low-pass filter at 30Hz. Data segmentation from 100 ms pre- and 900 ms poststimulus onset was performed, followed by a manual check and bad-channel replacement by surrounding channels (1 channel in 1 subject was replaced). As part of artifact detection, we identified bad segments (threshold 200 μV), eyeblinks and eye movements (eye channel threshold 150 μV). Then bad segments and bad channels (with over 50% bad segments) were replaced. The average number of replaced segments was 26 per subject (*SD* = 25, range: 0–148). After averaged reference and baseline correction (using the first 100 ms before the event), trials of the same condition were averaged together. Trials with any eye blinks or eye movements were rejected. We also rejected trials with more than 10 bad channels. Subjects with less than 15 trials per condition were excluded from later analysis. Twenty-one participants had sufficient data.

Measures

Cyberball social exclusion task–ERP version. The current paradigm (Crowley, Wu, McCarty, et al., 2009; Crowley et al., 2010) was adapted from the original Cyberball task (see Williams & Jarvis, 2006). The task involved tossing a ball back and forth while participants were led to believe that they were interacting with two same-aged peers over the Internet (see below for details of the deception). Subjects used a response pad to throw to the left (Button 1) or right (Button 4) coplayer. In reality, coplayers were computer generated and their throws adhered to a preprogrammed script (described in more detail below). Coplayers were represented by photographs of individuals with neutral facial expressions (age, gender and racial origin matched to participant drawing on a preselected picture bank) and a colored baseball mitt. Crowley, Wu, McCarty, et al., 2009, created an ERP variant in E-prime (Psychology Software Tools, Inc.), time-locking events to inclusions and exclusions. Accordingly, throws were operationalized by letting the ball vanish from the glove before reappearing 1 cm adjacent to the glove, either ostensibly traveling away from the participant ("participant-throw" event), toward the participant ("inclusion" event), or from one coplayer to the other coplayer ("not my turn"/ "rejection" event; see Figure 1). After reappearing, the ball remained stationary for 1000 ms as an event to time lock to for the measurement of ERPs. This event was further defined by a contingent color change of the ball to orange or yellow in order to index an inclusion or exclusion event, respectively.

Unbeknownst to the participant, the game passed through two consecutive phases, fair play and social rejection/exclusion. Fair play alternated between favors (participant is thrown the ball), ball tosses (participant throws the ball) and "not my turn" events (the ball is passed between the two virtual coplayers, during fair play) in a predefined set order unknown to the participant, with each event repeated 36 times (fair play consisted of 108 trials involving 36 favors, 36 "not my turn" events, and 36 ball tosses). The rejection block was composed of 47 trials, 41 rejection events, three favors, and three ball tosses to maintain attention (Trials 14–15, 25–26, and 39–40). During exclusion, only the final 36 rejection events were analyzed (i.e., the first five throws of the block were excluded) to ensure children were aware of the rejection. Following data preprocessing, 82% of favor, 79% of "not my turn" and 78% of rejection trials were kept. The average number of trials across all conditions was 29 (range: 18–36). ERPs during these trials were sampled, then submitted to principal components analysis (PCA), which revealed factor scores that functioned as indices of neural response to rejection.

Resembling previous research (Williams, Cheung, & Choi, 2000), and attempting to render the interaction as real-to-life as possible, participants were informed they would be playing with peers via the Internet (whose brain activity was also being recorded in affiliated labs). In accordance with Eisenberger, Lieberman, and Williams (2003), they were provided a *Nature* "News Feature" article (Nadis, 2002) printed in color, referring to simultaneous brain scanning ("Hyperscanning") as a cover story for this procedure. Furthermore, two important modifications were undertaken by Crowley et al. (2009) in order to enhance engagement with and believability of the task. First, the paradigm commenced with a Google screenshot, which, after the experimenter ostensibly clicked on a pseudo-"Cyberball" web link, proceeded to a colorful "Cyberball" introduction screen, informing participants that the game was loading with a progress bar. Next, a screen appeared allowing participants to pick their favorite of six variably designed gloves. A prerecorded female voice narrated the instructions and glove-choice screens.

Two additional modifications to Cyberball were designed to make it more appropriate for ERP methodology in adolescents. First, to facilitate fixation to each event, the time the ball remained with each coplayer randomly varied between 1,000 and 3,000 ms before leaving the glove (see Figure 1). Second, the ball's trajectory varied between a straight line, an arc and a sine wave and was accompanied by one of a variety of "swoosh" as well as "catch" sounds, all of which were randomly assigned trial by trial.

Ostracism distress. The Need Threat Scale (NTS; van Beest & Williams, 2006) was specifically designed to tap the extent to which needs for acceptance are threatened during Cyberball and has shown excellent internal consistency and high correlations with neural markers of social pain, supporting construct validity (e.g., Eisenberger et al., 2003; Williams et al., 2000). It was adapted for use in children (Crowley et al., 2010) by simplifying question wording and comprises subscales assessing belonging (e.g., "I felt rejected." Reverse scored), self-esteem (e.g., "I felt liked"), meaningful existence (e.g., "I felt invisible." Reverse

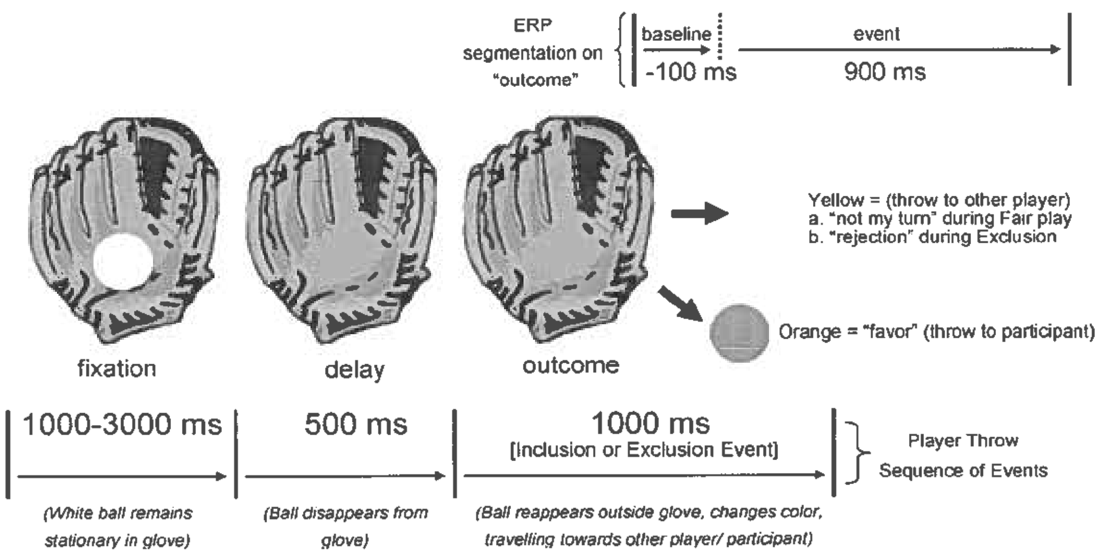

Figure 1. Schematic diagram of a cyber-player's glove and events. The ball arrives at one of the cyber-player's gloves, remains for a fixation period, disappears (delay), and reappears as an outcome event (yellow ball for exclusion, orange for inclusion). ERPs segmented on the outcome event.

scored), and control (e.g., "I felt I had control over the course of the game."), which were summed to create a total score. High scores indicated more ostracism distress. Participants were requested to rate all 21 items on a Likert scale ranging from 1 (*not at all*) to 5 (*extremely*). Questions appeared on the screen and were simultaneously played to the subject via recordings.

Child attachment interview. The Child Attachment Interview (Shmueli–Goetz et al., 2004) is a semistructured interview designed to tap state of mind regarding attachment in middle childhood (attachment security), yielding both classifications (secure, insecure–dismissing, insecure–preoccupied, insecure–disorganized) and continuous scales measuring attachment security. Both continuous and categorical approaches are legitimately applicable for research purposes (Shmueli–Goetz et al., 2008). The interview has recently been extended to encompass the age range 8–15 years. It is videotaped and comprises 19 questions (e.g., "What happens when your mom gets mad at you?") lasting approximately 30–60 min. The interviews were transcribed and then scored by a trained, reliable coder based on videos and transcripts using a coding manual (Shmueli–Goetz et al., 2004) as detailed elsewhere (Borelli et al., 2010). Coding proceeds on eight 9-point feeder subscales informing overall coherence, which is also assessed on a 9-point scale (see Shmueli–Goetz et al., 2008). The patterning of these scales, especially coherence, is used to determine the ultimate classification. The CAI has been validated and shown to be reliable in clinical and nonclinical samples (Shmueli–Goetz et al., 2008). To maximize power and limit the number of comparisons, we chose to focus on overall coherence as a continuous index of attachment security and the dismissal and idealization subscales as the primary scales determining dismissing classification. Idealization refers to the tendency to describe attachment figures in positive terms, but a failure to substantiate these with relevant autobiographical memories. Dismissal, on the other hand, refers to the tendency to downplay dependency on attachment figures or trivialize the impact of attachment experiences. Coherence refers to the relative absence of insecure strategies and a capacity to provide relevant and parsimonious examples, both for positive and negative portrayals of attachment figures (Shmeuli–Goetz et al., 2004).

Due to high intercorrelations between mother and father subscales for idealization, $r = .88$; $p < .001$, as well as dismissal, $r = .98$; $p < .001$, subscales were composited to reduce data and number of comparisons. Previous research indicates that overall coherence and dismissal scales have shown acceptable test–retest reliability at 3 months ($r > .60$) though scores are slightly lower for idealization of mother ($r = .52$) and father ($r = .42$). One-year stability is high for overall coherence ($r = .75$) and is somewhat diminished, though significant for dismissal of mother ($r = .44$) and father ($r = .39$). However, for idealization of mother ($r = .25$) and of father ($r = .08$), 1-year stability is low (Shmueli–Goetz et al., 2008).

Data Analysis

EEG electrodes were parcellated into five regions per hemisphere in accordance with previous models (Mayes, Molfese, Key, & Hunter, 2005). Recorded activity was averaged for the left frontal region (18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 33, 34, 39, 128) and for the right frontal region (1, 2, 3, 4, 8, 9, 10, 14, 15, 121, 122, 123, 124, 125) as previous studies found rejection-specific slow-wave activity mainly within frontal regions (Crowley, Wu, McCarty, et al., 2009; Crowley et al., 2010). Data were entered into a single temporal PCA with varimax rotation using factor loadings of 0.4 and above as the threshold, in order to window ERP data (Dien, 2010). The temporal PCA yielded a positive-going slow wave. This factor accounted for 37.9% of the variance with a time interval of 500–900 ms (peak time: 824 ms).

Data Analytic Plan

In a preliminary step, we conducted a manipulation check to validate frontal slow-wave ERP as a correlate of ostracism distress as in previous studies. We also tested whether ostracism distress would be more strongly associated with left- or right-lateralized frontal slow-wave activity. In the first step of the main analysis, independent samples t tests and correlational analyses were initially performed with attachment classifications and relevant attachment dimensions (coherence, idealization, and dismissal) as independent variables and ostracism distress and left and right frontal slow waves during rejection as the dependent variables. For any associations that emerged between neural measures and attachment during rejection, we checked associations with slow waves in the same region for "not my turn" events and favors during fair play to assess specificity to the rejection condition. We also checked lateralization of effects by regressing ostracism distress and dismissal on left and right frontal slow-wave activity. All significant associations between frontal ERP and attachment dimensions were followed up with regression analyses to confirm the robustness of any findings from step one, inserting SES, gender and age as covariates, and to investigate the overlap with ostracism distress in predicting the ERP response. In a final step, we computed correlations and partial correlations to assess whether higher levels of dismissing attachment coincided with a dissociation between self-reports and neural indices of ostracism. Adding interaction terms for ostracism distress × dismissing attachment (classifications or dimensions) in a series of regression analyses after considering the main effects of single predictors contributed no significant variance to the models and were therefore omitted.

Results

Manipulation Check: Frontal Slow-Wave ERP to Exclusion and Ostracism Distress

To check whether the average amplitude of the slow wave in the left and right frontal regions during rejection would predict subjective ostracism distress as in previous studies (Crowley, Wu, McCarty, et al., 2009; Crowley et al., 2010), we conducted a regression analysis, entering slow-wave activity from both regions simultaneously. A single predictor model was significant ($p = .029$), explaining 32.4% of variance in ostracism distress, with the magnitude of left frontal slow wave, $\beta = -.63$, $p = .009$, but not right frontal slow wave, $\beta = .26$, $p = .24$, as a significant predictor. To assess the specificity of this relationship, we also checked that ostracism distress was unrelated to the left frontal slow wave during favors, $r(19) = -.26$, $p = .25$, and "not my turn," $r(19) = -.32$, $p = .16$, and right frontal slow-wave activity during favors $r(19) = .17$, $p = .47$, and "not my turn," $r(19) = -.09$, $p = .70$.

Hypothesis 1: Dismissing Status as a Predictor of Negative Frontal ERPs During Rejection

In order to assess whether subjective ostracism distress or the amplitude of the left frontal slow wave during rejection varied as a function of attachment classification we submitted the data to multiple independent samples t tests. No significant differences were found between secure and dismissing groups on ostracism distress ($p = .57$), left or right frontal slow-wave ERP during rejection ($p = .31$ and $p = .18$, respectively).

Next, correlational analyses were conducted using the continuous indices of attachment to predict the amplitude of the left frontal slow wave during rejection as well as ostracism distress from the relevant attachment dimensions. Neither *coherence* nor idealization was significantly associated with the slow-wave amplitudes or ostracism distress (see Table 1). We also found no evidence of a significant correlation between dismissal and subjective ostracism distress, $r(19) = -.07$, $p = .75$, or dismissal and the right frontal slow wave during rejection, $r(19) = -.40$, $p = .07$. Yet as hypothesized, increases in dismissal significantly predicted decreases in left frontal slow wave, $r(19) = -.51$, $p = .019$ (see Table 1 and Figure 2). This effect was specific for rejection in the left frontal region, as evidenced by the low correlations between dismissal and left frontal slow-wave magnitude for "not my turn," $r(19) = -.22$, $p = .34$, and favor events, $r(19) = .02$, $p = .95$. Regressing dismissal on both frontal regions yielded a significant model ($r^2 = .29$; $p = .044$) with no significant contribution of the right frontal area, $\beta = -.22$, $p = .34$, but a nonsignificant trend in the left frontal region, $\beta = -.41$, $p = .08$. A model regressing left frontal slow wave on ostracism distress and dismissal covarying for SES, age, and gender, was significant, $p = .007$, explaining 62.5% of the variance. Both β-coefficients for ostracism distress, $\beta = -.52$, $p = .005$, and dismissal, $\beta = -.52$, $p = .008$, were significant (see Table 2). These results indicate that dismissal and self-reported distress make independent contributions to the variance in the left frontal slow wave.

Hypothesis 2: Dismissing Status and Underreporting Distress Indicated by the Neural Level

In a final step, we computed a measure of dissociation of neural response and self-reported ostracism distress during exclusion by z-standardizing each dimension before subtracting the latter from the former.[1] Whereas high scores on dissociation would reflect a tendency to manifest neural responses suggesting higher distress than indicated by self-reports ("underreporting distress"), the converse would be implicated by low scores. Consistent with our predictions, we found that increased dismissal significantly predicted higher scores on dissociation, $r(19) = .49$, $p = .024$. After partialing out SES, age, and gender, this effect of dismissal remained significant: $r(17) = .54$, $p = .022$. No significant effects emerged for dismissing as compared with secure classifications ($p = .27$) or the correlations between dissociation and coherence, $r(19) = -.38$, $p = .09$, or idealization, $r(19) = .30$, $p = .19$.

Table 1
Correlations Between Subjective Ostracism Distress and the Left-Frontal Slow Wave in Response to Rejection and Dismissing Attachment Dimensions

CAI dimensions	Ostracism distress	Left frontal slow-wave ERP	Right frontal slow-wave ERP
Coherence	$.20^{a}$	$.30^{b}$	$.39^{b\dagger}$
Dismissal	$-.07^{a}$	$-.51^{b*}$	$-.40^{b\dagger}$
Idealization	$-.26^{a}$	$-.10^{b}$	$-.04^{b}$

$^{a}n = 23$. $^{b}n = 21$.
$^{*}p \leq .05$. $^{**}p \leq .01$. $^{\dagger}p < .10$.

Discussion

In this study, we detected links between neural response to rejection by unknown peers in real time and an interview-based attachment assessment in early adolescence. We employed high-density EEG and a task designed expressly to assess event-related aspects of Cyberball to extract ERPs for rejection events. The major aim of this study was to examine the neural correlates of attachment patterns in a standardized social context involving unfamiliar peers. We confirmed that elevated dismissal—part of an insecure internal working model thought to influence how individuals experience relationships—is related to a more negative left anterior slow wave on experiencing rejection. We also found support for a generalization of an attachment-related dismissing cognitive–affective strategy in that dismissal coincided with a distinct pattern of underreporting on self-reports of distress relative to the neural measure. In keeping with the assumed importance of distress to discriminate between attachment classifications (e.g., Ainsworth, 1990), the relation between dismissal and a more negative left frontal slow wave was specific to rejection trials. That is, effects did not carry over to conditions that were outwardly identical and nonidentical to rejection ("not my turn" events and favors), but occurred during nondistressing fair play.

Negative late frontal slow-wave magnitude has been linked to the anticipation of aversive events (Baas et al., 2002; Crowley, Wu, Bailey et al., 2009; Regan & Howard, 1995). The association between increased dismissal and greater negative frontal slow wave may therefore suggest a bias to expect more extensive or lasting exclusion from the game. Such a bias might also entail a more negative appraisal of the interaction, given that these data and previous studies link a lower magnitude of frontal slow waves to rejection events as compared with inclusion events and higher self-reported distress during Cyberball (Crowley, Wu, McCarty, et al., 2009; Crowley et al., 2010). Extrapolating to working models of attachment, rejection events may thus cue corresponding schemata of previous rejections (e.g., by the caregiver)—thought to be more prominent in dismissing attachment (Isabella, 1993)—which may, in turn, bias expectations toward exclusion for the remainder of the game.

[1] For the purposes of this analysis, we first had to ensure that both scales of measurement were pointing in the same direction with regard to distress. In a preliminary step, we therefore inverted the neural measure, so that higher values for ERP amplitude corresponded to higher scores on ostracism distress.

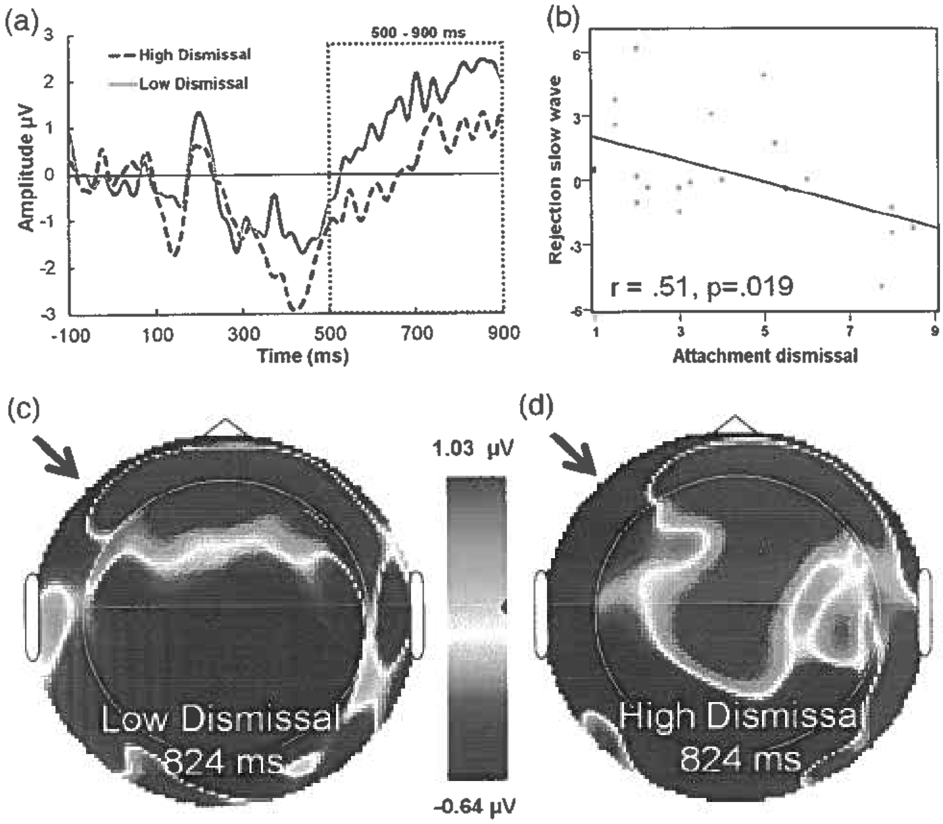

Figure 2. Event-related potential waveforms, association with attachment dismissal and scalp topography for rejection events. To illustrate the correlation waveforms and voltage maps are displayed for participants with the highest (≥5) and lowest (<3) scores on dismissal (n = eight per group). (a) Event-related potential (ERP) waveforms of rejection (principal component analysis-derived left-frontal slow wave, 500 900 ms) for the average of left frontal electrodes. (b) Scatter plot of mean slow wave data for exclusion events and dismissal. Scalp topographies during rejection (principal component analysis-derived slow wave, 500–900 ms, peak time: 824 ms) for participants (c) low on dismissal and (d) high on dismissal.

Negative left frontal slow waves have also been linked to retrieval and maintenance of autobiographical memories and imagined events in working memory (e.g., Conway, Pleydell–Pearce, Whitecross, & Sharpe, 2003). Data from other modalities also implicate this region in memory retrieval in the service of predicting future events (see Schacter & Addis, 2007), a core function of working models (see Bretherton & Munholland, 2008). Our data thus mesh with contemporary conceptualizations of IWMs. In particular, heightened dismissal may lead participants, once they face rejection, to extrapolate part of their negative expectations derived from their working models predicting how the new peer encounter in Cyberball will unfold.

We observed that dismissal was significantly associated with a left-lateralized as compared with a right-lateralized frontal slow wave (nonsignificant trend). Positive left frontal slow waves have specifically been linked to evaluative processing of positively valenced stimuli and approach motivation (Cunningham et al., 2005; Gable & Harmon–Jones, 2010; Graham & Cabeza, 2001; van de Laar, Licht, Franken, & Hendriks, 2004). The more negative slow wave in this region during rejection for children higher on dismissal may thus indicate a mitigated desire to approach or receive the ball, as an appetitive "token of inclusion." Bearing the nature of the interaction in mind, which segues seamlessly from social inclusion into rejection, it may be of value to initially preserve an approach motivation in the face of rejection, to potentially help repair the interaction. This interpretation parallels findings showing that dismissing individuals may exhibit less neural activity associated with approach (Dawson et al., 2001) or reward to social stimuli (Vrticka, Andersson, Grandjean, Sander, & Vuilleumier, 2008), including pictures of their own sad or smiling infants (Strathearn, Fonagy, Amico, & Montague, 2009). The relative absence of neural activity linked to this motivation in children high versus low on dismissal may therefore suggest a lack of expectation and incentive to be reincluded after rejection, even during new encounters.

Besides attachment-related expectations, children also seemed to generalize their attachment-specific regulatory strategies to the new encounter. Thus, despite the indications that high as compared with low-dismissal children showed neural activity linked to distress, dismissal itself remained uncorrelated with self-

Table 2
Summary of the Hierarchical Regression Analysis Predicting Left Frontal Slow-Wave Activity From Ostracism Distress and Attachment Dismissal Covarying for Age and Gender

	B	SE B	β	ΔR^2
Step 1				
Age	.16	.47	.08	.11
Gender	.17	1.23	.03	
SES	.11	.07	.33	
Step 2				
Age	.27	.40	.13	.28†
Gender	−.41	1.05	−.08	
SES	.11	.06	.33	
Ostracism distress	−.14	.05	−.53*	
Step 3				
Age	.14	.33	.07	.23**
Gender	1.28	.90	.24	
SES	.09	.05	.27	
Ostracism distress	−.13	.04	−.52**	
Attachment dismissal	−.54	.18	−.52**	

$^{*}p \leq .05$. $^{**}p \leq .01$. $^{\dagger}p < .10$.

reported distress during peer rejection. Notably, the scale of ostracism distress has proven a reliable and valid predictor of frontal response to exclusion in numerous studies apart from this one (e.g., Eisenberger et al., 2003; Masten et al., 2009), including those using ERP (Crowley, Wu, McCarty, et al., 2009; Crowley et al., 2010). Yet, as dismissal rose, self-reports became increasingly dissociated from left frontal slow waves, such that children showed a significant pattern of reporting lower ostracism distress than would be expected from their neural data.

This finding dovetails with earlier psychophysiological work (e.g., Dozier & Kobak, 1992; Roisman, Tsai, & Chang, 2004) implying that attachment dismissal leads to underreporting of distress on self-reports observable at the physiological level. Elevated attachment-related dismissal reflects a strategy of managing distress by minimizing personal vulnerability, especially in the face of challenging interpersonal events (Shmueli–Goetz et al., 2004). Children may initially resort to avoidant or dismissing strategies, including a denial of dependency, to cushion the blow of rejection by the caregiver (Mikulincer & Shaver, 2008; Bowlby, 1980), but extrapolate this pattern to other relationships over time. Such strategies that inhibit expression of negative affect despite internal distress, could also serve the evolutionary purpose of maximizing the degree of proximity possible to an overwhelmed, hostile or unmotivated parent, who may have otherwise been driven away (Simpson & Belsky, 2008). Our findings are consistent with the idea that these strategies may also extend to new peer contexts, perhaps also to minimize the odds of rejection from the peer group.

As dismissing strategies require an inferential leap (i.e., attributing distress where none is reported), it is important that heightened distress has been verifiable by independent objective means, as indicated here and in previous psychophysiological research (e.g., Dozier & Kobak, 1992; Roisman et al., 2004). In this study, we have moved the evidence for the putative mismatch between subjective reports and physiological responses to the central nervous system. At the same time, it is possible that high-dismissal children have come to rely on categorically different neural systems to appraise rejection and therefore their lower subjective reports of distress relative to ERP reflect veridical responses (relative to other neural correlates). Yet, it is worth mentioning that the aforementioned psychophysiological data suggests their strategies are less efficient in managing distress as also observed clinically (Allen, Porter, McFarland, McElhaney, & Marsh, 2007; Shmueli–Goetz et al., 2008). In turn, the direction of the dissociation between self-report and neural response was systematic and matched our theoretically grounded predictions (cf. Hesse, 2008). Thus, we believe that we have tapped into a pattern of underreporting distress *relative* to a neural index of distress.

Limitations

Some characteristics of these findings should be borne in mind. First, although we assessed attachment classifications prior to collecting neural data, the correlational nature of these findings do not warrant causal inferences. Although it may be tempting to conclude that attachment classifications *influence* the neural response to rejecting encounters with unknown peers, it is theoretically conceivable that rejection in Cyberball taps into social responsivity or temperamental characteristics that precede and codetermine formation of IWMs.

Second, we found attachment-specific neural activity during peer-interactions involving rejection, in particular. Rejection may function as an especially potent context to cue differential neural responses as a function of attachment due to its surface similarities to separation (Eisenberger, 2006). Separation figures prominently in attachment theory (Bowlby, 1969) and measurement of attachment patterns in infancy (Ainsworth et al., 1978) and may therefore elicit differential responses at later stages as well. Given that working models have primarily been conceptualized as determinants of responses to relational distress (Bowlby, 1973) and some previous evidence indicates that their effects may not extend to nonrelational contexts (Borelli et al., 2010; Crowell & Waters, 1996), we speculate that these effects generalize to situations involving social negativity, but not negative affectivity, per se. Future research should attempt to distill the exact socioemotional contingencies evoking effects of attachment. Third, we assessed a young adolescent sample only. Thus our findings cannot illuminate whether dismissing attachment coincides with sensitivity to social negativity more broadly or a circumscribed sensitivity, specific to this age, when youth are generally thought to be more sensitive to peer contexts (see Casey, Getz, & Galvan, 2008).

Fourth, confirmation of our hypothesis was primarily ascertained on a subscale tapping into the assessment of attachment security rather than the categorical security classifications or the overarching scale of overall coherence (except a trend for an inverse association between coherence and underreporting distress). This might, in part, reflect increased power of a dimensional approach to attachment because it preserves the variability within classifications (Roisman et al., 2007). In addition, the subscales allow researchers to discriminate if a particular dismissing classification hinges on a tendency to idealize or to dismiss attachment experiences (see Hesse, 2008). Hence, these subscales may prove especially useful when studying neural and physiological correlates of attachment (e.g., Rifkin–Graboi, 2008) as they may more accurately capture narrative or regulatory strategies as related to neurological processes.

Some methodological considerations are also of note. Attachment was assessed on average three years before the present data-collection point, begging the question of whether or not mental representations of attachment remain stable over this period. To date, research has implied that stability of narrative attachment measures is relatively high over a one and 4-year period during early adolescence (Ammaniti, van Ijzendoorn, Speranza, & Tambelli, 2000; Shmueli–Goetz et al., 2008). Our data are consistent with such continuity. However, our longitudinal approach may have favored those dimensions, which have proven more stable (e.g., dismissal) as compared with those showing greater variability over time (e.g., idealization; see Shmueli–Goetz et al., 2008) and concurrent measurements of attachment may therefore yield different patterns. Second, the sample size was small, indicating that the present investigation was only powered to find moderate to large effects. As such, replication in a larger sample is needed. However, because our attachment findings are embedded in a replication of Crowley and colleagues' (2009) findings, we believe we have assessed reliable associations particularly vis-à-vis felt ostracism and concomitant neural response to rejection.

Conclusion

This study—by examining real-time social interactions nested in a highly standardized laboratory context—provides an important step in testing long-held assumptions regarding the role of IWMs under tightly controlled conditions affording neural measurements. In keeping with attachment theory, variations in attachment were differentially teased apart by mildly aversive rather than nonaversive social exchanges. Specifically, higher dismissal predicted a negative left frontal slow wave during rejection, an ERP waveform implicated in distress during social exclusion and anticipation for negative events, more generally. At the same time, dismissal was uncorrelated with self-reported distress during peer rejection, instead predicting a tendency to underreport distress indicated by ERPs. Overall, neural measures and self-reports yielded a pattern of data supporting the relevance of attachment-related concerns and differential neural responding to new social encounters in early adolescence.

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