Empirical Article

Clinical Psychological Science
1–16

DOI: 10.1177/2167702620902463
www.psychologicalscience.org/CPS

Effects of Maternal Depression and Mother–Child Relationship Quality in Early Childhood on Neural Reactivity to Rejection and Peer Stress in Adolescence: A 9-Year Longitudinal Study

Autumn Kujawa[1], Kodi B. Arfer[2], Megan C. Finsaas[3], Ellen M. Kessel[3], Emma Mumper[3], and Daniel N. Klein[3]
[1]Department of Psychology and Human Development, Vanderbilt University; [2]Icahn School of Medicine at Mount Sinai; and [3]Department of Psychology, Stony Brook University

Abstract
Problems in mother–child relationships are thought to be key to the intergenerational transmission of depression. To evaluate neural and behavioral processes involved in these pathways, we tested effects of maternal depression and maternal-child relationship quality in early childhood on neural and interviewer-based indicators of social processes in adolescence. At age 3, children and mothers ($N = 332$) completed an observational parenting measure and diagnostic interviews with mothers. At age 12, adolescents completed a task in which event-related potentials (ERPs) were recorded in response to peer acceptance and rejection feedback and interviews to assess peer stress. Lower mother–child relationship quality at age 3 was associated with enhanced reactivity to rejection, as measured by N1, and greater peer stress at age 12. Indirect effects of maternal depression through mother–child relationship quality were observed for N1 and peer stress. Findings inform understanding of disruptions in social functioning that are likely to be relevant to the intergenerational transmission of depression.

Keywords
depression, psychological stress, psychophysiology, risk factors, social processes

Received 5/12/19; Revision accepted 11/24/19

Offspring of depressed mothers are approximately 3 times more likely than offspring of nondepressed mothers to develop depression (Weissman et al., 2006). Identifying mechanisms of intergenerational transmission of depression is needed to inform prevention. Critically, transmission of depression from mothers to offspring is not fully accounted for by genetics, and parenting and disruptions in the family environment are key mechanisms of the effects of maternal depression on offspring depression (Garber & Cole, 2010; Hammen & Brennan, 2001; Hammen, Shih, & Brennan, 2004; Harold et al., 2011). Despite variability in parenting, there is consistent evidence that compared with nondepressed mothers, depressed mothers exhibit fewer positive parenting behaviors (e.g., support and warmth) and more negative behaviors (e.g., criticism and intrusiveness; Cummings & Davies, 1994; Goodman & Gotlib, 1999). Although problematic parenting behaviors are particularly apparent among currently depressed mothers, there is also evidence that mothers with a past history of depression exhibit lower levels of positive parenting (Ewell Foster, Garber, & Durlak, 2008; Weinberg & Tronick, 1998).

It is well established that the quality of relationships with caregivers in early childhood predicts later relationships with peers (Groh et al., 2014; Schneider, Atkinson, & Tardif, 2001). That is, robust evidence indicates that

Corresponding Author:
Autumn Kujawa, Department of Psychology and Human Development, Peabody College #552, 230 Appleton Pl., Nashville, TN 37203-5721
E-mail: autumn.kujawa@vanderbilt.edu

secure attachments in early childhood and greater mother–child relationship quality are related to better peer functioning, including child popularity, social competence, and romantic-relationship quality (Bohlin, Hagekull, & Rydell, 2000; Groh et al., 2014; Katz, Hammen, & Brennan, 2013; Schneider et al., 2001). Likewise, substantial evidence indicates that maternal depression is associated with interpersonal stress and impairment in social functioning in offspring (Feurer, Hammen, & Gibb, 2016; Hammen & Brennan, 2001; Katz et al., 2013). Critically, the interpersonal effects of maternal depression on offspring are not limited to parent–child relationships; instead, problems in the early family environment disrupt social development, which leads to difficulties in later peer and romantic relationships (Feurer et al., 2016; Hammen et al., 2004; Katz et al., 2013). Furthermore, less secure attachment with parents and disruptions in the quality of mother–child relationships are associated with increased risk of psychiatric symptoms, particularly depression (Allen et al., 2007; Eberhart, Shih, Hammen, & Brennan, 2006; Hammen et al., 2004).

The effects of early relationships with caregivers on later relationships with peers is thought to be mediated by the development of social and emotional brain networks (E. E. Nelson, Jarcho, & Guyer, 2016; Schriber & Guyer, 2016). Consistent with this theory, parenting style predicts reward-related brain function in offspring, particularly among offspring of depressed parents (Kujawa, Proudfit, Laptook, & Klein, 2015; Morgan, Shaw, & Forbes, 2014), but only a few small studies have examined the effects of parenting on brain function in the context of peer interactions. In functional MRI studies, authoritative parenting in middle childhood was associated with activation of the striatum in response to peer rejection in adolescence (Guyer et al., 2015), and cross-sectional associations were observed between maternal negative affect and adolescents' responses to peer acceptance in the amygdala and anterior cingulate cortex (ACC; Tan et al., 2014). In a recent study of adolescent girls, higher youth-reported parent–child relationship quality was associated with decreased responses in dorsal ACC to social exclusion (Rudolph et al., 2020). Taken as a whole, this literature suggests that parenting quality might shape neural responses to feedback from peers in adolescence, which has potential implications for understanding the intergenerational transmission of depression.

The extant literature points to a developmental pathway in which early parent–child relationships serve as a mechanism of the negative effects of maternal depression on the quality of later peer relationships in offspring. In turn, dysfunction in relationships with peers and elevated social stress increase risk for later depression in offspring (Hammen, 2009; Prinstein, Cheah, Borelli, Simon, & Aikins, 2005), particularly among those high in rejection sensitivity (Chango, McElhaney, Allen, Schad, & Marston, 2012). However, the neural processes underlying the effects of maternal depression and early parenting on peer functioning have been largely unexamined.

We developed a computerized peer-interaction task for measuring neural responses to peer acceptance and rejection feedback using event-related potentials (ERPs) derived from the electroencephalogram (EEG; Kujawa, Arfer, Klein, & Proudfit, 2014; Kujawa, Kessel, Carroll, Arfer, & Klein, 2017). During the task, participants vote to reject and accept coplayers and receive a combination of rejection and acceptance feedback. The task elicits a series of ERP components that are differentially modulated by peer acceptance and rejection feedback (Kujawa et al., 2017). Although neural responses to social feedback appear to be more complex than those observed in response to monetary feedback (Kujawa et al., 2017; Kujawa et al., 2018), two ERP components consistently emerge in response to peer rejection and acceptance feedback in this task and appear particularly relevant to depression risk: reward positivity (RewP) and N1 (i.e., a negative component around 100 ms after feedback; Babinski, Kujawa, Kessel, Arfer, & Klein, 2019; Ethridge et al., 2017; Kujawa et al., 2017).

Peer-acceptance feedback reliably elicits a RewP component (Ethridge & Weinberg, 2018; Kujawa, Arfer, et al., 2014; Kujawa et al., 2017), which presents as a relative positivity in the ERP wave beginning around 250 ms that is enhanced for positive feedback. RewP is also referred to as the feedback negativity and was originally thought to present as a negativity in the ERP wave in response to negative performance feedback and losses. More recent evidence from temporospatial principal component analyses (PCA) and other methods indicate that this component is better characterized by a positivity that is enhanced in response to positive performance and reward feedback and reduced to negative feedback (for a review, see Proudfit, 2015). Consistent with this evidence, using PCAs on ERP data obtained from both social and monetary reward tasks in children and adolescents, we found that a positive component consistent with the RewP consistently emerges in response to both social and monetary reward feedback (Kujawa et al., 2017; Kujawa et al., 2018). Most research on RewP uses performance or monetary reward tasks. In these tasks, RewP correlates with positive emotionality (Kujawa, Proudfit, Kessel, et al., 2015) and activation of the ventral striatum (Becker, Nitsch, Miltner, & Straube, 2014) and prospectively predicts depressive symptoms (Bress, Meyer, & Proudfit, 2015; Kujawa, Hajcak, & Klein, 2019; B. D. Nelson, Perlman, Klein, Kotov, & Hajcak, 2016).

We identified an N1 component that emerged before RewP in the ERP wave and that was enhanced for rejection relative to acceptance feedback (Kujawa et al., 2017). N1, an early visual attention component, presents as a negative deflection in the ERP around 100 to 150 ms after stimulus onset that is enhanced in response to attended stimuli (Coch & Gullick, 2012; Luck, Woodman, & Vogel, 2000). In Island Getaway, N1 is enhanced in response to rejection compared with acceptance cues (Kujawa et al., 2017), which suggests that rejection feedback may more immediately capture attention. We previously observed a cross-sectional association between an enhanced (i.e., more negative) N1 in response to rejection and self-reported rejection sensitivity, which supports this component's utility as a measure of individual differences in reactivity to social feedback that may be relevant for depression risk (Babinski et al., 2019).

Our prior work indicates that, in addition to RewP and N1, later ERP components, including P3 and late positive potential, also appear to be sensitive to social feedback valence and likely reflect sustained attentional allocation toward social feedback cues (Kujawa et al., 2017). In this study, we focus our analyses on N1 and RewP, given prior evidence that these neural measures relate to individual differences in self-reported rejection sensitivity and positive emotionality, respectively (Babinski et al., 2019; Kujawa, Proudfit, Kessel, et al., 2015), and an extensive literature linking RewP to depression risk (Keren et al., 2018; Kujawa & Burkhouse, 2017; B. D. Nelson, Perlman, et al., 2016).

The goal of this longitudinal study was to examine pathways from maternal depression and early parenting to later neural processing of social feedback and chronic peer stress using a multimethod approach. We evaluated observed mother–child relationship quality at age 3 as a predictor of multiple indicators of social processes 9 years later (i.e., N1 in response to peer rejection, RewP in response to peer acceptance, chronic peer stress) and tested indirect effects of maternal depression on social processes through mother–child relationship quality. We examined relationship quality in early childhood because of evidence that the family environment in the first few years of life has lasting impacts on child social and emotional development (Cavanagh & Huston, 2008; Woodward, Fergusson, & Belsky, 2000) and to test parenting variables as prospective predictors of neural reactivity to social feedback and peer stress. This is consistent with our prior work on parenting and emotional development (Kujawa, Dougherty, et al., 2014; Kujawa, Proudfit, Laptook, & Klein, 2015). Given evidence that broad disruption in parent–child attachment and relationship quality are associated with impairments in peer function and depressive symptoms in offspring (Hammen et al., 2004; Schneider et al., 2001), our primary focus was on overall observed quality of mother–child relationships. Social processes measures were obtained in early adolescence, a time when the importance of peer relationships increases but prevalence of clinical depression remains relatively low (Brown, 2004; Hankin et al., 1998), which allowed us to examine social problems that might emerge before depressive disorders. We focused on maternal, rather than paternal, depression and relationships given weaker effects of paternal depression on internalizing symptoms in offspring (Connell & Goodman, 2002; Tully, Iacono, & McGue, 2008) and because mothers spend greater time caregiving than fathers on average (Phares, Fields, & Kamboukos, 2009).

Primary analyses examined the overall quality of the reciprocal relationship between mothers and children in early childhood and tested the effects of maternal depression and mother–child relationship quality on three indicators of social processes at age 12: N1 in response to rejection, RewP in response to acceptance, and interviewer-rated chronic peer stress. We hypothesized that lower mother–child relationship quality at age 3 would be associated with an enhanced N1 in response to rejection, reduced RewP in response to acceptance, and greater peer stress at age 12 and would mediate the effects of maternal depression on neural reactivity to peer feedback and peer stress. Following significant effects of relationship quality, secondary exploratory analyses evaluated the extent to which these pathways were driven by more specific parenting behaviors by mothers that could be targeted for prevention. Specifically, we examined dimensions of positive (i.e., confidence, support, and instruction) and negative parenting behavior (i.e., hostility and intrusiveness), consistent with our prior work that identified distinct associations between these two dimensions of parenting and neural processing of monetary reward in offspring (Kujawa, Proudfit, Laptook, & Klein, 2015) and some evidence linking more specific features of maternal positivity and sensitivity to depressive symptoms and social functioning in offspring (Garber & Cole, 2010; Roisman, Booth-LaForce, Cauffman, & Spieker, 2009). To test specificity of these pathways for maternal depression as opposed to maternal psychopathology more broadly defined, we also tested mediation models including maternal history of anxiety and substance use disorders as covariates. Finally, given sex differences in rates of depression and experiences of interpersonal stress (Hankin, Wetter, & Cheely, 2008; Rudolph, 2002) as well as evidence of differential patterns of parental emotion socialization for boys compared with girls (Chaplin, Cole, & Zahn-Waxler, 2005; Fivush, Brotman, Buckner, & Goodman, 2000), additional exploratory analyses examined generalizability of these pathways

for both girls and boys by testing sex as a moderator of the direct and indirect effects of maternal depression on neural reactivity to social feedback and peer stress.

Method

Participants

Participants were from the Stony Brook Temperament Study (SBTS), a predominantly middle-class community sample of children recruited when they were 3 years old (Klein & Finsaas, 2017; Kujawa, Proudfit, & Klein, 2014; Olino, Klein, Dyson, Rose, & Durbin, 2010). At age 3, a total of 559 children and their parents were enrolled in the larger study. The size of the sample was determined by power analyses for the aims of the parent project. Of these participants, 490 children and biological mothers completed the observational parenting assessment and diagnostic interviews. At age 12, adolescents completed an EEG assessment, and both the adolescent and a parent were interviewed concerning stress experienced by the child. A total of 367 youths who completed assessments at age 3 also completed the EEG assessment at age 12. EEG data were excluded for 26 participants because of noisy EEG data or technical errors (Kujawa et al., 2017), and stress data were missing for 9 participants, which left a final analysis sample of 332. The mean age of the sample was 3.54 years (SD = 0.26) at the time of the parenting assessment and 12.66 years (SD = 0.43) at the EEG assessment. The analysis sample was 46.7% female, 9.0% Hispanic/Latino, 94.9% White, 2.1% African American, 2.1% Asian, 0.3% Native American, and 0.6% other race. Participants who completed the measures at age 3 but were missing data at age 12 did not significantly differ from included participants on distributions of maternal depression, child sex, race, or ethnicity or on observed mother–child relationship quality (ps > .24).

All task conditions and data exclusions are reported in this article, along with all measures for the current research questions. A complete list of parental psychopathology, parenting, functioning, and EEG/ERP measures administered at the age 3 and age 12 assessments is available in the Supplemental Material available online. This study was not preregistered because data collection and analyses began before preregistrations were common in clinical psychological science. The SBTS began in 2004, the EEG peer-feedback task was added to the study in 2014, and cross-sectional analyses of the EEG data began in 2015 to characterize the neural response to social acceptance and rejection feedback (Kujawa et al., 2017). Although our primary analyses in the this study were informed by theories of interpersonal dysfunction in the intergeneration transmission of depression, the analyses for this specific study were not planned at the start of the SBTS and should be considered exploratory.

Procedure

This protocol was approved by Stony Brook University's Institutional Review Board. Informed consent was obtained from parents and assent from participants. At age 3, children and mothers visited the laboratory to complete observational measures of mother–child relationship quality and parenting. Mothers also completed diagnostic interviews to assess depression history. Families returned to the lab when the child was around age 12, and the EEG assessment was completed. Following the laboratory assessment, participants completed a home assessment in which one parent and the adolescent were interviewed about stress in the preceding 12 months.

Measures

Maternal depression. Biological mothers were interviewed using the Structured Clinical Interview for DSM–IV (First, Spitzer, Gibbon, & Williams, 2002). Interviews were conducted by telephone, which yields comparable results to face-to-face interviews (Rohde, Lewinsohn, & Seeley, 1997; Sobin, Weissman, Goldstein, & Adams, 1993). Two master's-level raters conducted diagnostic interviews under the supervision of a licensed clinical psychologist. Independent ratings of diagnoses based on audiotapes of 30 interviews indicated that interrater reliability (κ) was .93 for depressive disorders.

Of the 332 children included in the current study, 29.8% (n = 99) of mothers had a lifetime history of depression, defined as major depressive disorder (MDD), dysthymia/persistent depressive disorder (PDD), or both, at the time of the age 3 assessment. Only 12.3% (n = 41) were estimated to have experienced depression during the child's first 3 years of life, and 3.3% (n = 11) endorsed past month MDD, dysthymia/PDD, or both at the time of the age 3 assessment. Although depression and parenting were assessed concurrently, 88.8% of mothers with depression were in remission at the time of the assessment. One mother had a history of bipolar disorder.[1] With regard to other common diagnoses, 31.3% of mothers (n = 104) had one or more lifetime anxiety disorders as defined in the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM–IV*; American Psychiatric Association, 1994), and 25.0% (n = 83) had lifetime alcohol or substance abuse or dependence.

Observed mother–child relationship quality. At age 3, children and mothers completed an observational

assessment based on the Teaching Tasks (Egeland et al., 1995), which included six standardized tasks (e.g., book reading, block building). Trained coders rated videotapes of each episode; ratings were then averaged across tasks (Kujawa, Dougherty, et al., 2014; Kujawa, Proudfit, Laptook, & Klein, 2015). Primary analyses examined global ratings of mother–child relationship quality. High ratings indicate clear evidence that mother and child respond to each other, exhibit reciprocity and harmony, enjoy each other, and are quick to resolve conflicts. Low ratings indicate negative emotions, lack of harmony and reciprocity, limited enjoyment of each other, failure to resolve conflicts, or a combination. Coders also rated each episode for maternal hostility (expression of anger, frustration, or annoyance), intrusiveness (failure to respect the child as an individual), confidence (degree to which mother seems to believe that she can work successfully with the child), support (expression of positive regard and emotional support), and instruction (ability to structure the situation so that the child understands the task). Hostility and confidence were dichotomized to reduce skewness/kurtosis. A negative parenting composite score included standardized scores on hostility and intrusiveness, and a positive parenting composite score included standardized scores on confidence, support, and instruction, similar to our prior work (Kujawa, Proudfit, Laptook, & Klein, 2015). Interrater reliability was acceptable to good for all variables; the lowest reliability observed was for maternal ratings of confidence, included in the positive parenting composite (intraclass correlation coefficient [ICC] = .79 for mother–child relationship quality; ICCs = .70–.83 for negative parenting variables; ICCs = .59–.85 for positive parenting variables, $n = 55$).

Neural reactivity to peer feedback. Participants completed the Island Getaway task (Kujawa, Arfer, et al., 2014) while EEG data were recorded (https://github.com/Kodiologist/Survivor). Prior evidence indicates that this task elicits reliable ERPs that are sensitive to social feedback from late childhood to adulthood (Ethridge et al., 2017; Ethridge & Weinberg, 2018). Participants were told that they would play a game with 11 peers of similar ages in which they would travel the Hawaiian Islands, vote whether they want each peer to continue on with them to the next island, and then receive feedback on how peers voted for them. All coplayer profiles and responses were fabricated. In the first round, participants created a profile including their photograph and reviewed coplayer profiles. Stock photographs and a stimulus set of child faces (Egger et al., 2011) were used for coplayer photographs. Coplayer photographs were selected such that coplayers appeared to be diverse with regard to race/ethnicity. In subsequent rounds, participants responded to a poll question (e.g., "Who do you most admire?") and reviewed coplayer responses to facilitate an exchange of personal information for the remaining voting-feedback phases.

Following review of profiles/poll responses, participants were prompted to vote to accept ("Keep") or reject ("Kick out") each coplayer. After each vote, participants saw feedback indicating whether that coplayer voted to accept or reject them. Acceptance feedback was indicated by a green "thumbs up," and rejection feedback was indicated by a red "thumbs down." Each voting trial began with a coplayer profile presented until participants voted. To simulate variability in coplayer response speed, a coplayer voting speed was selected for each trial on the basis of actual variability in voting patterns from previously collected data. If participants voted faster than the simulated voting time for that coplayer, the message "Waiting for [coplayer] to vote . . . " was displayed. Finally, a fixation cross was presented for 1,000 ms, followed by feedback for 2,000 ms. A blank screen was presented for 1,500 ms before the start of the next trial. After each round, participants were told that one of the coplayers had been sent home, and after completing the sixth round, participants were informed that they made it to the "Big Island." The task included a total of 51 feedback trials over six rounds split evenly between acceptance and rejection; the last trial type was determined randomly.

Continuous EEG was recorded using a 34-electrode cap (32 channels, FCz, and Iz; 10–20 system) and a BioSemi system (Amsterdam, The Netherlands). Eye movements and blinks were recorded using facial electrodes placed approximately 1 cm above and below one eye and 1 cm from the outer corners of the eyes. Electrodes were also placed on the left and right mastoids. Recordings were digitized at a sampling rate of 1024 Hz.

Offline processing was conducted using BrainVision Analyzer software (Munich, Germany). Data were referenced to the average mastoids, filtered with cutoffs of 0.1 and 30 Hz, and segmented from 200 ms before until 1,000 ms after feedback onset. Eye movement correction (Gratton, Coles, & Donchin, 1983) and artifact rejection procedures were conducted. Criteria of a voltage step of 50 μV between sample points, maximum difference of 300 μV within a 200-ms interval, and minimum activity of 0.5 μV were used to automatically detect artifacts; additional artifacts were removed manually. All included participants had a minimum of 22 trials per condition remaining after artifact rejection ($M = 25.42$ for acceptance, $M = 25.48$ for rejection). ERPs were averaged for acceptance and rejection and baseline corrected to the 200 ms before feedback onset. ERPs were scored in

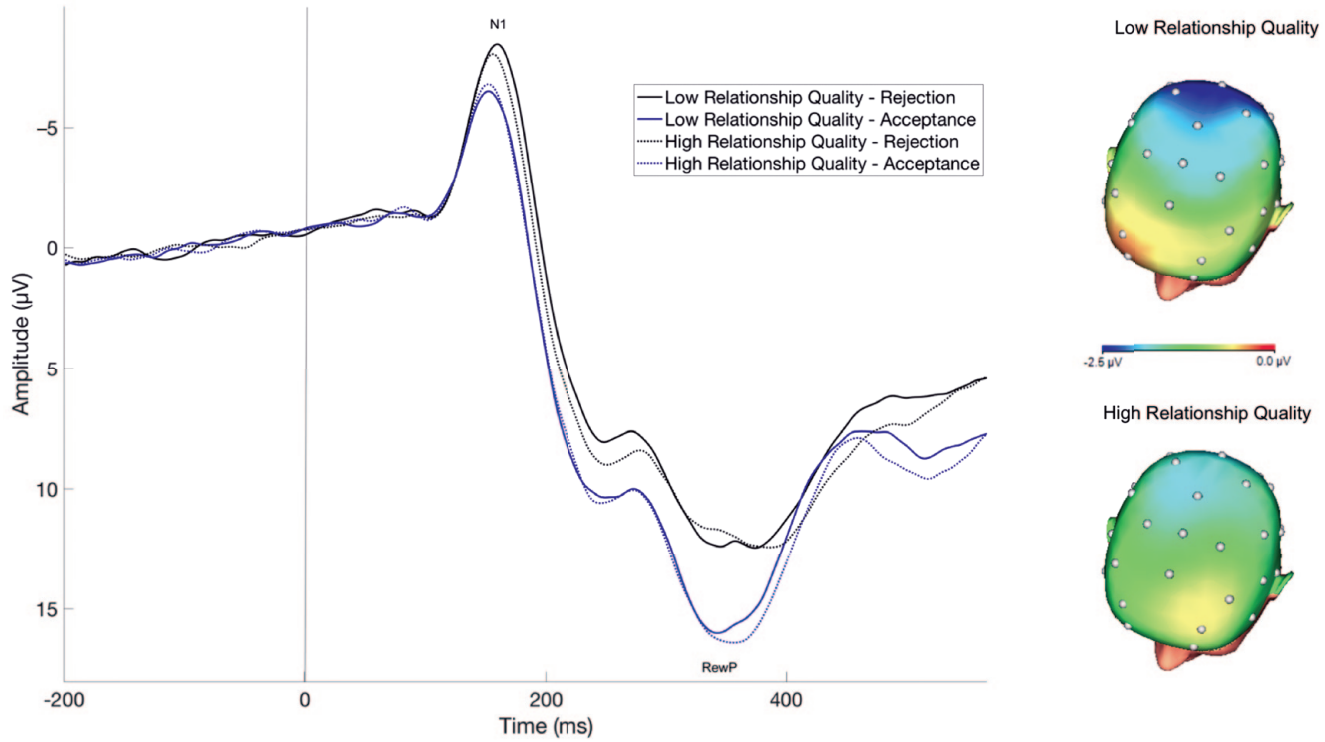

Fig. 1. Event-related potentials (negative up) at Cz following rejection and acceptance feedback and scalp distributions depicting the rejection minus acceptance difference 140 to 180 ms after feedback onset (i.e., N1) for adolescents low and high in mother–child relationship quality at age 3. A median split of relationship quality was calculated to group participants for illustrative purposes only (all analyses used continuous measures of relationship quality).

accordance with a prior PCA using these data (Babinski et al., 2019; Kujawa et al., 2017): N1 was scored at 140 to 180 ms at Cz, and RewP was scored at 300 to 375 ms at Cz (Fig. 1). Consistent with recommendations (Meyer, Lerner, de los Reyes, Laird, & Hajcak, 2017) and with our prior work examining ERPs from the Island Getaway task (Babinski et al., 2019; Kujawa et al., 2017), residual scores were computed for each component to isolate the relative variance in the ERP attributed to processing of rejection or acceptance feedback. Specifically, we evaluated residual scores for N1 in response to rejection adjusting for responses to acceptance (more negative values indicated enhanced early attention toward rejection cues) and residual scores for RewP in response to acceptance adjusting for responses to rejection (more positive values indicated enhanced reactivity to acceptance feedback).

Peer stress in early adolescence. At age 12, adolescents and one parent (92.2% biological mother, 7.8% biological father) were separately interviewed using the youth version of the UCLA Chronic Life Stress Interview (LSI; Rudolph & Hammen, 1999). The LSI has been extensively validated in adolescent and adult samples; consistent evidence of associations between chronic stress, particularly interpersonal stress, and depressive risk and symptoms has been found (Adrian & Hammen, 1993; Hammen et al., 2004; Rudolph et al., 2000). The LSI uses a semistructured interview format to assess chronic stress in the 12 months before the interview. Stress in each domain was rated by interviewers on a scale from 1 to 5; higher scores indicated greater stress. Ratings based on parent and adolescent reports were highly correlated ($rs > .64$). Interviewers incorporated information obtained from participants and parents to derive combined ratings that reflect the best estimate of adolescents' chronic stress given all available information. Given our interest in social functioning beyond the parent–child relationship, we averaged ratings of chronic stress in close friendships (which integrated information obtained from parent and adolescent reports of number of close friends and degree of satisfaction with friendships, conflict, confiding, and stability) and broader social life (which included parent and adolescent reports of degrees of popularity, bullying, and engagement in social activities with a wider peer group). Independent ratings of 35 videotaped interviews indicated that interrater reliability (ICC) for chronic stress in friendships and social life was .82 and .86, respectively.

Data analysis

First, bivariate correlations were computed to examine descriptive associations between maternal depression

(presence or absence of lifetime depressive disorder), age 3 parenting variables, and age 12 social processes measures. Next, three simple mediation analyses were conducted using ordinary-least-squares path analyses in PROCESS (Hayes, 2013) to test mother–child relationship quality at age 3 as a mediator of the association between maternal depression and indicators of social processes and relationships at age 12 (N1 in response to rejection residual, RewP in response to acceptance residual, chronic peer stress). Models with significant effects of mother–child relationship were followed up with exploratory parallel mediation analyses to examine positive and negative parenting behaviors as mediators of the association between maternal depression and indicators of social processes. Finally, exploratory analyses tested sex as a moderator of the direct and indirect effects of maternal depression on social processes at age 12.[2]

Results

Bivariate correlations

Descriptive statistics and bivariate associations between study variables are presented in Table 1. Maternal depression at age 3 correlated with lower mother–child relationship quality and positive parenting, but the association between maternal depression and negative parenting was not significant. The association between maternal depression at age 3 and low peer stress in early adolescence did not reach significance. Both low relationship quality and positive parenting in early childhood were modestly correlated with greater peer stress in adolescence (Fig. 2). Maternal depression was not significantly correlated with ERP measures, but lower mother–child relationship quality and positive parenting were modestly correlated with an enhanced N1 in response to rejection. No significant correlations were observed between parenting measures and RewP or between peer stress and ERP measures (ps > .41), which suggests that neural and interviewer-based measures reflect distinct aspects of social processes.

Mediation models

Three simple mediation models were computed to test direct and indirect effects of maternal depression on outcome variables (residuals of N1 in response to rejection, residuals of RewP in response to acceptance, LSI chronic peer stress), with age 3 relationship quality as the mediator. Model coefficients for primary analyses are presented in Table 2, and model coefficients for exploratory follow-up analyses of positive and negative parenting behaviors are presented in Table 3.

Maternal depression in early childhood had an indirect effect on an enhanced (i.e., more negative) N1 in response to rejection cues through its effect on mother–child relationship quality. Maternal depression was associated with lower mother–child relationship quality ($b = -0.18$), which related to an enhanced N1 in response to rejection feedback (i.e., enhanced early attention toward rejection cues; $b = 0.84$). A bias-corrected bootstrap 95% confidence interval for the indirect effect of maternal depression on N1 in response to rejection ($b = -0.15$, $SE = 0.10$), calculated on the basis of 5,000 bootstrap samples, was below 0 (95% CI = [−0.38, −.002]).[3] The partially standardized effect size was −0.04 ($SE = 0.02$), which indicates that the maternal depression groups differ on average 0.04 *SD* in N1 in response to rejection as a result of the indirect pathway through mother–child relationship quality (Hayes, 2013). The direct effect of maternal depression on N1 in response to rejection was not significant ($b = 0.23$, $SE = 0.51$, $p = .66$).

Next, an exploratory parallel mediation model was computed to test the indirect effect of maternal depression through positive and negative parenting (Table 3). Bootstrap 95% confidence intervals for the indirect effects of maternal depression on N1 in response to rejection through positive parenting were entirely below 0 (95% CI = [−0.47, −0.004]), which supports an indirect effect of maternal depression on N1 in response to rejection through positive parenting. The partially standardized effect size indicated a comparable effect size as was observed for relationship quality ($b = -0.04$, $SE = 0.03$). The indirect effect through negative parenting included 0 (95% CI = [−0.07, 0.20]).

A comparable pathway for RewP in response to acceptance feedback was not supported. Mother–child relationship quality was not significantly associated with RewP in response to acceptance ($p = .93$), the direct effect of maternal depression on RewP in response to acceptance feedback was not significant ($p = .49$), and the bootstrap 95% confidence interval for the indirect effect included 0 (95% CI = [−.28, .30]).[4]

Similar to the N1 results, maternal depression had an indirect effect on peer stress through mother–child relationship quality. Lower mother–child relationship quality was observed among mothers with a history of depression ($b = -0.18$), and lower mother–child relationship quality was related to greater peer stress in early adolescence ($b = -0.11$). A bias-corrected bootstrap 95% confidence interval for the indirect effect of maternal depression on peer stress ($b = 0.02$, $SE = 0.01$), calculated on the basis of 5,000 bootstrap samples, was above 0 (95% CI = [0.001, 0.05]).[5] The partially standardized effect size was comparable to that observed for the indirect effect on N1 ($b = 0.04$, $SE = 0.03$). The direct

Table 1. Descriptive Statistics and Bivariate Correlations Between Key Study Variables

Variable	1		2		3		4		5		6		*M*	Range
1. Maternal depression		—											—	—
2. Age 3 relationship quality	−.15**	[−.26, −.04]		—									4.00 (0.56)	1.83–5.00
3. Age 3 positive parenting	−.12*	[−.24, −.003]	.61***	[.52, .69]		—							0.00 (2.50)	−10.80–2.85
4. Age 3 negative parenting	.06	[−.05, .18]	−.45***	[−.55, −.33]	−.58***	[−.66, .47]		—					0.00 (1.64)	−1.84–6.92
5. N1 residual	.01	[−.11, .12]	.11*	[.01, .21]	.12*	[.01, .23]	.01	[−.13, .10]		—			0.00 (4.22)	−12.66–12.99
6. RewP residual	−.04	[−.16, .08]	.01	[−.11, .13]	.05	[−.06, .15]	−.04	[−.15, .07]	−.26***	[−.35, −.16]		—	0.00 (6.48)	−16.13–20.66
7. Chronic peer stress	.10†	[−.02, .22]	−.14*	[−.24, −.03]	−.12*	[−.22, −.01]	.06	[−.07, .18]	.04,	[−.09 .16]	−.04	[−.14, .06]	2.13 (0.50)	1.00–4.50

Note: Values in brackets are 95% confidence intervals; values in parentheses are standard deviations. RewP = reward positivity.
†$p = .07$. *$p < .05$. **$p < .01$. ***$p < .001$.

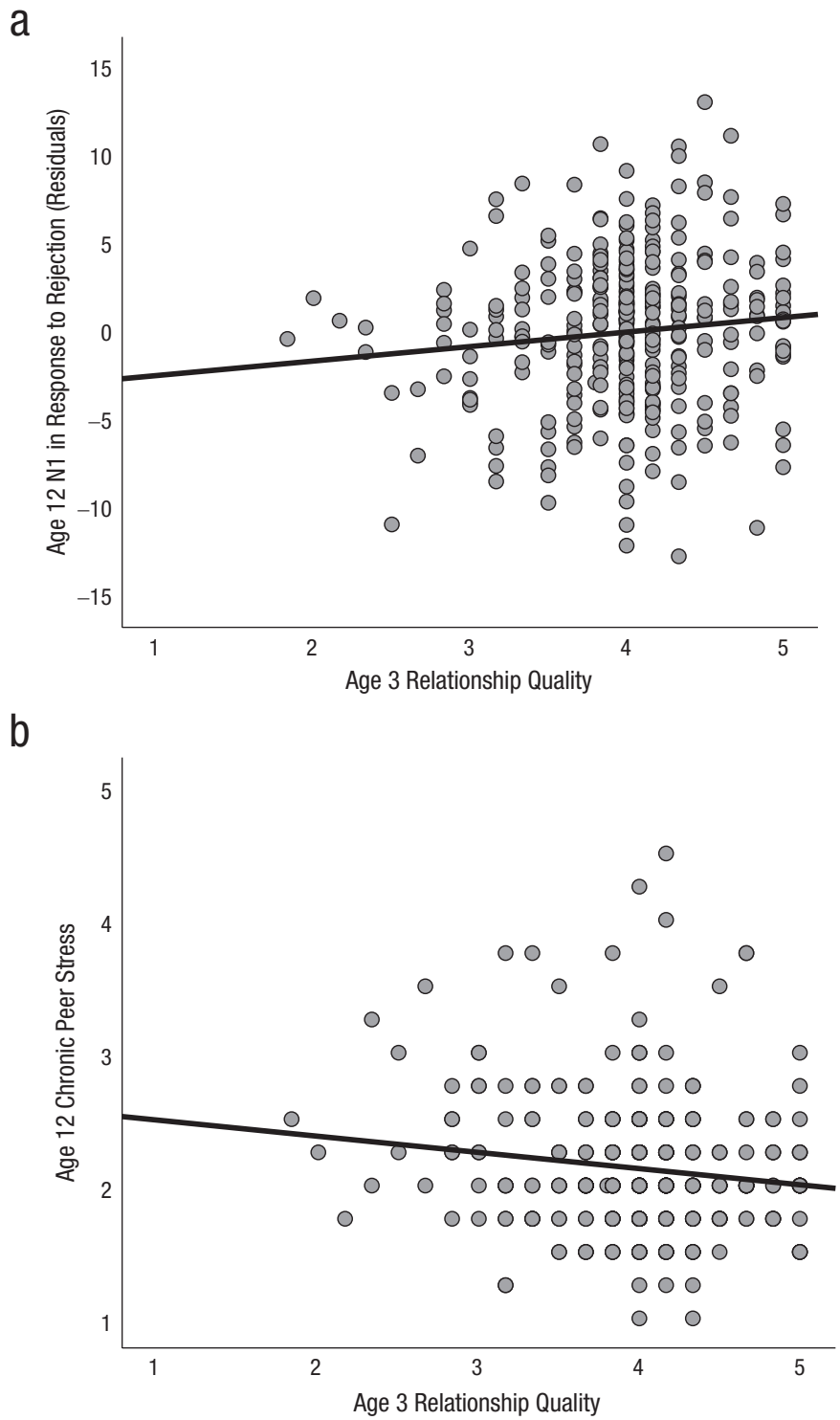

Fig. 2. Scatterplots (with best-fitting regression lines) depicting the association between age 3 mother–child relationship quality and age 12 social variables: N1 response to peer-rejection cues (a) and chronic peer stress (b).

effect of maternal depression on age 12 peer stress did not reach significance ($b = 0.09$, $SE = 0.06$, $p = .14$). Next, parallel mediation models were computed to test the indirect effect of maternal depression through positive and negative parenting. Bootstrap 95% confidence intervals for indirect effects of maternal depression on peer stress through positive and negative parenting reached or included 0 (95% CI = [0.00, 0.04] and [–0.01, 0.02],

Table 2. Model Coefficients for Simple Mediation Models Testing Effects of Age 3 Maternal Depression and Relationship Quality on Age 12 Social-Processing Variables

	Mediator			Outcome variable								
	Relationship quality[a]			N1 residual[b]			RewP residual[c]			Chronic peer stress[d]		
Predictor	*b*	95% CI	*SE*	*b*	95% CI	*SE*	*b*	95% CI	*SE*	*b*	95% CI	*SE*
Maternal depression	−0.18**	[−0.31, −0.05]	0.07	0.23	[−0.78, 1.23]	0.51	−0.54	[−2.09, 1.01]	0.79	0.09	[−0.03, 0.21]	0.06
Relationship quality	—	—	—	0.84*	[0.03, 1.66]	0.42	0.05	[−1.21, 1.32]	0.65	−0.11*	[−0.21, −0.02]	0.05
Constant	4.05***	[3.98, 4.12]	0.04	−3.44***	[−6.80, −0.09]	1.71	−0.05	[−5.24, 5.14]	2.64	2.55***	[2.15, 2.94]	0.20

Note: RewP = reward positivity; *b* = unstandardized regression coefficient; CI = confidence intervals from 5,000 bootstrap samples; *SE* = standard error.
[a]R^2 = .02, $F(1, 330) = 7.42$**. [b]R^2 = .01, $F(2, 329) = 2.07$. [c]R^2 = .00, $F(2, 329) = 0.25$. [d]R^2 = .03, $F(2, 329) = 4.29$*.
*$p < .05$. **$p < .01$. ***$p < .001$.

Table 3. Model Coefficients for Exploratory Parallel Mediation Models Testing Effects of Age 3 Maternal Depression and Parenting Behaviors on Age 12 N1 in Response to Rejection and Chronic Peer Stress

	Mediator						Outcome variable					
	Negative parenting[a]			Positive parenting[b]			N1 residual[c]			Chronic peer stress[d]		
Predictor	*b*	95% CI	*SE*	*b*	95% CI	*SE*	*b*	95% CI	*SE*	*b*	95% CI	*SE*
Maternal depression	0.23	[−0.16, 0.61]	0.20	−0.66*	[−1.25, −0.07]	0.30	0.21	[−0.79, 1.21]	0.51	0.09	[−0.02, 0.21]	0.03
Negative parenting	—	—	—	—	—	—	0.22	[−0.12, 0.56]	0.17	0.00	[−0.04, 0.04]	0.02
Positive parenting	—	—	—	—	—	—	0.28*	[0.06, 0.50]	0.11	−0.02†	[−0.05, 0.00]	0.01
Constant	−0.07	[−0.28, 0.14]	0.11	0.20	[−0.12, 0.52]	0.16	−0.06	[−0.60, 0.48]	0.28	2.10***	[2.03, 2.16]	0.03

Note: RewP = reward positivity; *b* = unstandardized regression coefficient; CI = confidence intervals from 5,000 bootstrap samples; *SE* = standard error.
[a]R^2 = .00, $F(1, 330) = 1.32$. [b]R^2 = .01, $F(1, 330) = 4.85$*. [c]R^2 = .02, $F(3, 328) = 2.06$†. [d]R^2 = .02, $F(3, 328) = 2.46$†.
†$p \leq 0.10$. *$p < .05$. ***$p < .001$.

respectively). Thus, the pathway appeared to be best explained by global ratings of relationship quality, which included both parent and child behaviors in relating to one another.

Although the primary focus of the current study was on developmental pathways involved in the intergenerational transmission of depression, to examine specificity of effects of maternal depression rather than maternal psychopathology more broadly, mediation models were computed with the addition of maternal anxiety and substance use disorders as covariates. Neither maternal anxiety nor substance use disorders were significantly associated with mother–child relationship quality (ps > .84); the association between maternal depression and relationship quality remained significant when controlling for anxiety and substance use disorders (p = .01), and the bootstrap 95% confidence intervals of the indirect effects of maternal depression on both N1 in response to rejection and chronic peer stress through mother–child relationship quality remained entirely below and above 0 (95% CI = [−0.38, −0.002] and [0.001, 0.05], respectively).

Finally, exploratory moderated mediation analyses were conducted to evaluate whether child sex moderates indirect or direct effects of maternal depression on N1 in response to rejection or chronic peer stress. Male and female participants did not significantly differ on parenting variables, N1 in response to rejection, RewP in response to acceptance, or chronic peer stress (ps > .42). Furthermore, the Maternal Depression × Child Sex interaction was not a significant predictor of N1 or chronic peer stress (ps > .67). In addition, the 95% confidence interval for the index of moderated mediation examining the difference between conditional indirect effects for male children as opposed to female children included 0 for both N1 in response to rejection (95% CI = [−0.36, 0.18]) and chronic peer stress (95% CI = [−0.02, 0.04]).

Discussion

We examined longitudinal associations between maternal depression and observed mother–child relationship quality in early childhood and neural and interviewer-based indicators of social processes 9 years later. Lower observed mother–child relationship quality in early childhood was modestly related to enhanced neural reactivity to peer rejection cues during a computerized peer interaction task (i.e., more negative N1 ERP in response to rejection) and greater chronic stress in peer relationships in early adolescence. Moreover, indirect effects of maternal depression on social measures through mother–child relationship quality were observed. That is, maternal depression was associated with lower mother–child relationship quality at age 3, which was associated with an enhanced N1 in response to peer rejection cues and greater chronic peer stress at age 12, which highlights a mechanism by which maternal depression shapes social development. The pathway from maternal depression to enhanced neural reactivity to peer rejection cues appeared to be driven by lower levels of positive parenting behaviors, including support, instruction, and confidence, whereas the pathway to chronic peer stress was best accounted for by observations of the overall quality of the relationship between mothers and children. Although lower relationship quality with mothers in early childhood was associated with multiple measures of social processing and functioning in early adolescence, neural reactivity to social feedback cues and chronic peer stress were not significantly associated with each other.

An enhanced N1 in response to peer rejection in the peer-interaction task likely reflects greater early attention toward rejection relative to acceptance cues (Coch & Gullick, 2012; Kujawa et al., 2017; Luck et al., 2000). We previously observed an association between N1 in response to rejection and self-reported rejection sensitivity such that adolescents who demonstrated an enhanced N1 in response to rejection feedback reported higher levels of rejection sensitivity in hypothetical scenarios (Babinski et al., 2019). Self-reported rejection sensitivity has also been linked to the later emergence of depression (Chango et al., 2012). Thus, one potential pathway by which maternal depression shapes risk for depression is through problems in the quality of relationships with mothers, which then leads to maladaptive processing of peer rejection cues and potentially heightened sensitivity to possible rejection in peer interactions. Although in need of replication, exploratory analyses indicated that positive parenting behaviors at age 3 were also associated with N1 in response to rejection cues, which suggests that lower parent support, instruction, and confidence in their parenting might lead to heightened sensitivity to peer rejection in offspring. These findings provide support for prevention efforts targeting positive parenting behaviors in early childhood and highlight a specific outcome to examine (i.e., neural reactivity to peer rejection cues). Given that we did not directly measure other aspects of parenting that might be relevant to social competence, such as positive and negative emotion socialization (e.g., Garner, Jones, & Miner, 1994), future research is needed to further examine possible components of parenting that could be important to target.

Indirect effects of maternal depression through mother–child relationship quality were also observed for chronic peer stress in adolescence. In contrast with the N1 model, neither positive nor negative parenting

behaviors accounted for these associations, but instead, the overall quality of the reciprocal relationship between mothers and children appears to set the framework for adolescents' later relationships with peers. Critically, our measure of peer stress did not include stress in family relationships, which provides evidence that the effects of maternal depression and early relationship quality on social functioning in offspring extend beyond the family and generalizes to peer functioning. Strain in peer relationships is a well-established risk factor for depression (Hammen, 2009; La Greca & Harrison, 2005; Prinstein et al., 2005), and this pathway may also be a key to understanding the intergenerational transmission of depression.

Neural and interviewer-based measures index distinct aspects of social processes; N1 reflects attentional allocation toward peer rejection cues, and LSI reflects broader stress and impairment in relationships. Given the lack of a correlation between these measures, neural reactivity to peer feedback as assessed by this task does not appear to be a mechanism of the effects of early relationships on peer relationships in adolescence. Instead, the current findings highlight two distinct pathways by which maternal depression disrupts mother–child relationship quality, which leads to both increased neural reactivity to rejection and chronic peer stress. That is, some adolescents might demonstrate enhanced attention toward rejection cues but still establish meaningful, supportive relationships, whereas others might have impairments in relationships that are not accounted for by reactivity to rejection cues. Both heightened reactivity to rejection cues and peer stress are likely to predict the emergence of depression later in adolescence. Further assessment of this sample will provide insight into the extent to which these two processes might reflect independent or interactive vulnerabilities for depressive symptoms across adolescence.

Despite consistent indirect effects across methods, direct and bivariate associations between maternal depression and age 12 social processes were not significant. Direct effects would indicate that the effects of maternal depression were significant independent of the influence of mother–child relationship quality. Thus, the current results suggest that early relationships between mothers and children are key to understanding social processing and functioning in offspring at risk for depression. The lack of a significant total effect might be due to the fact that intergenerational transmission of depression is characterized by multiple additive and interactive pathways and mechanisms, which might have opposing effects (Hayes, 2013; Shrout & Bolger, 2002). Further research is needed to identify additional mediators of the association between maternal depression and social processes in adolescence. It should also be noted that the lack of significant associations between maternal depression and social outcomes is likely to be partly explained by the length of time between the maternal depression and age 12 assessments.

No significant associations were observed between relationship quality and RewP in response to social acceptance. Although N1 reflects early attentional allocation to social cues, RewP is thought to index reward prediction signals (Holroyd, Krigolson, & Lee, 2011; Proudfit, 2015). Because reward systems undergo substantial developmental change from childhood to adolescence (Casey, Jones, & Hare, 2008; Galvan, 2010), effects of early parenting on reward-related brain function may be weaker in adolescence or only observable when examining developmental change in RewP. In addition, much of the literature on RewP comes from monetary reward or performance tasks. Although there is growing research directly comparing RewP in both monetary and social reward tasks (Distefano et al., 2018; Ethridge et al., 2017; Ethridge & Weinberg, 2018), further research is needed to better understand the specific processes reflected by RewP in social interaction tasks.

Although we identified effects of mother–child relationship quality across methods, the association between early childhood relationship quality and indicators of social processing and functioning, including both N1 and chronic peer stress, were modest in magnitude. Furthermore, we tested mediation models for three distinct indicators of social processes in adolescence, and given the number of models tested, significant results must be interpreted cautiously pending replication. We examined longitudinal associations between observed parenting and both neural and interviewer-based measures of social functioning, and the lack of shared method variance and length of time between assessment may partly account for modest effects. In addition, peer functioning in early adolescence is complex and shaped by a range of factors, and one aspect of the environment may not be expected to account for large amounts of variance. Despite the small effects, the current study is unique in its multimethod longitudinal approach to examining social processes and highlights a specific neural process (N1 in response to rejection) that warrants further study in research on peer functioning.

A few additional limitations of the current study should be noted. We did not administer an observational assessment of mother–child relationship quality at age 12 and were unable to test the distinct and combined effects of relationship quality in early childhood and adolescence on neural or behavioral indicators of social processing at age 12. Likewise, we did not collect neural and interview measures of social functioning in early

childhood and cannot test bidirectional associations between neural reactivity to rejection cues, peer stress, and mother–child relationship quality. Although most cases of maternal depression were not current at the age 3 assessment, which supports the theory that maternal depression shapes later relationship quality with offspring, maternal depression and parenting variables were assessed concurrently, and thus, we did not examine bidirectional associations between these variables across time. Finally, it should be noted that neural response to social acceptance and rejection feedback might differ as function of participant votes to accept or reject peers. The current task design is not well suited to examine this possibility because of variability in the proportion of participant votes to reject and accept peers (Kujawa et al., 2017), but further research is needed to evaluate this possibility.

The current findings are consistent with attachment theory and interpersonal perspectives on the intergenerational transmission of depression (Groh et al., 2014; Hammen & Brennan, 2001; Schneider et al., 2001), but this study is among the first to identify a specific neural process that appears to be shaped by the effects of maternal depression on early relationships with mothers—neural reactivity to peer rejection cues. We tested developmental pathways across levels of analysis from observed behavior to neurophysiology and gold-standard measures of peer chronic stress spanning 9 years of development. Results provide insight into the lasting effects of maternal depression and early mother–child relationships on brain function and social behavior and identify specific mechanisms of the effects of maternal depression on peer relationships and processing of social cues in adolescence. These findings have important implications for prevention and suggest that among mothers with depression history, enhancing positive parenting behaviors and mother–child relationship quality in the preschool years could alter the course of social development in offspring and promote later resilience. Furthermore, results highlight a potential neural process (i.e., N1 in response to peer rejection cues) to examine in depression risk and prevention research.

Transparency

Action Editor: John J. Curtin
Editor: Scott O. Lilienfeld
Author Contributions

A. Kujawa and D. N. Klein developed the study concept and design. K. B. Arfer contributed to the computerized social interaction task design and programming. M. C. Finsaas contributed to the design for assessing chronic peer stress. E. M. Kessel and E. Mumper contributed to the electroencephalogram assessment design. A. Kujawa performed the data analysis and interpretation and drafted the manuscript along with D. N. Klein. All of the authors provided critical revisions and approved the final manuscript for submission.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

Funding

This study was funded by National Institute of Mental Health Grant R0-MH069942 (to D. N. Klein).

ORCID iDs

Autumn Kujawa https://orcid.org/0000-0002-0560-4589
Megan C. Finsaas https://orcid.org/0000-0001-8290-7500

Acknowledgments

We thank Alice Bartoldus, Katherine Curry, Caitlin Jellinek, Laura Klein, Rebecca Laptook, Dawna Shimabukuro, and Allison Stumper for help with data collection and Joanne Davila for training in the Life Stress Interview.

Supplemental Material

Additional supporting information can be found at http://journals.sagepub.com/doi/suppl/10.1177/2167702620902463

Notes

1. Analyses were computed with the participant with maternal bipolar disorder excluded, and no substantive changes in results were observed.
2. The deidentified data set is available from A. Kujawa.
3. We also tested mediation models with a Holm-Bonferroni correction (Holm, 1979) applied to tests of the three primary indirect effects of interest (i.e., maternal depression effects on N1 in response to rejection, RewP in response to acceptance, and chronic peer stress through mother–child relationship quality). With three tests, this correction requires $p < .017$ for the model with the lowest p value and $p < .025$ for the model with the second lowest p value. The Holm-Bonferroni-corrected test of the indirect effect of maternal depression on N1 in response to rejection through mother–child relationship quality using a 97.5% confidence interval reached 0 (97.5% CI = [–.43, .01]).
4. Given evidence of interactive effects of depression and parenting behavior on RewP in response to monetary reward (Kujawa, Proudfit, Laptook, & Klein, 2015), exploratory analyses tested the Maternal Depression × Mother–Child Relationship Quality interactions for RewP in response to acceptance. The interaction effect did not reach significance ($p = .10$).
5. The Holm-Bonferroni-corrected test of the indirect effect of maternal depression on peer stress through mother–child relationship quality using a 98.3% confidence interval reached 0 (98.3% CI = [–0.002, 0.06]).

References

Adrian, C., & Hammen, C. (1993). Stress exposure and stress generation in children of depressed mothers. *Journal of Consulting and Clinical Psychology*, *61*, 354–359.

Allen, J. P., Porter, M., McElhaney, K. B., Marsh, P., McFarland, C., McElhaney, K. B., & Marsh, P. (2007). The relation of attachment security to adolescents' paternal and peer relationships, depression, and externalizing behavior. *Child Development*, *78*, 1222–1239.

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Babinski, D., Kujawa, A., Kessel, E. M., Arfer, K. B., & Klein, D. N. (2019). Sensitivity to peer feedback in young adolescents with symptoms of ADHD: Examination of neurophysiological and self-report measures. *Journal of Abnormal Child Psychology*, *47*, 605–617. doi:0.1007/s10802-018-0470-2

Becker, M. P. I., Nitsch, A. M., Miltner, W. H. R., & Straube, T. (2014). A single-trial estimation of the feedback-related negativity and its relation to BOLD responses in a time-estimation task. *The Journal of Neuroscience*, *34*, 3005–3012. doi:10.1523/JNEUROSCI.3684-13.2014

Bohlin, G., Hagekull, B., & Rydell, A. M. (2000). Attachment and social functioning: A longitudinal study from infancy to middle childhood. *Social Development*, *9*, 24–39. doi:10.1111/1467-9507.00109

Bress, J. N., Meyer, A., & Proudfit, G. H. (2015). The stability of the feedback negativity and its relationship with depression during childhood and adolescence. *Development and Psychopathology*, *17*, 1285–1294.

Brown, B. B. (2004). Adolescents' relationships with peers. In R. M. Lerner & L. Steinberg (Eds.), *Handbook of adolescent psychology* (Vol. 2, pp. 363–394). Hoboken, NJ: John Wiley & Sons, Inc.

Casey, B. J., Jones, R. M., & Hare, T. A. (2008). The adolescent brain. *Annals of the New York Academy of Sciences*, *1124*, 111–126. doi:10.1196/annals.1440.010

Cavanagh, S. E., & Huston, A. C. (2008). The timing of family instability and children's social development. *Journal of Marriage and Family*, *70*, 1258–1270.

Chango, J. M., McElhaney, K. B., Allen, J. P., Schad, M. M., & Marston, E. (2012). Relational stressors and depressive symptoms in late adolescence: Rejection sensitivity as a vulnerability. *Journal of Abnormal Child Psychology*, *40*, 369–379.

Chaplin, T. M., Cole, P. M., & Zahn-Waxler, C. (2005). Parental socialization of emotion expression: Gender differences and relations to child adjustment. *Emotion*, *5*, 80–88. doi:10.1037/1528-3542.5.1.80

Coch, D., & Gullick, M. M. (2012). Event-related potentials and development. In S. J. Luck & E. S. Kappenman (Eds.), *The Oxford handbook of event-related potential components* (pp. 475–511). New York, NY: Oxford University Press.

Connell, A. M., & Goodman, S. H. (2002). The association between psychopathology in fathers versus mothers and children's internalizing and externalizing behavior problems: A meta-analysis. *Psychological Bulletin*, *128*, 746–773. doi:10.1037/0033-2909.128.5.746

Cummings, E. M., & Davies, P. T. (1994). Maternal depression and child development. *Journal of Child Psychology and Psychiatry*, *35*, 73–122.

Distefano, A., Jackson, F., Levinson, A. R., Infantolino, Z. P., Jarcho, J. M., & Nelson, B. D. (2018). A comparison of the electrocortical response to monetary and social reward. *Social Cognitive and Affective Neuroscience*, *13*, 247–255. doi:10.1093/scan/nsy006

Eberhart, N. K., Shih, J. H., Hammen, C. L., & Brennan, P. A. (2006). Understanding the sex difference in vulnerability to adolescent depression: An examination of child and parent characteristics. *Journal of Abnormal Child Psychology*, *34*, 495–508. doi:10.1007/s10802-006-9020-4

Egeland, B., Weinfield, N. S., Heiester, M., Lawrence, C., Pierce, S., Chippendale, K., & Powell, K. (1995). *Teaching tasks administration and scoring manual*. Minneapolis Institute of Child Development, University of Minnesota.

Egger, H. L., Pine, D. S., Nelson, E., Leibenluft, E., Ernst, M., Towbin, K. E., & Angold, A. (2011). The NIMH Child Emotional Faces Picture Set (NIMH-ChEFS): A new set of children's facial emotion stimuli. *International Journal of Methods in Psychiatric Research*, *20*, 145–156. doi:10.1002/mpr.343

Ethridge, P., Kujawa, A., Dirks, M. A., Arfer, K. B., Kessel, E. M., Klein, D. N., & Weinberg, A. (2017). Neural responses to social and monetary reward in early adolescence and emerging adulthood. *Psychophysiology*, *54*, 1786–1799. doi:10.1111/psyp.12957

Ethridge, P., & Weinberg, A. (2018). Psychometric properties of neural responses to monetary and social rewards across development. *International Journal of Psychophysiology*, *132*, 311–322. doi:10.1016/j.ijpsycho.2018.01.011

Ewell Foster, C. J., Garber, J., & Durlak, J. A. (2008). Current and past maternal depression, maternal interaction behaviors, and children's externalizing and internalizing symptoms. *Journal of Abnormal Child Psychology*, *36*, 527–537. doi:10.1007/s10802-007-9197-1

Feurer, C., Hammen, C. L., & Gibb, B. E. (2016). Chronic and episodic stress in children of depressed mothers. *Journal of Clinical Child and Adolescent Psychology*, *45*, 270–278. doi:10.1080/15374416.2014.963859

First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. W. (2002). *Structured clinical interview for DSM-IV-TR axis I disorders, research version, patient edition* (SCID-I/P). New York, NY: Biometrics Research, New York State Psychiatric Institute.

Fivush, R., Brotman, M. A., Buckner, J. P., & Goodman, S. H. (2000). Gender differences in parent-child emotion narratives. *Sex Roles*, *42*, 233–253.

Galvan, A. (2010). Adolescent development of the reward system. *Frontiers in Human Neuroscience*, *4*, Article 6. doi:10.3389/neuro.09.006.2010

Garber, J., & Cole, D. A. (2010). Intergenerational transmission of depression: A launch and grow model of change across adolescence. *Development and Psychopathology*, *22*, 819–830. doi:10.1017/S0954579410000489

Garner, P. W., Jones, D. C., & Miner, J. L. (1994). Social competence among low-income preschoolers: Emotion socialization practices and social cognitive correlates. *Child Development*, *65*, 622–637.

Goodman, S. H., & Gotlib, I. H. (1999). Risk for psychopathology in the children of depressed mothers: A developmental model for understanding mechanisms of transmission. *Psychological Review*, *106*, 458–490. doi:10.1037/0033-295x.106.3.458

Gratton, G., Coles, M., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography & Clinical Neurophysiology*, *55*(4), 468–484. doi:10.1016/0013-4694(83)90135-9

Groh, A. M., Fearon, R. P., Bakermans-Kranenburg, M. J., Van IJzendoorn, M. H., Steele, R. D., & Roisman, G. I. (2014). The significance of attachment security for children's social competence with peers: A meta-analytic study. *Attachment & Human Development*, *16*, 103–136.

Guyer, A. E., Jarcho, J. M., Pérez-Edgar, K., Degnan, K. A., Pine, D. S., Fox, N. A., & Nelson, E. E. (2015). Temperament and parenting styles in early childhood differentially influence neural response to peer evaluation in adolescence. *Journal of Abnormal Child Psychology*, *43*, 863–874. doi:10.1007/s10802-015-9973-2

Hammen, C. (2009). Adolescent depression: Stressful interpersonal contexts and risk for recurrence. *Current Directions in Psychological Science*, *18*, 200–204. doi:10.1111/j.1467-8721.2009.01636.x

Hammen, C., & Brennan, P. A. (2001). Depressed adolescents of depressed and nondepressed mothers: Tests of an interpersonal impairment hypothesis. *Journal of Consulting and Clinical Psychology*, *69*, 284–294. doi:10.1037/0022-006X.69.2.284

Hammen, C., Shih, J. H., & Brennan, P. A. (2004). Intergenerational transmission of depression: Test of an interpersonal stress model in a community sample. *Journal of Consulting and Clinical Psychology*, *72*, 511–522. doi:10.1037/0022-006X.72.3.511

Hankin, B. L., Abramson, L. Y., Moffitt, T. E., Silva, P. A., McGee, R., & Angell, K. E. (1998). Development of depression from preadolescence to young adulthood: Emerging gender differences in a 10-year longitudinal study. *Journal of Abnormal Psychology*, *107*, 128–140. doi:10.1037/0021-843X.107.1.128

Hankin, B. L., Wetter, E., & Cheely, C. (2008). Sex differences in child and adolescent depression: A developmental psychopathological approach. In J. R. Z. Abela & B. L. Hankin (Eds.), *Handbook of depression in children and adolescents* (pp. 377–414). New York, NY: Guilford Press.

Harold, G. T., Rice, F., Hay, D. F., Boivin, J., Van Den Bree, M., & Thapar, A. (2011). Familial transmission of depression and antisocial behavior symptoms: Disentangling the contribution of inherited and environmental factors and testing the mediating role of parenting. *Psychological Medicine*, *41*, 1175–1185. doi:10.1017/S0033291710001753

Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. New York, NY: Guilford.

Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics*, *6*, 65–70.

Holroyd, C. B., Krigolson, O. E., & Lee, S. (2011). Reward positivity elicited by predictive cues. *NeuroReport*, *22*, 249–252.

Katz, S. J., Hammen, C. L., & Brennan, P. A. (2013). Maternal depression and the intergenerational transmission of relational impairment. *Journal of Family Psychology*, *27*, 86–95.

Keren, H., Callaghan, G. O., Vidal-Ribas, P., Buzzell, G. A., Brotman, M. A., Leibenluft, E., . . . Stringaris, A. (2018). Reward processing in depression: A conceptual and meta-analytic review across fMRI and EEG studies. *American Journal of Psychiatry*, *175*, 1111–1120. doi:10.1176/appi.ajp.2018.17101124

Klein, D. N., & Finsaas, M. C. (2017). The Stony Brook Temperament Study: Early antecedents and pathways to emotional disorders. *Child Development Perspectives*, *11*, 257–263. doi:.1111/cdep.12242

Kujawa, A., Arfer, K. B., Klein, D. N., & Proudfit, G. H. (2014). Electrocortical reactivity to social feedback in youth: A pilot study of the Island Getaway task. *Developmental Cognitive Neuroscience*, *10*, 140–147. doi:10.1016/j.dcn.2014.08.008

Kujawa, A., & Burkhouse, K. L. (2017). Vulnerability to depression in youth: Advances from affective neuroscience. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *2*, 28–37. doi:10.1016/j.bpsc.2016.09.006

Kujawa, A., Carroll, A., Mumper, E., Mukherjee, D., Kessel, E. M., Olino, T., . . . Klein, D. N. (2018). A longitudinal examination of event-related potentials sensitive to monetary reward and loss feedback from late childhood to middle adolescence. *International Journal of Psychophysiology*, *132*, 323–330. doi:10.1016/j.ijpsycho.2017.11.001

Kujawa, A., Dougherty, L., Durbin, C. E., Laptook, R., Torpey, D., & Klein, D. N. (2014). Emotion recognition in preschool children: Associations with maternal depression and early parenting. *Development and Psychopathology*, *26*, 159–170. doi:10.1017/S0954579413000928

Kujawa, A., Hajcak, G., & Klein, D. N. (2019). Reduced reward responsiveness moderates the effect of maternal depression on depressive symptoms in offspring: Evidence across levels of analysis. *Journal of Child Psychology and Psychiatry*, *60*, 82–90.

Kujawa, A., Kessel, E. M., Carroll, A., Arfer, K. B., & Klein, D. N. (2017). Social processing in early adolescence: Associations between neurophysiological, self-report, and behavioral measures. *Biological Psychology*, *128*, 55–62. doi:10.1016/j.biopsycho.2017.07.001

Kujawa, A., Proudfit, G. H., Kessel, E. M., Dyson, M., Olino, T., & Klein, D. N. (2015). Neural reactivity to monetary rewards and losses in childhood: Longitudinal and concurrent associations with observed and self-reported positive emotionality. *Biological Psychology*, *104*, 41–47. doi:10.1016/j.biopsycho.2014.11.008

Kujawa, A., Proudfit, G. H., & Klein, D. N. (2014). Neural reactivity to rewards and losses in offspring of mothers and fathers with histories of depressive and anxiety disorders. *Journal of Abnormal Psychology*, *123*, 287–297. doi:10.1037/a0036285

Kujawa, A., Proudfit, G. H., Laptook, R., & Klein, D. N. (2015). Early parenting moderates the association between parental depression and neural reactivity to rewards and losses in offspring. *Clinical Psychological Science*, *3*, 503–515. doi:10.1177/2167702614542464

La Greca, A. M., & Harrison, H. M. (2005). Adolescent peer relations, friendships, and romantic relationships: Do they predict social anxiety and depression? *Journal of Clinical Child and Adolescent Psychology*, *34*, 49–61. doi:10.1207/s15374424jccp3401_5

Luck, S. J., Woodman, G. F., & Vogel, E. K. (2000). Event-related potential studies of attention. *Trends in Cognitive Sciences*, *4*, 432–440. doi:10.1016/S1364-6613(00)01545-X

Meyer, A., Lerner, M. D., de los Reyes, A., Laird, R. D., & Hajcak, G. (2017). Considering ERP difference scores as individual difference measures: Issues with subtraction and alternative approaches. *Psychophysiology*, *54*, 114–122. doi:10.1111/psyp.12664

Morgan, J. K., Shaw, D. S., & Forbes, E. E. (2014). Maternal depression and warmth during childhood predict age 20 neural response to reward. *Journal of the American Academy of Child & Adolescent Psychiatry*, *53*, 108–117. doi:10.1016/j.jaac.2013.10.003

Nelson, B. D., Perlman, G., Klein, D. N., Kotov, R., & Hajcak, G. (2016). Blunted neural response to rewards prospectively predicts the development of depression in adolescent girls. *The American Journal of Psychiatry*, *173*, 1223–1230. doi:10.1176/appi.ajp.2016.15121524

Nelson, E. E., Jarcho, J. M., & Guyer, A. E. (2016). Social re-orientation and brain development: An expanded and updated view. *Developmental Cognitive Neuroscience*, *17*, 118–127. doi:10.1016/j.dcn.2015.12.008

Olino, T. M., Klein, D. N., Dyson, M. W., Rose, S. A., & Durbin, C. E. (2010). Temperamental emotionality in preschool-aged children and depressive disorders in parents: Associations in a large community sample. *Journal of Abnormal Psychology*, *119*, 468–478. doi:10.1037/a0020112

Phares, V., Fields, S., & Kamboukos, D. (2009). Fathers' and mothers' involvement with their adolescents. *Journal of Child and Family Studies*, *18*, 1–9. doi:10.1007/s10826-008-9200-7

Prinstein, M. J., Cheah, C. S. L., Borelli, J. L., Simon, V. A., & Aikins, J. W. (2005). Adolescent girls' interpersonal vulnerability to depressive symptoms: A longitudinal examination of reassurance-seeking and peer relationships. *Journal of Abnormal Psychology*, *114*, 676–688. doi:10.1037/0021-843X.114.4.676

Proudfit, G. H. (2015). The reward positivity: From basic research on reward to a biomarker for depression. *Psychophysiology*, *52*, 449–459. doi:10.1111/psyp.12370

Rohde, P., Lewinsohn, P. M., & Seeley, J. R. (1997). Comparability of telephone and face-to-face interviews in assessing axis I and II disorders. *American Journal of Psychiatry*, *154*, 1593–1598. doi:10.1176/ajp.154.11.1593

Roisman, G. I., Booth-LaForce, C., Cauffman, E., & Spieker, S. (2009). The developmental significance of adolescent romantic relationships: Parent and peer predictors of engagement and quality at age 15. *Journal of Youth and Adolescence*, *38*, 1294–1303. doi:10.1007/s10964-008-9378-4

Rudolph, K. D. (2002). Gender differences in emotional responses to interpersonal stress during adolescence. *Journal of Adolescent Health*, *30*, 3–13.

Rudolph, K. D., Davis, M. M., Modi, H. H., Fowler, C., Kim, Y., & Telzer, E. H. (2020). Differential susceptibility to parenting in adolescent girls: Moderation by neural sensitivity to social cues. *Journal of Research on Adolescence*, *30*(Suppl. 1), 177–191. doi:10.1111/jora.12458

Rudolph, K. D., & Hammen, C. (1999). Age and gender as determinants of stress exposure, generation, and reactions in youngsters: A transactional perspective. *Child Development*, *70*, 660–677.

Rudolph, K. D., Hammen, C., Burge, D., Lindberg, N., Herzberg, D., & Daley, S. E. (2000). Toward an interpersonal life-stress model of depression: The developmental context of stress generation. *Development and Psychopathology*, *12*, 215–234.

Schneider, B. H., Atkinson, L., & Tardif, C. (2001). Child-parent attachment and children's peer relations: A quantitative review. *Developmental Psychology*, *37*, 86–100. doi:10.1037/0012-1649.37.1.86

Schriber, R. A., & Guyer, A. E. (2016). Adolescent neurobiological susceptibility to social context. *Developmental Cognitive Neuroscience*, *19*, 1–18. doi:10.1016/j.dcn.2015.12.009

Shrout, P. E., & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: New procedures and recommendations. *Psychological Methods*, *7*, 422–445.

Sobin, C., Weissman, M. M., Goldstein, R. B., & Adams, P. (1993). Diagnostic interviewing for family studies: Comparing telephone and face-to-face methods for the diagnosis of lifetime psychiatric disorders. *Psychiatric Genetics*, *3*, 227–233. doi:10.1097/00041444-199324000-00005

Tan, P. Z., Lee, K. H., Dahl, R. E., Nelson, E. E., Stroud, L. J., Siegle, G. J., . . . Silk, J. S. (2014). Associations between maternal negative affect and adolescent's neural response to peer evaluation. *Developmental Cognitive Neuroscience*, *8*, 28–39.

Tully, E. C., Iacono, W. G., & McGue, M. (2008). An adoption study of parental depression and environmental liability for adolescent depression and childhood disruptive disorders. *American Journal of Psychiatry*, *165*, 1148–1154.

Weinberg, M. K., & Tronick, E. Z. (1998). Emotional characteristics of infants associated with maternal depression and anxiety. *Pediatrics*, *102*(Suppl, E1), 1298–1304. Retrieved from http://pediatrics.aappublications.org/content/pediatrics/102/Supplement_E1/1298.abstract

Weissman, M., Wickramaratne, P., Nomura, Y., Warner, V., Pilowsky, D., & Verdeli, H. (2006). Offspring of depressed parents: 20 years later. *American Journal of Psychiatry*, *163*, 1001–1008. doi:10.1176/appi.ajp.163.6.1001

Woodward, L., Fergusson, D. M., & Belsky, J. (2000). Timing of parental separation and attachment to parents in adolescence: Results of a prospective study from birth to age 16. *Journal of Marriage and Family*, *62*, 162–174.