Published in final edited form as:

Child Maltreat. 2019 November ; 24(4): 424–434. doi:10.1177/1077559519847770.

Childhood Maltreatment Disrupts Brain-Mediated Pathways Between Adolescent Maternal Relationship Quality and Positive Adult Outcomes

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Abstract

The quality of early caregiving may partially shape brain structure and circuits involved in regulating emotions, including the frontal cortex, affecting vulnerability to the development of psychopathology and maladaptation. Given the profound impact of child maltreatment (CM) on psychological and neural development, we tested whether CM alters the pathways linking mother–adolescent relationship, frontal cortex, and adult outcomes. We used structural equation modeling to investigate whether CM history affected the association between mother–child relationship quality during early adolescence, frontal lobe volume in adulthood, and adult internalizing and externalizing symptomatology and competence. Participants from a longitudinal high-risk, low-income sample included 48 adults with a history of CM and 40 adults without such history ($M = 30.0$ years). Results showed that greater frontal lobe volume predicted higher levels of adult adaptive functioning and fewer adult internalizing symptoms but showed no relation to adult externalizing symptoms. Frontal lobe volume significantly mediated the effect of adolescent maternal relationship quality on both adult internalizing symptoms and adult adaptive functioning, but only for individuals with no maltreatment history. Given the observed relationship between frontal lobe volume and healthy adult functioning across the full sample, it will be important to identify protective factors in maltreated individuals that foster frontal lobe development.

Keywords

childhood maltreatment; parent–child relationships; psychopathology; structural equation modeling

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Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Supplemental Material

Supplemental material for this article is available online.

Exposure to severe stress in childhood is widespread (prevalence 30–53%; Andersen, 2015; Stoltenborgh, Bakermans-Kranenburg, Alink, & van IJzendoorn, 2015), poses significant risks for biological and psychological maladaptation, and accounts for over one third of all mood and anxiety disorders in the United States (Cicchetti & Toth, 2005; Green et al., 2010; McLaughlin et al., 2012). Childhood maltreatment (CM), one of the most adverse and stressful challenges that confronts children, is linked to increased rates of depression, anxiety, substance abuse, eating disorders, suicidal symptomatology, and psychosis (Bendall, Jackson, Hulbert, & McGorry, 2007; Norman, Byambaa, De, Butchart, Scott, & Vos, 2012). Identifying how CM disrupts typical developmental pathways to adult mental health and competence is critical in order to develop targets for preventive interventions.

One proximal effect of CM that has received extensive study, and may be involved in the pathway from CM to psychopathology, is insecure caregiver attachment relationships. Child abuse and neglect reflect a deficiency in the kind of sensitive and available caregiving necessary for the development of a secure attachment relationship. Consistent with theory and research, maltreated infants and children are less likely to be securely attached to caregivers, and more likely to have disorganized attachment, than nonmaltreated children (Baer & Martinez, 2006; Carlson, Cicchetti, Barnett, & Braunwald, 1989; Pickreign Stronach et al., 2011). Abuse history is also associated with higher levels of attachment-related emotionality, negativity, and psychological confusion during adolescence (Roisman et al., 2017). Individuals with a history of CM also show reduced attachment security in adult relationships (Weinfield, Sroufe, & Egeland, 2000).

A sizable literature links early attachment and the development of psychopathology (see Fearon, Groh, Bakermans-Kranenburg, van IJzendoorn, & Roisman, 2016, for review). Attachment theorists argue that early interactions with one's caregivers, one's own behaviors, and the sensitivity of feedback one received from those interactions are major determinants in individual differences in attachment security or in how one mentally represents relationships (Bowlby, 1983; Sroufe, 1985). Strong empirical support for the association between parent–child relationship quality and the development of psychopathology comes from large studies and meta-analytic reviews. One large, longitudinal study ($N = 924$) examining attachment in adolescence and early adulthood psychopathology and adjustment demonstrated that lower parent–child relationship quality predicted poorer adult psychosocial functioning (Raudino, Fergusson, & Horwood, 2013). Furthermore, meta-analyses of insecure attachment during infancy or early childhood and later internalizing and externalizing behavior have indicated significant, positive relationships (Fearon, Bakermans-Kranenburg, van IJzendoorn, Lapsley, & Roisman, 2010; Madigan, Atkinson, Laurin, & Benoit, 2013). Additionally, a prospective study with matched groups ($N = 650$) revealed a similar relationship between psychopathology and adult attachment styles in individuals with past CM. Higher levels of anxious and avoidant adult attachment styles were observed in the CM group and partially explained the relationship between CM and adult internalizing symptomatology (Widom, Czaja, Kozakowski, & Chauhan, 2018). Together, these findings highlight the role of the attachment relationship in the development of psychopathology.

An association between attachment relationships during childhood and success on a series of age-salient issues (e.g., regulating arousal, functioning more autonomously, establishing peer and romantic relations) has also been demonstrated (for review, see Schneider, Atkinson, & Tardif, 2001). Early research established that secure attachment in infancy is related to greater personal and interpersonal competence in toddlerhood and early childhood (Sroufe, 1979; Waters, Wippman, & Sroufe, 1979). The effect of infant attachment security on social competence across childhood has been replicated in a meta-analytic review that included over 4,000 families (Groh et al., 2014). Less research has focused on outcomes in adulthood; however, a positive relationship has been observed between secure and coherent attachment in adolescence and better coping and higher capacity for mature intimacy in early adulthood (Scharf, Mayseless, & Kivenson-Baron, 2004).

Research has implicated children's developing emotion regulation abilities as a potential mediator of the relationship between early parent-child relationships and later maladjustment. For instance, multiple longitudinal studies have found that children's effortful control of emotion mediates the relationship between parenting behaviors and externalizing problems (Choe, Olson, & Sameroff, 2013; Eisenberg et al., 2005). Children's constructive coping has also been identified as a mediator of the relationship between maternal attachment and peer competence (Contreras, Kerns, Weimer, Gentzler, & Tomich, 2000). Additionally, a recent meta-analysis including 80,850 child and adolescent participants found small-to-medium effect sizes linking adaptive coping and emotion regulation to fewer symptoms of psychopathology (Compas et al., 2017). Furthermore, the positive association between disorganized mother-child attachment pattern at 10–12 years and concurrent anxiety symptoms is partially mediated by maladaptive emotion regulation processes (Brumariu, Kerns, & Seibert, 2012). Similar patterns have been observed in maltreated children who tend to have impaired inhibitory control compared to nonmaltreated counterparts (Cowell, Cicchetti, Rogosch, & Toth, 2015). Lower levels of emotion regulation appear to mediate the relationship between CM and psychopathology symptoms in both children (Alink, Cicchetti, Kim, & Rogosch, 2009; Kim & Cicchetti, 2010) and adults (Jennissen, Holl, Mai, Wolff, & Barnow, 2016).

Research focused on the neurobiological consequences of early life stress, and CM in particular, has revealed abnormalities in structures and circuits involved in regulating emotions, including the limbic system and frontal cortex (Teicher et al., 2003). The subcortical limbic system is involved in automatic sensitivity and reactivity to emotionally salient information, whereas prefrontal regions are implicated in regulating signals from lower structures (Phillips, Drevets, Rauch, & Lane, 2003). The modulation of the amygdala by these higher regions affects physiological responses throughout the body, as limbic regions send signals to the nervous and endocrine systems (Bush, Luu, & Posner, 2000). Frontal lobe structure is particularly sensitive to early adversity (Hart & Rubia, 2012; Hodel et al., 2015; Lim, Radua, & Rubia, 2014). Development of frontal regions is protracted compared to lower level structures (Gogtay et al., 2004), and extends into late adolescence to early adulthood, rendering children less able to use neocortical-related mechanisms to regulate behavior and emotions compared to adults (Steinberg, 2005). As such, early in development, emotion, and behavior are often regulated by strategies employed by caregivers, such as soothing/comforting, distraction, and assistance with problem-solving

and cognitive restructuring (Thompson, 2014). Parents' sensitive and effective use of these strategies seems to be linked to the development of successful internal regulation in children. A small body of research suggests that early caregiving quality relates to total brain volume (Kok et al., 2015; Sethna et al., 2017) and may partially shape the physiological systems involved in regulation, including limbic–prefrontal neural circuitry (Thijssen et al., 2017).

While the relationship between the quality of early caregiving and frontal lobe volume has not yet been established, we predict that poor relationship quality during adolescence may relate to reduced volume of the developing frontal lobe. Frontal lobe volume correlates with skills critical to effective self-regulation, such as executive functioning (Yuan & Raz, 2014) and delaying gratification (Bjork, Momenan, & Hommer, 2009). Therefore, it may follow that frontal lobe volume serves as an index of self-regulatory skills that have been found to mediate the association between poor parent–child relationships and adult psychopathology and low competence. Further, given the aforementioned findings of frontal lobe sensitivity to early adversity, we expect that this association may be reduced in those with history of CM.

Structural equation modeling has indicated that maltreatment history alters two broad vulnerability factors, internalizing and externalizing, that underlie multiple forms of psychiatric and behavioral disturbance (Vachon, Krueger, Rogosch, & Cicchetti, 2015). Therefore, in the present study, we used structural equation modeling to assess whether maltreatment history affects the impact of maternal relationship quality on the physical development of the frontal lobe and in turn adult functioning (including internalizing and externalizing symptomatology and adaptive competence). In light of the frontal lobe's involvement in self-regulation (an ability shown to mediate the link between parenting quality and psychopathology), we predicted that greater frontal lobe volume would mediate the relationship between better parent–child relationship quality in adolescence and more positive adult functional outcomes.

Methods and Materials

Participants

Participants included 88 adults ($M = 30.0$ years; 42 males and 46 females) who were part of a longitudinal sample, first recruited through a research summer camp for low-income, high-risk children when they were 6–12 years, and subsequently assessed during adolescence (between 13 and 15 years) prior to the current adult assessment. All participants provided informed consent in compliance with the University of Rochester's Institutional Review Board and were compensated for their time. At the initial recruitment, 93% of parents reported a history of receiving public assistance. Demographic information for the sample is provided in Table 1.

Data collected from an additional 28 individuals were excluded from the final sample due to serious mental illness identified by the history of hospitalization (2 CM), structural brain anomalies (3 CM, 3 comparison), excessive head motion (3 CM, 3 comparison), metal in the body (1 comparison), claustrophobia (2 CM), too large to scan (6 CM, 3 comparison), or unknown number of types of CM (2 CM). An additional 57 longitudinal participants were

contacted and screened but were not enrolled due to incarceration, death, scheduling conflicts, MRI contraindications, or refusal to participate in the adult time point.

Measure of Maltreatment History

Forty-eight participants had a history of CM (22 males and 26 females) as documented by Department of Human Services (DHS) records and another 40 participants were classified as non-CM (20 males and 20 females) based on a lack of DHS records through age 17 years. Comprehensive DHS records were coded using the Maltreatment Classification system (Barnett, Manly, & Cicchetti, 1993) to classify the type of each report of substantiated maltreatment. In addition to DHS records, the Maternal Maltreatment Classification Interview (Cicchetti, Toth, & Manly, 2003), a parent-report measure, was used to confirm CM and rule out unreported or unsubstantiated instances of maltreatment in the non-CM group. The majority (73%) of those with prior CM experienced more than one type of maltreatment during childhood. Coded maltreatment subtypes include neglect, emotional maltreatment, physical abuse, and sexual abuse. Thus, scores on our childhood maltreatment measure are continuous, range from 0 to 4, and index the variety of maltreatment experiences an individual has experienced. This method of coding maltreatment has significant precedence in the literature and has proven to be an important conceptualization (e.g., Cicchetti, Rogosch, Sturge-Apple, & Toth, 2009; Handley, Rogosch, Guild, & Cicchetti, 2015; Kim & Cicchetti, 2010).

Measure of Maternal Relationship Quality

The majority of adolescents in this sample lived in female-headed, single-parent households and among those with a history of CM, almost all mothers were implicated in the perpetration of maltreatment (90%). Therefore, maternal relationships were examined in this study. Maternal relationship quality during adolescence (13–15 years) was assessed using the Inventory of Parent and Peer Attachment (IPPA; Armsden & Greenberg, 1987). The IPPA evaluates adolescents' perceptions of their relationship with their primary female caregiver using 25 items within the domains of trust, communication, and anger/alienation on a Likert-type scale from 1 = *almost never or never true* to 5 = *almost always or always true*. Maternal relationship quality was assessed using a composite of these three domains, with higher scores reflecting higher maternal relationship quality. This variable was mean centered.

Measures of Internalizing and Externalizing Psychopathology

Respondents' perceptions of their internalizing and externalizing problems were assessed using the Youth Self-Report Form of the Child Behavior Checklist (Achenbach, 1991) at the adolescent assessment point (13–15 years) and the Adult Self-Report (ASR; Achenbach & Rescorla, 2003) in adulthood (23–37 years). These measures produce two broadband scales (measuring internalizing and externalizing behavior problems). Age- and sex-adjusted *t*-scores for each scale were used to enable statistical comparison across time points.

Measure of Adult Adaptive Functioning

Adult adaptive functioning, or competence, was assessed by examining each participant's competence or success on several stage-salient developmental tasks. A developmental task is a task typical to a certain period of life for which successful achievement leads to approval by society and competence or future successes, at least over the next 10-year period (Havighurst, 1956; Schulenberg, Bryant, & O'Malley, 2004). We used a composite (range 0–14) of rank scores based on participants' progress in seven domains of development: education, work, financial autonomy, romantic involvement, peer involvement, family involvement, and substance abuse. Information from each domain was drawn from the ASR and a demographics questionnaire. Adaptive functioning was defined in relation to others from similar economic and social backgrounds, as participants were ranked in one of three categories for each domain based on their success on the developmental task relative to other study participants. For each domain, rankings were based on cutoffs that approximately divided the participants into thirds (lowest, middle, and highest; see details in the Supplemental Material). This approach was based on work by Schulenberg, Bryant, and O'Malley (2004) and has been previously published by our group (Demers et al., 2018). While this approach limits external validity, it increases our ability to observe individual variation within our study population.

MRI Acquisition and Processing

Structural and functional MRI data were acquired on a Siemens 3-Tesla Trio scanner using a 32-channel head coil. High-resolution, T1-weighted images were acquired for each participant using an MPRAGE sequence (echo time = 3.44 ms, repetition time = 2,530 ms, field of view = 256 mm, slice matrix = 256×256 , thickness = 1 mm, flip angle = 7° , 192 sagittal slices). Cortical reconstruction and volumetric segmentation were performed with the FreeSurfer image analysis suite, version 5.1.0, which is documented and freely available for download online (<http://surfer.nmr.mgh.harvard.edu/>). All image outputs were visually inspected prior to and following segmentation and were rejected for either excess participant motion or high rates of brain segmentation errors. Frontal lobe volume was calculated by summing the volumes of the following Desikan-Killiany regions: superior frontal, rostral, and caudal middle frontal; pars opercularis; pars triangularis; pars orbitalis; lateral and medial orbitofrontal; precentral; and paracentral (Desikan et al., 2006). Estimated individual intracranial volume was used as a covariate. Gray matter volume of each frontal lobe was combined across the left and right hemispheres. We used square root transformed values for bilateral frontal lobe volume and total intracranial volume variables to facilitate the estimation in Mplus.

Data analytic plan.—Longitudinal structural equation modeling was conducted using Mplus Version 8 (Muthén & Muthén, 1998–2017) to test for moderated mediation. Two separate models were tested: an adult symptomatology model and an adult adaptive functioning model. Specifically, we tested whether bilateral frontal lobe volume mediated the relation between adolescent maternal relationship quality and adult outcomes differently for individuals with varying numbers of maltreatment subtypes (continuous variable ranging from 0 to 4).

The adult symptomatology model was specified such that adolescent maternal relationship quality, number of maltreatment subtypes, and the cross-product interaction term (Relationship $\times$ Maltreatment) were entered as exogenous variables, all specified to predict bilateral frontal lobe volume in adulthood. Total intracranial volume was entered as a covariate predicting bilateral frontal volume. Given sex differences in total intracranial volume, sex was modeled as a predictor of total intracranial volume. Adult internalizing and externalizing symptoms were modeled as outcomes to be predicted by bilateral frontal lobe volume and total intracranial volume, as well as maternal relationship quality and maltreatment. Adolescent internalizing and externalizing symptoms were included as covariates predicting the respective adult symptom domain. The residual covariance between adult internalizing and externalizing symptoms was also modeled. The adult adaptive functioning model was estimated similarly using maternal relationship quality, maltreatment experience, and frontal brain volume to predict adult adaptive functioning. Total intracranial volume and sex were entered as covariates as in the previous model. Internalizing and externalizing measures were not modeled in either adolescence or adulthood. However, adult age was modeled as a predictor of adult adaptive functioning, as competence was expected to vary by chronological age.

Missing data for endogenous variables were handled using full information maximum likelihood. Model fit was evaluated using the comparative fit index (CFI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). CFI values greater than 0.95, RMSEA values less than 0.06, SRMR values less than 0.06, and a nonsignificant χ^2 statistic were considered evidence of good model fit (Hu & Bentler, 1999; Yu, 2002). Significance of the indirect effects was determined using 95% asymmetric confidence intervals from RMediation (Tofighi & MacKinnon, 2011). Confidence intervals that do not include the value 0 indicate significant mediation.

Results

Adult Symptomatology Model

Internalizing and externalizing symptoms did not differ by group. A path model was estimated to examine whether bilateral frontal lobe volume mediated the relation between adolescent maternal relationship quality and adult symptomatology and to determine whether this mediated effect varied by maltreatment experience. Overall, the model evidenced good fit to the data, $\chi^2(14) = 7.03$, $p = .93$, CFI = 1.00, RMSEA = .00, SRMR = .04 (see Figure 1 for a graphical representation of the results). Greater bilateral frontal lobe volume was predicted by higher levels of maternal relationship quality, $b = .22$ ($SE = .08$), $p = .01$; fewer maltreatment subtypes, $b = -.13$ ($SE = .06$), $p = .04$; and the interaction of relationship quality and maltreatment, $b = -.18$ ($SE = .09$), $p = .03$. Greater bilateral frontal lobe volume was also predicted by total intracranial volume, $b = .81$ ($SE = .04$), $p < .001$. Males had significantly greater total intracranial volume, $b = -.68$ ($SE = .06$), $p < .001$. Regarding adult internalizing symptoms, greater bilateral frontal lobe volume predicted fewer adult internalizing symptoms, $b = -.40$ ($SE = .15$), $p = .01$, did smaller intracranial volume, $b = .45$ ($SE = .15$), $p = .002$, and higher maternal relationship quality, $b = -.22$ ($SE = .09$), $p = .02$. Maltreatment did not have a significant unique effect on adult internalizing

symptoms. Finally, greater bilateral frontal lobe volume did not significantly predict adult externalizing symptoms. However, less total intracranial volume, $b = .42$ ($SE = .15$), $p = .01$, and higher maternal relationship quality, $b = .20$ ($SE = .10$), $p = .047$, both predicted fewer adult externalizing symptoms. Maltreatment was not a significant unique predictor of adult externalizing symptoms. Finally, there was evidence of longitudinal stability in internalizing symptoms, $b = .31$ ($SE = .08$), $p < .001$, and externalizing symptoms, $b = .24$ ($SE = .09$), $p = .01$, from adolescence to adulthood.

The significant interaction of maternal relationship quality and number of maltreatment subtypes in the prediction of bilateral frontal lobe volume was probed at various levels of number of CM subtypes following the guidelines of Cohen, Cohen, West, and Aiken (2003). Results indicated that for nonmaltreated individuals, higher maternal relationship quality predicted greater bilateral frontal lobe volume, $b = .22$ ($SE = .08$), $p = .01$. For individuals who experienced one subtype of CM only, higher maternal relationship quality was marginally related to greater bilateral frontal lobe volume, $b = .11$ ($SE = .06$), $p = .07$. For individuals who experienced two or three subtypes of CM, maternal relationship quality was unrelated to bilateral frontal lobe volume, $b_{2 \text{ subtypes}} = .01$ ($SE = .07$), $p = \text{n.s.}$; $b_{3 \text{ subtypes}} = -.10$ ($SE = .11$), $p = \text{n.s.}$ Thus, results indicate that maternal relationship quality is associated with greater bilateral frontal lobe volume for nonmaltreated individuals, marginally associated for individuals who experienced one subtype of CM and not associated for those who experienced more than one subtype of CM. Moderated mediational analyses indicated that greater bilateral frontal lobe volume significantly mediated the effect of maternal relationship quality on adult internalizing symptoms only for nonmaltreated individuals (LCL = -2.991 , UCL = $-.152$).

Adult Adaptive Functioning Model

A second path model was estimated to examine whether bilateral frontal lobe volume mediated the relation between adolescent maternal relationship quality and adult adaptive functioning and to determine whether this mediated effect varied by maltreatment experience. Overall, the model evidenced good fit to the data, $\chi^2(8) = 8.77$, $p = .36$, CFI = 1.00, RMSEA = .03, SRMR = .04 (see Figure 2 for a graphical representation of the results). Consistent with Model 1, males evidenced greater total intracranial volume, $b = -.68$ ($SE = .06$), $p < .001$, and greater frontal lobe volume was predicted by greater total intracranial volume, $b = .81$ ($SE = .04$), $p < .001$; greater maternal relationship quality, $b = .22$ ($SE = .08$), $p = .01$; and fewer maltreatment subtypes, $b = -.13$ ($SE = .06$), $p = .04$. The interaction of maternal relationship quality and maltreatment subtypes was also a significant predictor of frontal lobe volume, $b = -.18$ ($SE = .09$), $p = .03$. Higher levels of adult adaptive functioning were predicted by greater frontal lobe volume, $b = .55$ ($SE = .15$), $p < .001$; greater total intracranial volume, $b = -.56$ ($SE = .15$), $p < .001$; and older age, $b = .23$ ($SE = .09$), $p = .01$. Maternal relationship quality and maltreatment were not significant unique predictors of adult adaptive functioning. Consistent with Model 1, there was evidence of moderated mediation such that greater frontal lobe volume mediated the effect of maternal relationship quality on adult adaptive functioning only for nonmaltreated individuals (LCL = .086, UCL = .953).

Discussion

Prospective path analyses were estimated to determine the role of bilateral frontal lobe volume in the associations between childhood maltreatment, adolescent maternal relationship quality, and adult outcomes, including (1) internalizing symptoms and externalizing symptoms and (2) adult adaptive functioning. Greater bilateral frontal lobe volume was predicted by the interaction of relationship quality and number of CM subtypes, such that higher maternal relationship quality was associated with greater bilateral frontal lobe volume for nonmaltreated individuals, marginally associated for individuals who experienced one subtype of CM and not associated for those who experienced more than one subtype of CM. Furthermore, greater bilateral frontal lobe volume predicted higher levels of adult adaptive functioning, and fewer adult internalizing symptoms, but not adult externalizing symptoms. Finally, as expected, results revealed that greater bilateral frontal lobe volume significantly mediated the effect of maternal relationship quality on adult internalizing symptoms, and also on adult adaptive functioning, but only for nonmaltreated individuals. While results are preliminary, to our knowledge, this is the first evidence of the developmental pathway from maternal relationship quality in adolescence to adult adaptive functioning and internalizing symptoms via frontal lobe volume. Moreover, it is noteworthy that results suggest that this developmental pathway depends on CM history.

While these findings are novel, they are consistent with the extant literature on the functions of the frontal cortex, highlighting its role in both automatic and effortful emotion regulation, which typically develop in part through interactions with a caregiver (Coan, 2008). A small body of research on quality of parental care in humans has demonstrated the importance of early familial relationships on brain development and self-regulation. Insensitive parenting in early childhood has been linked to smaller total brain and gray matter volumes at age 8 (Kok et al., 2015). Less sensitive parenting may also lead to accelerated development in terms of pubertal timing and tempo (Ellis, Shirtcliff, Boyce, Deardorff, & Essex, 2011) and development of amygdala–medial prefrontal cortex (mPFC) circuitry (Thijssen et al., 2017). This accelerated development could have costs, including reduced learning opportunities during development that could serve the individual in adulthood. Given the importance of both the adolescent period and the role of amygdala–mPFC circuitry in self-regulation, the possible costs of insensitive parenting could contribute to the development of internalizing symptoms in adulthood. Further support for this argument comes from a study that found that insecure compared to secure attachment status at 18 months of age predicts relative inefficiency in the neural regulation of positive affect 20 years later (Moutsiana et al., 2014). Specifically, individuals classified as insecure had greater activation in prefrontal regions involved in cognitive control while attempting to upregulate positive emotions (Moutsiana et al., 2014). There is coherence between this previous literature and our findings of a relationship between maternal relationship quality in adolescence and greater adult frontal lobe volume, which affects both adaptive functioning and less internalizing symptomatology in adulthood. However, at this point, it is unclear why adult frontal lobe volume predicts internalizing and not externalizing symptoms in adulthood.

Importantly, our results are indicative of a different (non-significant) relationship between adult frontal lobe volume and earlier maternal relationship quality in those with a history of

CM. Our results suggest that the experience of maltreatment may disrupt this normative developmental process by which maternal relationship quality impacts frontal lobe volume. There has been extensive preclinical research examining the neurobiological effects of early maternal separation, loss, abuse or neglect, and social deprivation in animal models (for review, see Sanchez, Ladd, & Plosky, 2001). Overall, this work suggests that early trauma is related to long-term alterations in emotional and behavioral regulation, coping style, social competence, cognitive function, neurotransmitter systems and neuroendocrine responsiveness to stress, brain structure and function, as well as gene expression levels ostensibly related to anxiety and mood disorders. It has been hypothesized that disruption to the regulatory functions associated with the mother–infant relationship may affect brain plasticity (Cirulli, Berry, & Alleva, 2003). Further, the most common finding to arise from whole brain analyses has been decreased prefrontal cortex volume in relation to childhood trauma (for review, see Hart & Rubia, 2012). Our results were consistent with the literature, showing a main effect of a number of CM subtypes on frontal lobe volume. Perhaps the effect of CM is enough that the effect of maternal relationship quality on adult frontal lobe volume is negligible. A similarly overpowering effect of CM was found by Cicchetti and Rogosch (2012), who observed that genetic variations influenced resilient functioning only in children with CM histories.

More research is needed to clarify the impact of CM on the pathway from maternal relationship quality in adolescence to adult frontal lobe volume, particularly because this study included frontal lobe volume at only one time point. We are not able to determine whether this relationship is only apparent in the adult brain, if it existed during adolescence, or even if stable variations in frontal lobe volume predated adolescence. Our findings also raise additional questions about the development of self-regulatory functions and supporting neural structures in individuals with CM. Despite the main effect of CM on frontal lobe volume in our sample, there were not group differences. It is possible that the maltreated individuals may have benefited from unmeasured resilience factors. Potential resilience factors include a positive relationship with another adult, learning or problem-solving skills, social engagement, self-confidence, or positive self-efficacy (Masten, Best, & Garnezy, 1990).

Despite important contributions to the maltreatment literature, this study has several limitations. While participants were followed longitudinally and prospectively from childhood, MRI assessment was conducted only at the most recent time point in adulthood. Therefore, we cannot determine whether frontal lobe volume is a cause or an effect of the maltreatment, adolescent maternal relationship quality, psychopathology symptoms, and adaptive functioning. In addition, it is likely that risk and protective factors across the life span contributed to which participants continued in this study. For instance, some participants had employment conflicts prohibiting research participation, while others were unable to participate owing to incarceration or health-related MRI contraindications (e.g., obesity or metal in the body). Also, our matched comparison group that drew participants from the same schools and neighborhoods appropriately controls for stressors often associated with CM (e.g., poverty, low parental education, poor school quality, neighborhood violence) but precludes our ability to generalize our findings to individuals from low-risk backgrounds. Additionally, while this sample, to our knowledge, is the only

sample matched on SES that can test this relationship in a prospective manner, replication with larger samples is warranted. Our sample size is on the low end of what is recommended for moderated mediation models (Kline, 2015), and therefore these results should be considered preliminary evidence suggestive of an altered relationship between adult frontal lobe volume and earlier maternal relationship quality in those with a history of CM. Finally, it should be noted that we did not directly measure regulatory control and relied on self-report of maternal relationship quality and symptomology. Future work should assess a more proximal measure of regulatory control (e.g., a behavioral measure, frontoparietal control network functional connectivity). Inclusion of interview-based measures and/or multiple informants would provide important cross-validation of the role of attachment in the development of the frontal lobe.

In conclusion, we found that CM moderated the association between adolescent–maternal relationship quality, adult frontal lobe volume, and both adult internalizing symptoms and adult adaptive functioning. These findings suggest that, in low-SES, nonmaltreated individuals, the size of the frontal lobe of the brain (which is associated with both level of adult adaptive functioning and adult internalizing symptoms but not with adult externalizing symptoms) seems to be predicted by earlier maternal relationship quality. It is plausible that secure attachment relationships may play a critical role training the brain region underlying self-regulatory capacity and that normally more secure attachment results in more well-tuned regulatory systems and more adaptive outcomes. However, our results suggest that this pathway may be altered in individuals with maltreatment histories. CM is associated with higher rates of insecure attachment, possibly precluding the tuning of frontal regulatory systems in the typical manner. Instead, it is possible that other methods for tuning the brain's regulatory system may become more influential in predicting individual adaptive functioning in maltreated individuals. These results highlight the capacity for resilience despite CM. In light of the strong link between self-regulation and frontal volume, findings support the use of intervention programs that promote positive adaptation, perhaps via positive relationships outside of the caregiving environment that promote learning or problem-solving skills, social engagement, self-confidence, self-soothing, or positive self-efficacy.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

We thank the staff at the Mt. Hope Family Center, University of Rochester, and the Institute of Child Development at the University of Minnesota. We thank the Minnesota Supercomputing Institute at the University of Minnesota for providing resources that contributed to the research results reported within this article (<http://www.msi.umn.edu>). We also thank Emily Hunt and Pat Weber for their work in data collection and the families and longitudinal participants of the Mount Hope Family Center for their participation.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by a McKnight Presidential Chair, William Harris Endowed Chair, and a Klaus J. Jacobs Research Prize (to DC), imaging support from the Rochester Center for Brain Imaging, and a pilot grant from the College of Arts, Science and Engineering, University of Rochester. Trainee support was provided by

the University of Minnesota's Institute of Child Development via a National Institute of Mental Health National Research Service Award Grant no. 2T32MH015755–39 (to LAD).

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Figure 1.

Adult symptomatology model. Standardized β s are presented. Nonsignificant paths are represented by dashed lines. The paths involved in the significant indirect effect are bolded.

Sex is coded 0 = male, 1 = female. * $p < .05$. ** $p < .01$. *** $p < .001$.

Figure 2.

Adult adaptive functioning model. Standardized β s are presented. Nonsignificant paths are represented by dashed lines. The paths involved in the significant indirect effect are bolded. Sex is coded 0 = *male*, 1 = *female*. $*p < .05$. $**p < .01$. $***p < .001$.

Table 1.

Demographics and Sample Characteristics for the Maltreated and Comparison Groups.

Sample Characteristics	Maltreated Group (N = 48)	Comparison Group (N = 40)	p Value
Age (years), <i>M</i> (<i>SD</i>)	30.71 (3.07)	29.10 (3.53)	.03
Male/Female, <i>n</i>	22 Males, 26 females	20 males, 20 females	.70
Race, <i>n</i> (%)			.80
Black	30 (62.5%)	30 (75.0%)	
White	13 (28.9%)	4 (10.0%)	
Other/multiracial	5 (10.4%)	6 (15.0%)	
Total annual family income, <i>M</i> (<i>SD</i>)	USD\$29,98k (\$19,04k)	USD\$31,49k (\$22,60k)	.57
Range	USD\$2,30k-\$99,90k	USD\$5,20k-\$99,90k	
Marital status, <i>n</i> (%)			.51
Not married	40 (83.3)	35 (87.5)	
Married	8 (16.7)	5 (12.5)	
Current work status, <i>n</i> (%)			.52
Working full time	21 (43.6)	19 (47.5)	
Working part time	9 (18.8)	8 (20.0)	
Not working	18 (37.6)	13 (32.5)	
Education, <i>n</i> (%)			.31
Some high school	9 (18.8)	4 (10.0)	
High school diploma or GED	20 (41.7)	15 (37.5)	
Tech degree, associate's degree, or some college	15 (31.3)	20 (50)	
Bachelor's or master's degree	4 (8.3)	1 (2.5)	
Number of CM subtypes, <i>M</i> (<i>SD</i>)	Range 1–4, 2.17 (0.91)	0	
Adolescent self-report maternal relationship quality, <i>M</i> (<i>SD</i>)	3.91 (4.96)	3.90 (5.00)	.94
YSR internalizing <i>t</i> -score, <i>M</i> (<i>SD</i>)	50.31 (11.64)	44.88 (11.09)	.56
YSR externalizing <i>t</i> -score, <i>M</i> (<i>SD</i>)	52.63 (11.98)	49.45 (10.73)	.20
ASR internalizing <i>t</i> -score, <i>M</i> (<i>SD</i>)	51.63 (10.08)	51.90 (12.56)	.91
ASR externalizing <i>t</i> -score, <i>M</i> (<i>SD</i>)	52.67 (9.05)	51.38 (10.63)	.54
Adult adaptive functioning, <i>M</i> (<i>SD</i>)	6.60 (2.77)	7.58 (2.61)	.10
Frontal lobe volume, <i>M</i> (<i>SD</i>)	163,336 mm ³ (15,943 mm ³)	166,508 mm ³ (16,573 mm ³)	.37

Sample Characteristics	Maltreated Group (N = 48)	Comparison Group (N = 40)	p Value
Total intracranial volume, <i>M</i> (<i>SD</i>)	1,478,176 mm ³ (151,772 mm ³)	1,480,254 mm ³ (151,102 mm ³)	.95

Note. Statistical effects were tested by ANOVA or two-tailed t test as appropriate for the number of levels. For full results, see Supplementary Material. ASR = Adult Self-Report; YSR = Youth Self-Report; *SD* = standard deviation; CM = childhood maltreatment; GED = General Education Development test.