

Archival Report

Separable Effects of Childhood Maltreatment and Adult Adaptive Functioning on Amygdala Connectivity During Emotion Processing

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ABSTRACT

BACKGROUND: Individuals with a history of maltreatment show altered amygdala reactivity to emotional stimuli, atypical frontal regulatory control, and differences in frontolimbic connectivity compared with nonmaltreated controls. However, despite early trauma, many individuals who experience maltreatment show resilience or adaptive functioning in adulthood including positive social, educational, and occupational outcomes.

METHODS: The present study used a psychophysiological interaction model to examine the effect of adult adaptive functioning on group differences between maltreated and nonmaltreated adults in task-based amygdala functional connectivity. The task used was a facial emotion-matching paradigm. Functional magnetic resonance imaging scans were collected from 41 adults with a history of substantiated childhood maltreatment and 39 nonmaltreated adults who were well matched on demographic variables, all of whom had been studied since childhood. Adaptive functioning was measured with a composite score of success on stage-salient developmental tasks.

RESULTS: Consistent with previous research, we found differences in task-related amygdala functional connectivity between the maltreated and nonmaltreated groups. Effects were seen in the left hippocampus, right dorsolateral prefrontal cortex, dorsomedial prefrontal cortex, and right thalamus. However, when adult functioning was included in the model, maltreatment-related differences in amygdala connectivity were observed only in the hippocampus. Adult adaptive functioning independently predicted task-related amygdala connectivity in frontal and parietal regions across the entire sample.

CONCLUSIONS: These results suggest that frontolimbic functional connectivity is predicted by positive developmental adaptation in this high-risk population, regardless of maltreatment history, whereas intralimbic connectivity (amygdala and hippocampus) is more specifically associated with maltreatment history.

Keywords: Adaptive functioning, Amygdala, Childhood adversity, Frontolimbic connectivity, Maltreatment, Neuroimaging

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Childhood maltreatment (CM) poses significant risks of biological and psychological maladaptation and increases the likelihood of psychopathology across the lifespan (1). Emotional reactivity and emotion processing are often affected in individuals with a history of CM (2). For instance, deficits in emotion recognition, response biases to angry facial expressions, and delayed disengagement from such stimuli have been noted in this population during childhood and adulthood (3–10). This persistent vigilance for negative facial expressions may help maltreated individuals detect and thereby avoid angry confrontations with their abusive caregivers; however, such hypersensitivity has been linked to maladaptive behavior outside of the context of CM, when there is no longer an imminent threat of abuse (11).

Extensive evidence has established a heightened response of the amygdala to threat-related cues in individuals with post-traumatic stress disorder and in adults with histories of

childhood emotional abuse or neglect, independent of psychiatric status (12,13). The prefrontal cortex (PFC), a region known to be involved in cognitive and behavioral control processes, has also been identified as functionally aberrant after early adversity and CM (14,15). Of course, these regions (amygdala and PFC) are known to be structurally and functionally connected (16). Connectivity within frontolimbic circuits has been related to efficient emotion regulation, fear conditioning, and fear extinction (17,18). The strength of functional connectivity (FC), or the degree to which regions within the emotion processing network coactivate, has recently been shown to be altered in individuals who experienced CM, when measured both at rest (19) and also when performing face emotion-processing tasks (20,21). Such work, including our own (21), has shown that adults with a history of CM show greater emotion-related frontolimbic connectivity compared with those without CM, which may indicate an inefficient regulatory system.

However, studies of maltreated samples generally do not consider individual differences that may affect long-term outcomes after early adversity. Furthermore, group comparisons can mask individual differences in the capacity for resilience or dynamic and positive adaptation in the presence of significant adversity (22). Early work has shown that even in the presence of chronic and severe adversity, most children have the capacity for resilient outcomes in one or more domains (23,24). However, there have been few studies on the neurobiological correlates of resilience. One study assessed effortful modification of emotional responses to negative pictures, and another measured resting-state FC. These two small studies have found that compared with both vulnerable trauma-exposed and non-trauma-exposed individuals, resilient trauma-exposed individuals show differential frontal brain activity (25,26). It remains unknown whether resilience—the process of, capacity for, or outcomes of adaptive functioning despite threat—may moderate differences in task-related frontolimbic FC that have been attributed to CM (27).

To fill this gap in the literature and build upon our previous work on frontolimbic connectivity after CM (21), we evaluated the effects of CM history and adult adaptive functioning on amygdala connectivity in adults performing a face emotion-processing task. Adults with a verified CM history and a matched comparison group were rated on an adaptive functioning scale to approximate resilient processes and completed an emotional faces task known to elicit limbic activation during functional magnetic resonance imaging (fMRI) (28). Psychophysiological interaction (PPI) connectivity analyses were performed to investigate differential amygdala connectivity to emotional and neutral stimuli in those with and without a history of CM. In light of the aforementioned findings of 1) greater frontolimbic FC in CM adults (20,21), and 2) differences in neural processing between resilient trauma-exposed individuals and patients with trauma-related psychopathology (25,26,29), we predicted that both maltreatment status and adult adaptive functioning would correlate with emotion-related amygdala connectivity. Specifically, we expected that individuals at highest risk (previous CM and low adaptive functioning scores) would show increased emotion-related frontolimbic connectivity compared with lower risk individuals (socioeconomic status-matched nonmaltreated or CM with high adaptive functioning scores).

METHODS AND MATERIALS

Participants

Participants included 80 adults who were part of a longitudinal sample, first recruited through a research summer camp for low-income, high-risk children when they were 6 to 12 years of age, and subsequently assessed once or twice during adolescence before the current adult assessment (30). All children were from low-income families, with 93% reporting a history of receiving public assistance. Forty-one participants had a history of CM as documented by Department of Human Services records, and 39 other participants were classified as non-CM via lack of Department of Human Services records through 17 years of age. The Maternal Maltreatment Classification Interview was used to further verify CM history or the lack thereof. Comprehensive Department of Human Services

records were coded using the maltreatment classification system to classify the type and developmental timing of each report of substantiated maltreatment (31). The majority (70%) the CM group experienced more than one type of maltreatment. Depressive or general internalizing symptoms [as measured by the Adult Self Report measure and Beck Depression Inventory-II (32,33)] did not differ by group. Demographic information for the final sample is provided in Table 1. All participants provided informed consent in compliance with the University of Rochester's Institutional Review Board and were compensated for their time. A subset of these data was reported previously by our group (21).

Data collected from an additional 23 individuals were excluded from the final sample owing to 1) task accuracy more than 2 SDs below the overall mean on control trials (<75% correct; 5 CM, 1 comparison); 2) serious mental illness identified by history of hospitalization (2 CM: 1 schizophrenia, 1 bipolar disorder); 3) structural brain anomalies (2 CM, 3 comparison); or 4) excessive head motion (6 CM, 4 comparison). An additional 53 longitudinal participants were contacted and screened but were unable to participate because of incarceration, death, scheduling conflicts, or MRI contraindications or because they declined to participate (Supplement).

Measure of Adult Adaptive Functioning

Contemporary conceptions of resilience align with a developmental psychopathology perspective that focuses on both negative and positive adaptation in response to stress. These adaptations can be measured along dimensions within various domains and at multiple levels of analysis (34,35). Therefore, we measured success on stage-salient developmental tasks to approximate resilient outcomes. A developmental task is a task typical to a certain period of life for which successful achievement leads to competence and later successes, while failure leads to incompetence in the individual, disapproval by society, and difficulty with later tasks (36). Developmental tasks in early adulthood have been shown to predict competence in adults over a 10-year period (36,37).

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. This approach was based on work by Schulenberg *et al.* (37). Information from each domain was drawn from the Adult Self Report measure (32) and a demographics questionnaire. Participants were ranked in one of three categories for each domain based on their success on the developmental task relative to other participants in the study. Therefore, successful development was defined in relation to others from similar economic and social backgrounds. For each domain, rankings were based on cutoffs that approximately divided the participants into thirds (lowest, middle, and highest) (details in the Supplement).

Behavioral fMRI Imaging Paradigm

In the scanner, participants were asked to perform a matching task of trials containing either emotionally expressive faces or simple geometric shapes. On each trial, they were required to

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