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Relationship of Early Life Maltreatment to Self Regulation During an Affective Stroop Task

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RELATIONSHIP OF EARLY LIFE MALTREATMENT TO SELF REGULATION DURING AN AFFECTIVE STROOP TASK

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Background: Previous research has found that childhood maltreatment is associated with emotional regulation difficulties, as well associations with brain structures, such as the amygdala and hippocampus. However, there are individual differences in the effect of maltreatment on emotional regulation, and this relationship may be dependent upon amygdala or hippocampal volume. The present study hypothesized that amygdala or hippocampal volume would moderate the relationship between maltreatment and emotional regulation. **Method:** Forty-nine college students were assessed for their history of parenting and participated in the magnetic resonance imaging (MRI) study. Moreover, to measure emotional regulation skills, participants completed the Affective Stroop task, which assessed reaction time for counting during three emotional distractors: positive, negative, and neutral images. Hierarchical regressions were conducted to test the interaction between childhood maltreatment and amygdala or hippocampal volumes in predicting reaction time during emotional distractors. **Results:** No main or interaction effect was found, but there were trends for reaction time during emotional images to be associated with the interaction between maltreatment and hippocampal volume. **Conclusions:** These findings suggest that early life maltreatment does not directly have an impact on emotional regulation and its effect does not interact with amygdala or hippocampal volume. These negative findings were discussed.

Keywords: amygdala; early life maltreatment; emotion regulation; hippocampus; trauma

For Great Grandma Enid "Breezy" Roberts

"You're off to Great Places!
Today is your day!
Your mountain is waiting,
So... get on your way!"
– Dr. Seuss

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Introduction

Background of Early Life Maltreatment

Trauma can happen to everyone unexpectedly as there is a lifetime prevalence rate of more than 60% (Caparos & Blanchette, 2014). According to the U.S. Department of Health and Human Services Administration for Children and Families Administration on Children, Youth and Families Children's Bureau (2020) in 2018, approximately 678,000 children were victims of maltreatment, which was an increase of 2,000 victims since 2017. Among child victims in the 2018 report, 60.8% were neglected, 10.7% were physically abused, and 7% were sexually abused; 84.5% were victims from a single maltreatment type whereas more than 15% were victims of two or more maltreatment types. Thus, a significant number of children experience a variety of traumatic maltreatments. Self-regulation is an overarching term to represent the ability to monitor, understand, and manage two psychological processes: emotions (also known as emotional regulation) and lower-order cognitive processes (also known as cognitive regulation) (Dvir et al., 2014). Early life trauma impairs self-regulation (Burns et al., 2010; Forbes et al., 2020; Pechtel & Pizzagalli, 2011) and mental well-being (Burns et al., 2010), possibly via structural and functional brain alterations (Blair et al., 2019; Pechtel & Pizzagalli, 2011). This study specifically focused on emotional regulation in early adulthood in relation to early life maltreatment and brain changes.

Maltreatment and Emotional Regulation

Emotional regulation is a process in which individuals are able to understand and manage their own emotions, distress, and emotional responses (Barlow et al., 2017; Caldwell et al., 2014; Dvir et al., 2014; Ehring & Quack, 2010; Teisl & Cicchetti, 2008). It has been argued that early life trauma, including childhood maltreatment, disrupts the development of emotional regulation (Burns et al., 2010; Caldwell et al., 2014; Dvir et al., 2014; Gruhn & Compas, 2020; Kuo et al., 2015; Shipman et al., 2000; Shipman et al., 2004; Shipman et al., 2007), leading to emotional outbursts, a difficulty in tolerating emotional distress, and neurobiological changes involved in emotion processing. For example, Shipman et. al. (2007) found that children aged 6-12 who were physically abused displayed increased emotional dysregulation, measured through the emotion regulation checklist (ERC), compared to children of the same age without physical abuse histories. Similarly, girls between the ages of 6 and 12 who had been sexually abused showed decreased ability in appropriately regulating their emotions; these maltreated girls struggled to display situationally appropriate emotions and had lower levels of empathy and self-awareness, as measured through assessments and interviews (Shipman et al., 2000). Even emotional abuse, which occurs more frequently and chronically relative to other types of maltreatment, also interferes with the development of emotional regulation skills (Burns et al., 2010).

The adverse effects of early life trauma on emotion processing can carry on into adulthood as there has been evidence that childhood trauma can disturb emotional development (Dye, 2018; Moretti & Craig, 2013; Shipman et al., 2004; Szabo et al., 2019). For instance, mothers who reported histories of maltreatment struggled with accurately interpreting children's emotional faces, depending on the type of childhood maltreatment which they experienced; those with history of physical abuse poorly interpreted fearful and sad faces; history of emotional abuse was related to poor interpretation of angry faces; and history of physical neglect was related to less accuracy in detecting angry faces (Turgeon et al., 2020). Gibb et. al. (2009) found that young adults who reported a history of moderate to severe childhood abuse were more likely to allocate their attention to angry faces, but not toward happy or sad faces. Children with histories of abuse have difficulty in disengaging from potentially threatening cues which represent anger and fear (Pechtel & Pizzagalli, 2011). These studies suggest that maltreatment is associated with misinterpreting negative emotional stimuli (Turgeon et al., 2020) and biased attention to negative emotional stimuli (Gibb et. al., 2009; Pechtel & Pizzagalli, 2011), and this might explain why maltreated victims show difficulty in emotional regulation in social interactions. In addition, childhood maltreatment is also a risk factor for later development of affective disorders, such as depression and anxiety disorders (Christ et al., 2019; Moretti & Craig, 2013). Furthermore, individuals who have a history of maltreatment, especially physical and emotional abuse, are more likely to experience post-traumatic stress symptoms later in life (Burns et al., 2010). Therefore, early life maltreatment crucially deteriorates emotional regulation even in adulthood.

Early Life Maltreatment and the Brain

Some brain regions involved in emotion processing are vulnerable to early life stress, and this finding provides evidence that such vulnerabilities may be linked impairments in higher-order functions (i.e., executive functioning) and emotional dysregulation (Pechtel & Pizzagalli, 2011). For example, childhood maltreatment was associated with reduced volumes of the hippocampus, corpus callosum, anterior cingulate cortex, orbitofrontal cortex, and dorsolateral prefrontal cortex in adults (Teicher et al., 2016). Aas et al. (2017) found that some cortical areas, such as the right angular gyrus, supramarginal gyrus, middle temporal gyrus, and the lateral occipital cortex, showed stronger activation in response to negative emotional faces relative to positive emotional faces when participants experienced more childhood traumas. A diffusion tensor imaging (DTI) analysis showed that severity of childhood maltreatment was linearly related to reduced fractional anisotropy in the white matter tract between the nucleus accumbens and frontal area (DeRosse et al., 2020).

However, the majority of previous studies has consistently focused on two brain subregions: amygdala and hippocampus. The amygdala and hippocampus have an important role in emotional and cognitive functioning during development and closely interact with activity of the hypothalamic-pituitary-adrenal (HPA) axis, which primarily responds to stress (Tottenham & Sheridan, 2010). Specifically, stress activates the HPA axis and increases cortisol, which is one type of glucocorticoid. Increased cortisol can act on glucocorticoid receptors which are highly concentrated in the amygdala and hippocampus (Agorastos et al., 2019). Hence, both the amygdala and hippocampus can be influenced by cortisol and stress, especially during sensitive periods of development (Womersley et al., 2020).

The amygdala is part of the limbic system which responds to emotional stimuli and projects them to other brain regions that control attention, memory, and decision making (Han et al., 2014; Wang et al., 2006). Indeed, the amygdala shows increased functional activation in response to fear (Caldwell et al., 2014; Fossati, 2012; Han et al., 2014; Wang et al., 2006), sadness (Wang et al., 2006), and happiness (Cunningham & Kirkland, 2013; Fossati, 2012). Functional and structural alterations of the amygdala may occur following chronic stress (Tottenham & Sheridan, 2010; Wymbs et. al., 2020). Interestingly, there is individual variation in sensitivity of amygdala response to negative stimuli, and amygdala activation to negative stimuli becomes greater when individuals have experienced early life maltreatment (Blair et al., 2019; Marusak et al., 2015; Suzuki et al., 2014; Teicher et al., 2016). Also, maltreatment is associated with lower negative functional connectivity between the amygdala and the perigenual anterior cingulate cortex, leading to deficits in engaging in emotional regulation processes (Marusak et al., 2015).

Increased functional amygdala activity to negative stimuli may reflect a difficulty in emotional regulation. For example, several studies have used images of facial expressions as emotional distractors during the presentation of another emotional word (e.g., “FEAR” appearing with a happy face) and found greater amygdala responses during the presentation of emotional distractors (Kray et al., 2020; Krug & Carter, 2012; Marusak et al., 2015; Minkova et al., 2017; Swartz et al., 2020). When this task was given to trauma-exposed youths, they showed amygdala hyper-reactivity during emotional distractors, meaning there was difficulty in suppressing that emotionally distracting stimuli (Marusak et al., 2015). Taken together, it is possible that early life trauma predisposes individuals to having amygdala hyperreactivity to negative stimuli, which may make it difficult for them to ignore emotional distractors.

Along with functional reactivity, structural changes also occur within the amygdala as a response to maltreatment. Small amygdala volume has been reported in relation to stressful life events (i.e., childhood violence exposure) (Weissman et al., 2020) and in women with histories of maltreatment and PTSD (particularly severe sexual abuse) (Veer et al., 2015). Similarly, Nogovitsyn et. al. (2020) found that participants were more likely to have smaller amygdala volumes when they had higher total trauma scores. However, Woon and Hedges’ (2008) meta-analyses of maltreatment-related PTSD suggested that amygdala volume did not appear to be affected by childhood maltreatment consistently. It seems that human studies regarding childhood maltreatment on functional amygdala responsiveness are conclusive whereas findings about volumetric changes in the amygdala are inconsistent (Agorastos et al., 2019). Furthermore, it is still uncertain whether amygdala volume is related to emotional regulation skills.

Another brain subregion which is influenced by stress is the hippocampus (Womersley et al., 2020). Structural magnetic resonance imaging (MRI) has displayed developmental differences in hippocampal volume in those exposed to trauma, across development, from birth through adulthood, although more hippocampal volumetric changes have been detected later in development compared to during childhood (Tottenham & Sheridan, 2010). That is, exposure to childhood stress is consistently related to reduced hippocampal volume in adulthood while there has been a lack of consistent evidence suggesting this hippocampal change among traumatized children (Badura-Brack et al., 2020; Tottenham & Sheridan, 2010; Weissman et al., 2020; Woon & Hedges, 2008). A meta-analysis showed that adults with PTSD due to childhood maltreatment exhibited significant reductions in bilateral hippocampal volume compared to healthy adults (Woon & Hedges, 2008). Women with histories of abuse showed decreased left and right hippocampal volumes (Nutt & Malizia, 2004). Similarly, depressed women with childhood trauma have smaller hippocampal volume compared to depressed women without trauma and healthy women (Vythilingam et al., 2011). Reduced hippocampal volume due to stress may influence emotional regulation skills; in one longitudinal study, school-aged children with early life stress and preschool onset depression showed reduced hippocampal volume and emotional dysregulation (Barch et al., 2019). To my knowledge, nevertheless, the relationship between hippocampal volume and emotional regulation in adulthood remains unclear.

Purpose of the Current Study

Previous studies have shown that childhood maltreatment influences emotional regulation skills (Burns et al., 2010; Dvir et al., 2014; Gibb et al., 2009; Gruhn & Compas, 2020; Kuo et al., 2015; Shipman et al., 2004; Turgeon et al., 2020), amygdala reactivity to negative stimuli (Marusak et al., 2015; Suzuki et al., 2014; Teicher et al., 2016), and hippocampal volume (Barch et al., 2019; Nutt & Malizia, 2004; Tottenham & Sheridan, 2010; Vythilingam et al., 2011; Woon & Hedges, 2008) respectively. Also, it has been reported that emotional regulation is associated with amygdala reactivity to emotional distractors (Marusak et al., 2015). However, it remains unclear whether emotional regulation may be associated with amygdala volume, as well as hippocampal volume, in adults. As previous studies have shown (Gibb et al., 2009; Turgeon et al., 2020), childhood maltreatment may lead individual to be less equipped in controlling emotions even in adulthood. However, there may be individual differences in vulnerability to the effect of childhood trauma on emotional regulation skills. For example, some individuals may show resilience to trauma or receive social support later (Agorastos et al., 2019; Dye, 2018; Wymbs et al., 2020), leading to less change in their amygdala or hippocampal volume, and they may not show impaired emotional regulation skills in their adulthood. Thus, the present study assessed whether childhood maltreatment was associated with emotional dysregulation in adulthood, moderated by amygdala or hippocampal volume. To measure emotional regulation skills, I specifically used the affective Stroop task, which presents respondents with emotional distractors (i.e., negative and positive emotional images) while the respondents are asked to count how many numbers are displayed on the screen as quickly as possible (Han et al., 2014; Hwang et al., 2016; Hwang et al., 2015; Marusak et al., 2015; Teicher et al., 2016). It was hypothesized that young adults with a history of maltreatment would show low emotional regulation skills, that is a slow reaction time in their counting task performance during emotional distractors (either negative or positive images or both), but that these difficulties would be more pronounced in individuals with smaller amygdala and/or hippocampal volume.

Methods

Participants

The current study was a part of a neuroimaging project investigating neurobiological effects of individuals with a history of bullying behavior and peer victimization. Participants were recruited at the University of Nebraska–Lincoln through classrooms and flyers, as well as recruited social media. After recruitment, 352 college students, voluntarily or for a course credit, participated in an online screening to assess their eligibility for MRI and provided behavioral background information for the main purpose of the project.

Following the screening process, 51 participants were selected and were further enrolled in the MRI study. One participant was excluded from the study post scan due to a brain abnormality found during MRI scanning. All other participants remained in the study as they did not have any major neurological illnesses, cognitive or developmental delays, or severe vision/hearing loss. Written informed consent was collected from participants before the online screening and MRI study. Study components were approved by the University of Nebraska–Lincoln's Institutional Review Board. Participants who took part in the MRI study received a gift card as compensation for partaking in the study.

Among the qualified participants, one participant had missing data on the task performance and was excluded from the analyses. The total sample size in the current study was $N = 49$ with a mean age of 22.5 ($SD = 4.70$): 51% of females and 49% males. Of all participants, 71.4% were Caucasians, 12.2% were African Americans, 8.2% were Asian Americans, 4.1% identified as mixed, and 4.1% identified as other. 8.2% of the sample ethnically identified as Hispanic/Latino. As for handedness, 87.8% of the sample were right-handed, 6.1% were left-handed, and 6.1% were mixed handed.

Measures

To assess eligibility for the MRI study, online screening was used which consisted of MRI eligibility questions (i.e., no magnetic objects in the body), as well as basic demographic questions. Once participants were deemed eligible, they were asked to complete the psychosocial assessment battery, which evaluated background information, including childhood trauma experiences. The current study selectively used the following assessments: The Childhood Trauma Questionnaire (CTQ) and Edinburgh Handedness Inventory (EHI).

Childhood Trauma Questionnaire (CTQ; (Bernstein & Fink, 1998): The CTQ was developed as a screening tool for the history of childhood abuse and neglect. This is a self-report questionnaire measuring 5 types of maltreatment: emotional abuse (EA), sexual abuse (SA), physical abuse (PA), physical neglect (PN), and emotional neglect (EN). The CTQ retrospectively assesses whether respondents had each of 28 traumatic events using a 5-point Likert-scale with responses ranging from "Never True (1)" to "Very Often True (5)" (See Appendix A). Individual responses were then summed for each subscale (some ratings were reversed), and higher scores indicate higher levels of the subscales. Some of the questions on the questionnaire are, *"when I was growing up… I felt that someone in my family hated me" (EA), "when I was growing up… someone tried to touch me in a sexual way, or tried to make me touch them (SA), "when I was growing up… I was punished with* a belt, a board, or a cord (or some *other hard object) (PA), "when I was growing up… I didn't have enough to eat (PN), "when I was growing up… I felt that I was loved (EN).* Each subscale consists of five questions with scores ranging from 5 to 25 and total trauma score ranging from 25 to 125.

Edinburgh Handedness Inventory (EHI; (Oldfield, 1971): The EHI was used to control for potential effects of handedness on amygdala and hippocampal volumes. This questionnaire asks respondents how much they prefer using their left or right hand in 10 routine activities (i.e., writing or using scissors) on a 5-point scale ranging from "Strongly Prefer Left (-100) to "Strongly Prefer Right (100) (See Appendix B). Individual ratings were quantified and combined; respondents who scored between -100 and -61 were considered as left-handed; participants between -60 and +60 were ambidextrous; and participants between +61 and +100 were right-handed.

MRI Task

Participants were asked to perform the Affective Stroop task (AST) (Blair et al., 2007) during the MRI scan, and the current study used the task performance data as the index of emotional regulation skills. Using this affective Stoop task, emotional and attentional regulation was assessed by presenting participants with emotional distractors of positive, negative, and neutral images, as well as having participants complete a counting task by reporting how many digits are presented on a screen. The digits were briefly bracketed by each emotional distractor.

As Figure 1 illustrates, during each trial, a central fixation point was presented (400 ms) followed by an emotional distractor (positive, negative, or neutral image) (400 ms), a numerical pattern (or a blank screen) (400ms), the same emotional distractor previously displayed (400ms), and a blank screen (1300 ms). Task trials required participants to press buttons corresponding to the number of digits (three to six) in the numerical pattern. The numerical pattern was either *congruent* or *incongruent*. For *congruent* trials, numerosity matched the number of digits displayed (i.e., five 5's). For *incongruent* trials, numerosity did not match the number of digits displayed (i.e., three 5's). Instead of the numerical pattern, participants were sometimes presented with a blank screen (called *view* trials). Participants were instructed to respond as quickly as possible but were able to respond at any point between the numerical presentation and the end of the blank screen (1700 ms). In addition, emotional distractors that were displayed before and after the numerical pattern consisted of 144 pictures, including 48 positive, 48 negative, and 48 neutral images. The images were selected from the International Affective Picture System (Lang et al., 2005). Participants completed two runs each involving 144 trials (16 trials in each of nine conditions, three types of image and three types of trials) and 40 fixation presentations. The trial order was randomized across all participants.

Procedure and Image Data Acquisition

To begin the study, qualified participants underwent an MRI scan. Neuroimaging data was acquired on a 3 Tesla Siemens Skyra MRI scanner (Siemens Medical Solutions) equipped with a 32-ch head coil MRI receiver. The MRI study was conducted with the following scans: (1) a localizer scan for prescribing the following scans, (2) a 6-min resting-state functional scan, (3) two 8.5-min functional scans during the affective Stroop task, (4) a 5-min T1-weighted (T1w) scan, (5) two 4.5-min functional scans during the face looming task, (6) two diffusion-weighted scans, (7) a 1.5-min scan of T2-weighted turbo spin echo (TSE), and (8) a 1.5-min gradient echo field-mapping scan in that order. In the current study, only T1w images were used, which were acquired in the sagittal plane by a three-dimensional magnetization prepared rapid gradient echo (MPRAGE) scan (TR = 2200 ms, TE = 3.37 ms, flip angle = 7°, FOV = 256 mm, sagittal slices per slab = 192, voxel volume = 1.0 × 1.0 × 1.0 mm3, acceleration factor PE = 2, sampling bandwidth = 200 Hz/Px). MRI scans lasted less than 1 hour in time. Following the MRI scan, participants completed the EHI and CTQ assessments online through Qualtrics.

Image Preprocessing

The FreeSurfer image analysis suite (http://surfer.nmr.mgh.harvard.edu/) was used to automatically segment gray matter and white matter on the MPRAGE images and identify different subcortical subregions, including the amygdala and hippocampus, according to the probabilistic atlas (Fischl et al., 2002). After this, the bilateral volumes within the amygdala and hippocampus, as well as intracranial volume (eTIV), were estimated (see Figure 2) and used for additional data analysis.

Statistical Strategy

To describe the history of childhood maltreatment in all participants, mean and standard deviation of CTQ score by maltreatment subtype were computed. Furthermore, Pearson's correlations were run to describe the relationship between CTQ score and reaction time during each image type, and partial correlations were used to describe the relationships between CTQ score and amygdala/hippocampal volume, controlling for gender, handedness, and eTIV. Finally, to describe emotional regulation in participants, reaction time for counting only during accurate responses was extracted. Then, the mean reaction times during the presentations of neutral, negative, and positive images, as well as the mean reaction times during the presentations of neutral and emotional images were compared using repeated-measures ANOVAs.

Furthermore, hierarchical regression analyses were performed to assess whether the interaction between CTQ score and amygdala or hippocampal volume significantly contributed to predicting reaction time during the presentation of each emotional distractor type, as well as neutral images. Before running hierarchical regression analyses, means of the following target variables were calculated: total score on CTQ, left and right amygdala volumes, and left and right hippocampal volumes. Then, these variables were centered around their mean (e.g., observed left amygdala volume – mean left amygdala volume). This centering process is necessary especially because left and right amygdala volumes, as well as left and right hippocampal volumes, are likely to be highly correlated with each other, causing a multicollinearity problem in subsequent regression models. Moreover, interaction variables were computed by multiplying the centered variables, including two-way interactions (i.e., CTQ score and left amygdala/hippocampal volume, CTQ score and right amygdala/hippocampal volume, and left and right amygdala/hippocampal volumes) and three-way interaction (i.e., CTQ score, left amygdala/hippocampal volume, and right amygdala/hippocampal volume).

Eight, four-block hierarchical regression models were conducted with reaction time during the presentations of neutral images, negative images, positive images, or both negative and positive images as dependent variables. Three variables, eTIV, gender, and handedness, were entered as covariates in the first block; main effect variables (i.e., CTQ score, left and right amygdala/hippocampal volumes alone) were entered in the second block; two-way interaction variables were entered in the third block; and three-way interaction variables in the fourth block.

Results

Childhood Trauma Reports

Physical neglect had a mean score of 6.51 (*SD* = 2.34), emotional neglect had a mean score of 8.94 (*SD* = 4.30), physical abuse had a mean score of 6.31 (*SD* = 2.43), emotional abuse had a mean score of 8.49 (*SD* = 4.27), sexual abuse had a mean score of 5.71 (*SD* = 2.72), and total childhood trauma had a mean score of 36.00 (*SD* = 12.81), shown in Table 1. All subscales have a possible range for scoring of 5 to 25, and total trauma score ranges from 25 to 125. According to correlational analyses, maltreatment was not correlated with amygdala volume, hippocampal volume, and reaction time regardless of image types.

Reaction Time During Presentation of Emotional Distractors

Reaction time during presentations of neutral images had a mean score of 755.13 (*SD* = 116.68), reaction time during presentations of negative images had a mean score of 763.50 (*SD* =

114.59), reaction time during presentations of positive images had a mean score of 765.39 (*SD* = 120.16), and reaction time during presentations of both negative and positive images had a mean score of 764.44 (*SD* = 116.45), shown in Table 2. A repeated-measures ANOVAs showed that there was no difference in reaction time between the conditions of neutral, negative, and positive images. But, when reaction times during the presentations of negative and positive images were averaged and compared with one during the presentations of neutral images, they were significantly different (Wilks' $\Lambda = .89$, $F(1,48) = 6.18$, $p < .05$). Participants had a slower reaction time when they were exposed to emotional images (mean = 764.44 ms) compared to neutral images (mean = 755.13 ms).

Relationship Between Childhood Trauma, Hippocampal Volume, and Reaction Time

There was no significant main effect or interaction effect between childhood trauma scores and hippocampal or amygdala volume on reaction time, regardless of whether task performance was distracted by emotional images or not (see Tables 3-10). However, it was found that some effects were marginally significant. Specifically, there was a trend for the interaction between the total CTQ score and right hippocampal volume to be associated with reaction time during the presentation positive images ($\beta = .59$ ($t(9,39) = 1.86$, $p = .071$) and both negative and positive images ($\beta = .56$ ($t(9,39) = 1.74$, $p = .089$). Additionally, left hippocampal volume interacted with CTQ score to predict reaction time during the presentation of positive images at a marginally significant level ($\beta = –.49$ ($t(9,39) = –1.76$, $p = .086$). These suggest that positive emotional stimuli slightly (but not significantly) influenced task performance, depending on a history of maltreatment and hippocampal volume. To interpret these marginally significant interactions, Figures 3-5 plots the relationships between CTQ score and reaction time, by three conditions of hippocampal volume: large hippocampal volume (mean volume + one standard deviation), average hippocampal volume (mean volume), and small hippocampal volume (mean volume – one standard deviation). When positive images were presented, reaction time was slightly slower among participants with maltreatment experience and either large right hippocampal volume (see Figure 3) or small left hippocampal volume (see Figure 5). In contrast, when participants reported few maltreatment experiences, there was no difference in reaction time regardless of hippocampal volume (see Figures 3 and 5). When emotional images in general were presented, participants with large right hippocampal volume somewhat showed slower reaction time than those with small right hippocampal volume, but this difference was visible only when participants reported maltreatment (see Figure 4). Additionally, there were no trends found between total CTQ score and amygdala volume on reaction time during presentations of neutral, negative, positive, and emotional images. Nevertheless, it is notable that none of these differences was statistically significant.

Discussion

The current study investigated whether childhood maltreatment was associated with emotional regulation and whether this hypothesized association was moderated by amygdala or hippocampal volume. Specifically, this study examined whether young adults with histories of maltreatment would show low emotional regulation, or a slow reaction time in counting during emotional distractors, depending on amygdala or hippocampal volume. Collectively, study findings do not suggest an overall tendency for childhood trauma or amygdala/hippocampal volume to be associated with emotional dysregulation. While there were no major interactions, there was a trend that a combination of maltreatment and hippocampal volume may place young adults at greater vulnerability for difficulties. That is, right hippocampal volume and CTQ score marginally interacted with each other to predict reaction time during the presentation of positive images respectively, as well as composite emotional images. Left hippocampal volume and CTQ score also showed a marginally significant interaction on reaction time during the presentation of positive images only. These marginal findings are somewhat consistent with Barch et al.'s (2019) study, where depressed children, who presumably experienced early life trauma (Suzuki et al., 2013; Suzuki et al., 2014), showed the relationship between their hippocampal volume and emotional regulation skills. One possible reason why these interaction effects did not meet the criteria for significance might be that a third variable effect, such as depression status analyzed in Barch et al.'s (2019) study, may additionally intervene in the interactions between maltreatment and hippocampal volumes. Future studies should consider and assess for such an additional effect when investigating the possible effects of childhood maltreatment and hippocampal volume on emotional regulation.

In addition to hippoampal volume, the present study also assessed the possible moderating role of bilateral amygdala volumes in the relationship between maltreatment and emotional regulation. Nevertheless, these interaction effects were not found, either. The majority of studies has demonstrated that amygdala activity to negative stimuli is a better index of maltreatment (Agorastos et al., 2019) and emotional regulation (Kray et al., 2020; Krug & Carter, 2012; Marusak et al., 2015; Minkova et al., 2017; Swartz et al., 2020). In contrast, amygdala volume might have a very weak (and not significant enough) effect on emotional regulation. It is possible that structural properties of the amygdala might interrelate with other brain regions to account for emotional regulation or might not be as vulnerable as the hippocampus to the damaging effects of chronic trauma and prolonged HPA axis stimulation. More research is needed in regard to childhood maltreatment and volumetric changes in the amygdala, as this relationship has been unclear thus far (Agorastos et al., 2019).

Implications of Findings

The lack of significant main effects of maltreatment indicates that, even if individuals may experience maltreatment during childhood, it does not necessarily mean that their emotional regulation skills are impaired in adulthood. The current study further hypothesized that a protective factor was amygdala or hippocampal volume, but this hypothesis was not supported by evidence. Future research should continue investigating what other neurobiological factors may act as buffers to the negative effects of maltreatment on emotional regulation. One study has found that access to positive, social support can improve negative impacts of child maltreatment on the functioning of brain circuits which are involved in emotional regulation (Wymbs et. al., 2020). Furthermore, the same study revealed that individuals with histories of greater maltreatment had increased amygdala (as well as the anterior cingulate cortex, insula, nucleus accumbens, and frontal pole) activation in response to threatening stimuli, but these elevated activations were found to be reduced in those with more positive support systems (Wymbs et al., 2020). Wymbs et al.'s (2020) findings suggest the presence of positive, social support as an important piece to building resilience, and future research should consider the effect of social support in accounting for emotional regulation.

Based on these findings, it is also noteworthy that amygdala or hippocampal volume alone does not determine emotional regulation skills in adults. In fact, previous studies have shown that not only the amygdala or hippocampus but also the anterior cingulate cortex, anterior insula, lateral frontal cortex, middle frontal cortex, and dorsolateral prefrontal cortex also play an important role in emotion processing (Blair et al., 2007; Pechtel & Pizzagalli, 2011; Teicher et al., 2016; Tottenham & Sheridan, 2010). Thus, future research should additionally examine a possible effect of structural or functional changes in these brain areas in relation to emotional regulation skills.

Study Limitations

There are several limitations that should be considered in respect to the current study. First, this study might have a relatively small sample size (N = 49), resulting in a large standard error of the mean for variables, such as childhood trauma scores, although my sample size was larger than the most highly cited neuroimaging studies (Szucs & Ioannidis, 2020). Another limitation is that childhood trauma was retrospectively reported through a self-report assessment, thus participants might not remember their childhood experiences well. Alternatively, because of social desirability, participants in the study were reporting experiences of minimal trauma. Moreover, this study sampled from a healthy population; hence my sample was likely to represent only those who experienced mild to moderate trauma or showed normative emotional regulation. Hence, different results may be obtained if a sample is drawn from not only a healthy population but also a psychiatric population. The present study recruited healthy college students; therefore, my results were likely to represent those who had the capacity for resilience and had relative advantages in other ways (i.e., university sample being relatively advantaged by access to higher education). Lastly, this study analyzed the effect of composite maltreatment, rather than subtypes of maltreatment (e.g., physical abuse, emotional neglect, sexual abuse). Future research should attempt to investigate the possible effects of trauma subtypes on emotional regulation and structural brain changes.

Conclusions

In conclusion, this study did not find any main effect or interaction effect between childhood maltreatment and amygdala or hippocampal volume. However, a few marginally significant interactions were found between right hippocampal volume and CTQ score to predict reaction time during presentations of negative, positive, and emotional (both negative and positive) images, as well as left hippocampal volume and CTQ score on reaction time during the presentation of positive images only. These data suggest that neither maltreatment nor amygdala/hippocampal volume directly influences emotional regulation; rather, other third variables should be considered to assess factors for emotional dysregulation.

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Table 1.

Means and Standard Deviations of CTQ Self-Report Scores

	M	*SD*
Physical Neglect	6.51	2.34
Emotional Neglect	8.94	4.30
Physical Abuse	6.31	2.43
Emotional Abuse	8.49	4.27
Sexual Abuse	5.71	2.72
Total Childhood Trauma	36.00	12.81

Note. *N* = 49; *M* = mean; *SD* = standard deviation.

Table 2.

Means and Standard Deviations of Reaction Time During Presentations of Task Images

	M	*SD*
Neutral	755.13	116.68
Negative	763.50	114.59
Positive	765.39	120.16
Emotional	764.44	116.45

Note. *N* = 49; *M* = mean; *SD* = standard deviation. Mean values are expressed in milliseconds.

Table 3.

Hierarchical regression model predicting reaction time during neutral images

		B	*SE*	β	*t*	*p*
1st block	eTIV	.000	.000	–.222	–1.222	.228
	Gender	–29.274	42.074	–.127	–.696	.490
	Handedness	–41.304	32.169	–.187	–1.284	.206
2nd block	CTQ (C)	.437	1.368	.048	.320	.751
	L Amg Vol (LAV)	–.111	.153	–.180	–.725	.473
	R Amg Vol (RAV)	–.054	.138	–.104	–.396	.694
3rd block	C x LAV	.023	.024	.322	.987	.330
	C x RAV	–.015	.021	–.218	–.696	.490
	LAV x RAV	.000	.000	.168	.960	.343
4th block	C x LAV x RAV	–.000	.000	–.230	–.969	.339

Note. B = unstandardized regression coefficient; *SE* = standard error; β = standardized regression coefficient; *t* = t-value; *p* = p-value. Each block included all variables entered in the previous block(s).

Table 4.

Hierarchical regression model predicting reaction time during negative images

		B	*SE*	*β*	*t*	*p*
1st block	eTIV	.000	.000	–.217	–1.192	.240
	Gender	–26.892	41.522	–.119	–.648	.520
	Handedness	–35.499	31.747	–.163	–1.118	.269
2nd block	CTQ (C)	1.058	1.346	.118	.786	.436
	L Amg Vol (LAV)	–.117	.151	–.193	–.776	.442
	R Amg Vol (RAV)	–.036	.135	–.070	–.263	.794
3rd block	C x LAV	.036	.024	.502	1.570	.125
	C x RAV	–.024	.020	–.368	–1.198	.238
	LAV x RAV	.000	.000	.176	1.030	.309
4th block	C x LAV x RAV	–.000	.000	–.153	–.655	.517

Note. B = unstandardized regression coefficient; *SE* = standard error; *β* = standardized regression coefficient; *t* = t-value; *p* = p-value. Each block included all variables entered in the previous block(s).

Table 5.

Hierarchical regression model predicting reaction time during positive images

		B	*SE*	*β*	*t*	*p*
1st block	eTIV	.000	.000	–.173	–.939	.353
	Gender	–21.968	43.892	–.092	–.501	.619
	Handedness	–33.883	33.558	–.149	–1.010	.318
2nd block	CTQ (C)	1.014	1.429	.108	.710	.482
	L Amg Vol (LAV)	–.084	.160	–.131	–.522	.605
	R Amg Vol (RAV)	–.064	.144	–.120	–.448	.657
3rd block	C x LAV	.033	.024	.443	1.364	.180
	C x RAV	–.018	.022	–.257	–.825	.414
	LAV x RAV	.000	.000	.215	1.237	.223
4th block	C x LAV x RAV	–.000	.000	–.247	–1.047	.302

Note. B = unstandardized regression coefficient; *SE* = standard error; *β* = standardized regression coefficient; *t* = t-value; *p* = p-value. Each block included all variables entered in the previous block(s).

Table 6.

Hierarchical regression model predicting reaction time during emotional images

		B	*SE*	*β*	*t*	*p*
1st block	eTIV	.000	.000	–.196	–1.071	.290
	Gender	–24.430	42.361	–.106	–.577	.567
	Handedness	–34.691	32.388	–.157	–1.071	.290
2nd block	CTQ (C)	1.036	1.376	.114	.753	.456
	L Amg Vol (LAV)	–.100	.154	–.163	–.650	.519
	R Amg Vol (RAV)	–.050	.138	–.096	–.361	.720
3rd block	C x LAV	.034	.023	.476	1.476	.148
	C x RAV	–.021	.021	–.314	–1.014	.317
	LAV x RAV	.000	.000	.198	1.147	.258
4th block	C x LAV x RAV	–.000	.000	–.203	–.863	.394

Note. B = unstandardized regression coefficient; *SE* = standard error; *β* = standardized regression coefficient; *t* = t-value; *p* = p-value. Each block included all variables entered in the previous block(s).

Table 7.

Hierarchical regression model predicting reaction time during neutral images

		B	*SE*	*β*	*t*	*p*
1st block	eTIV	.000	.000	–.222	–1.222	.228
	Gender	–29.274	42.074	–.127	–.696	.490
	Handedness	–41.304	32.169	–.187	–1.284	.206
2nd block	CTQ (C)	.234	1.435	.026	.163	.871
	L Hipp Vol (LHV)	–.054	.113	–.153	–.479	.634
	R Hipp Vol (RHV)	.020	.080	.066	.250	.804
3rd block	C x LHV	–.014	.009	–.424	–1.504	.141
	C x RHV	.011	.008	.452	1.405	.168
	LHV x RHV	.000	.000	.060	.372	.712
4th block	C x LAV x RAV	–.000	.000	–.088	–.351	.728

Note. B = unstandardized regression coefficient; *SE* = standard error; *β* = standardized regression coefficient; *t* = t-value; *p* = p-value. Each block included all variables entered in the previous block(s).

Table 8.

Hierarchical regression model predicting reaction time during negative images

		B	*SE*	*β*	*t*	*p*
1st block	eTIV	.000	.000	–.217	–1.192	.240
	Gender	–26.892	41.522	–.119	–.648	.520
	Handedness	–35.499	31.747	–.163	–1.118	.269
2nd block	CTQ (C)	.955	1.406	.107	.679	.501
	L Hipp Vol (LHV)	–.065	.111	–.189	–.591	.558
	R Hipp Vol (RHV)	.009	.079	.031	.118	.907
3rd block	C x LHV	–.014	.009	–.439	–1.572	.124
	C x RHV	.012	.008	.509	1.595	.119
	LHV x RHV	.000	.000	.085	.534	.596
4th block	C x LAV x RAV	–.000	.000	–.023	–.092	.927

Note. B = unstandardized regression coefficient; *SE* = standard error; *β* = standardized regression coefficient; *t* = t-value; *p* = p-value. Each block included all variables entered in the previous block(s).

Table 9.

Hierarchical regression model predicting reaction time during positive images

		B	*SE*	*β*	*t*	*p*
1st block	eTIV	.000	.000	–.173	–.939	.353
	Gender	–21.968	43.892	–.092	–.501	.619
	Handedness	–33.883	33.558	–.149	–1.010	.318
2nd block	CTQ (C)	.813	1.487	.087	.547	.587
	L Hipp Vol (LHV)	–.079	.117	–.218	–.677	.502
	R Hipp Vol (RHV)	.024	.083	.075	.283	.779
3rd block	C x LHV	–.017	.010	–.492	–1.759	.086
	C x RHV	.015	.008	.592	1.855	.071
	LHV x RHV	.000	.000	.069	.433	.668
4th block	C x LAV x RAV	–.000	.000	–.062	–.250	.804

Note. B = unstandardized regression coefficient; *SE* = standard error; *β* = standardized regression coefficient; *t* = t-value; *p* = p-value. Each block included all variables entered in the previous block(s).

Table 10.

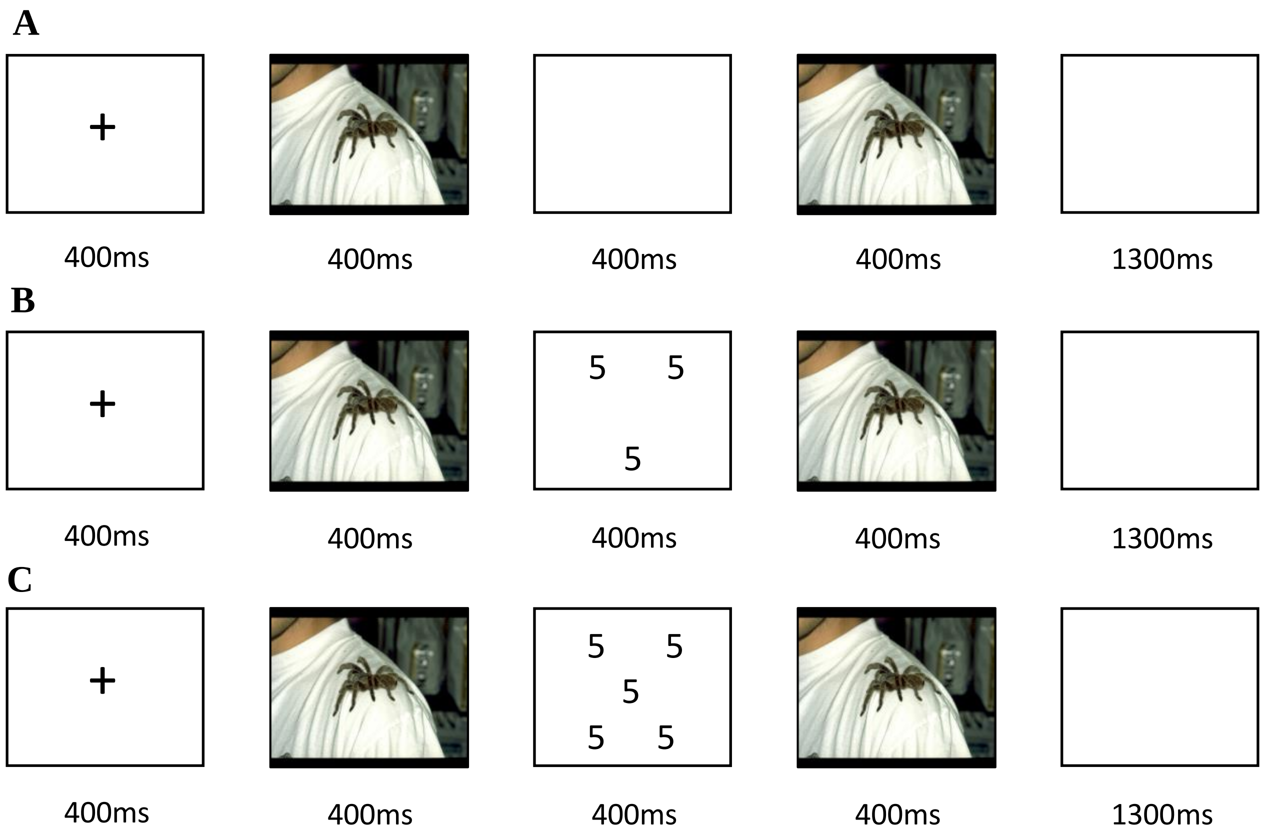
Hierarchical regression model predicting reaction time during emotional images

		B	*SE*	*β*	*t*	*p*
1st block	eTIV	.000	.000	–.196	–1.071	.290
	Gender	–24.430	42.361	–.106	–.577	.567
	Handedness	–34.691	32.388	–.157	–1.071	.290
2nd block	CTQ (C)	.884	1.435	.097	.616	.541
	L Hipp Vol (LHV)	–.072	.113	–.205	–.640	.525
	R Hipp Vol (RHV)	.016	.080	.054	.204	.839
3rd block	C x LHV	–.016	.009	–.470	–1.682	.100
	C x RHV	.014	.008	.555	1.743	.089
	LHV x RHV	.000	.000	.077	.486	.629
4th block	C x LAV x RAV	–.000	.000	–.043	–.174	.863

Note. B = unstandardized regression coefficient; *SE* = standard error; *β* = standardized regression coefficient; *t* = t-value; *p* = p-value. Each block included all variables entered in the previous block(s).

Figure 1.

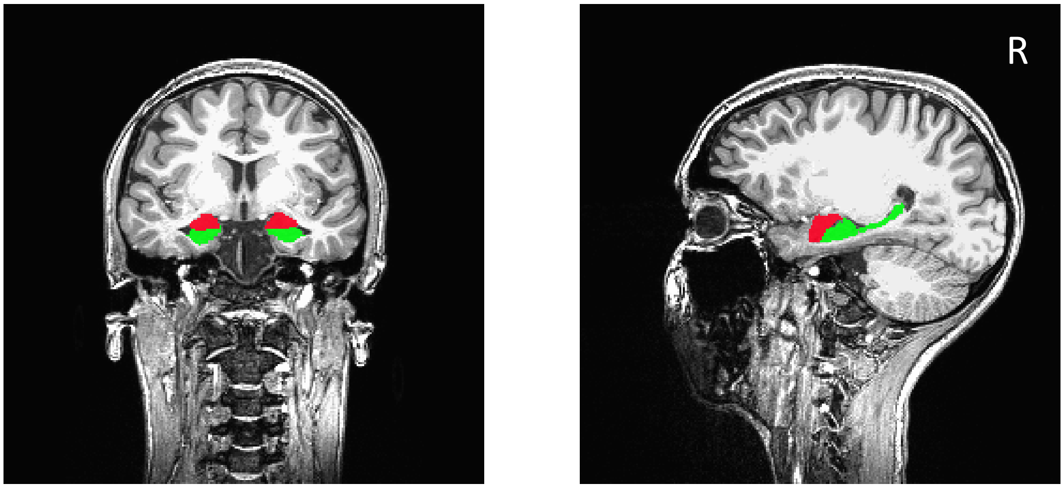
Examples of Experimental Trials



Note. The task consisted of view trials (A), incongruent trials (B), and congruent trials (C). The presented images varied by emotional valence (negative, positive, or neutral).

Figure 2.

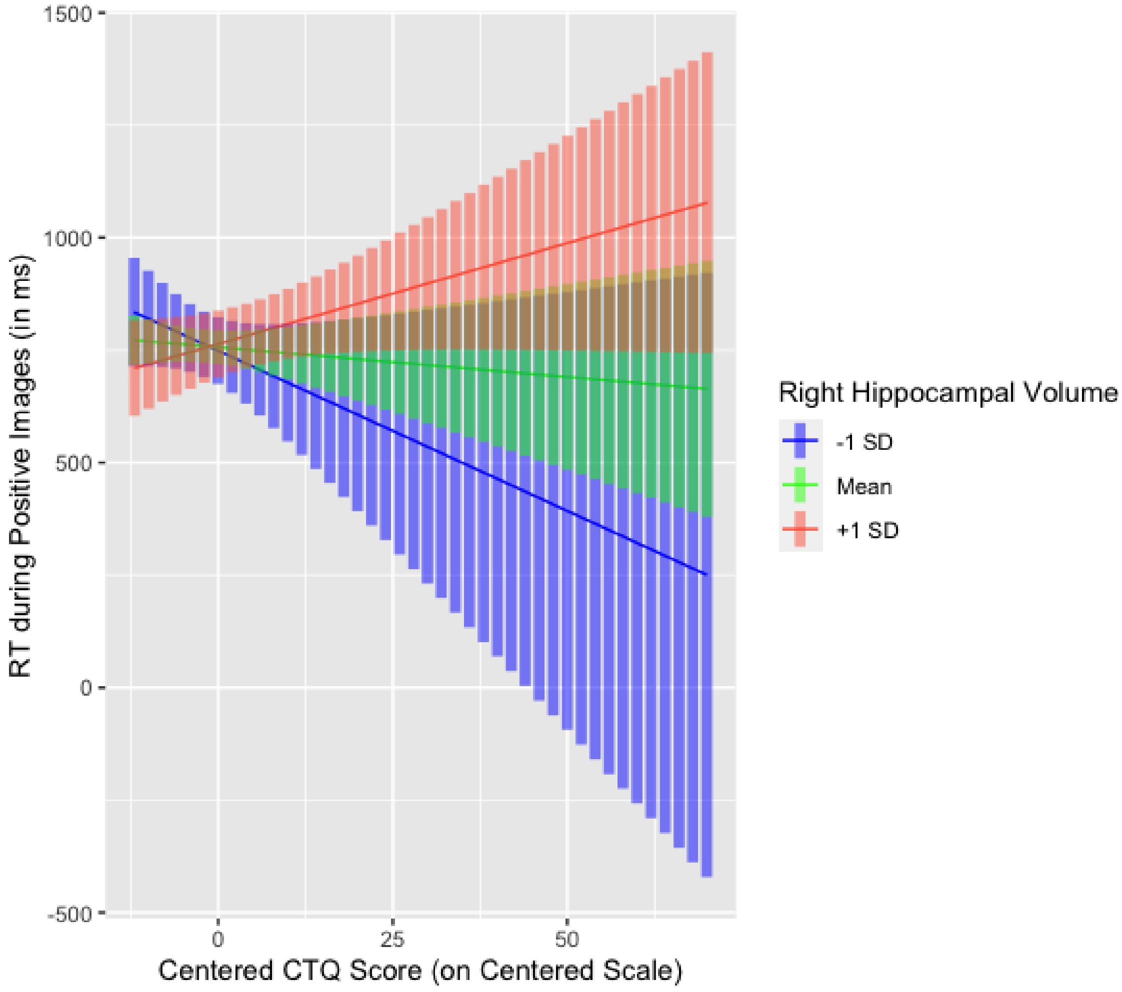
Locations of the Amygdala and Hippocampus



Note. Sagittal (left) and coronal (right) views of the amygdalae (red) and hippocampi (green). The capital R indicates the right side of the body.

Figure 3.

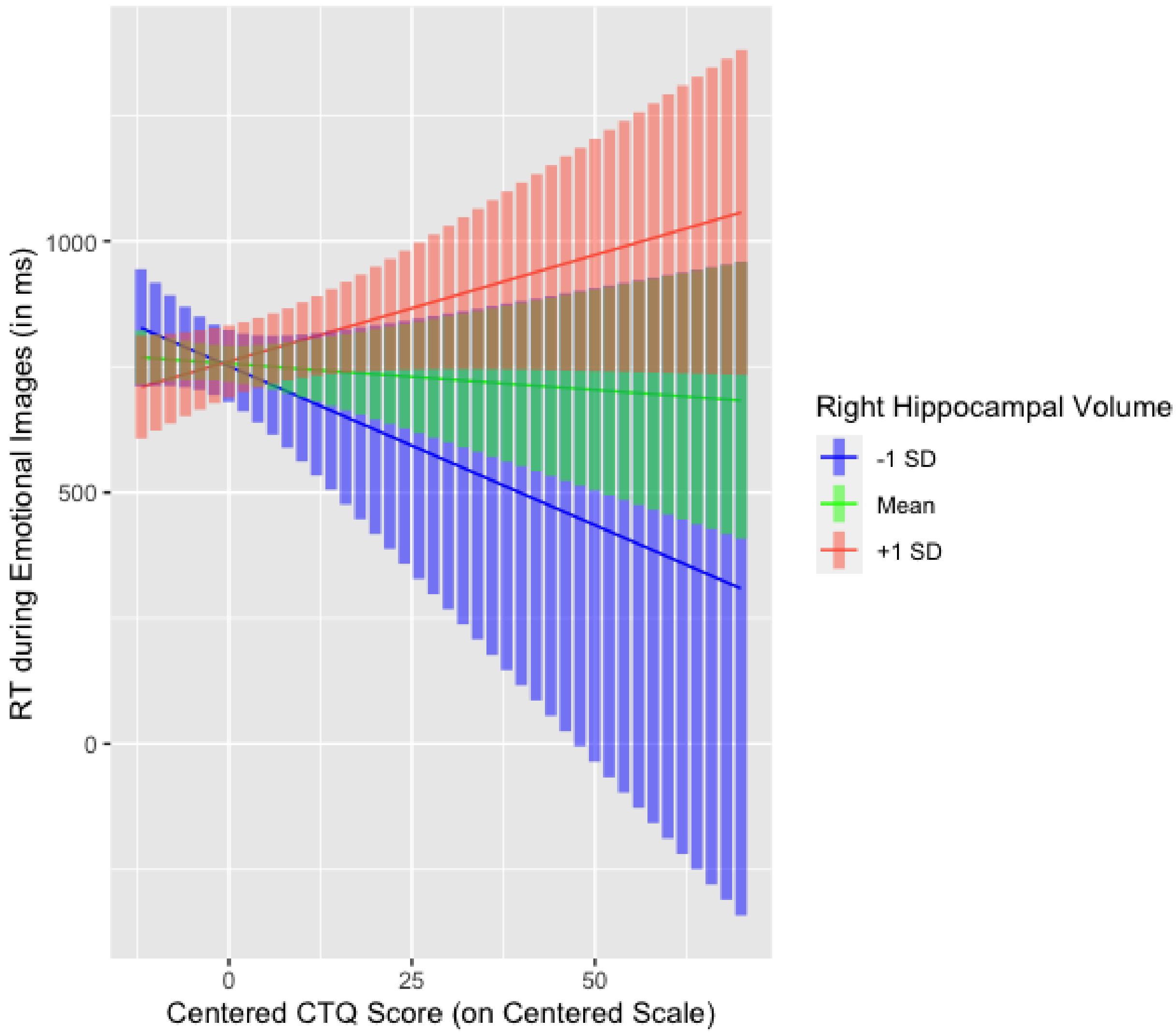
Reaction Time During Positive Images as Functions of Maltreatment and Right Hippocampal Volume



Note. Relationship between centered CTQ score and reaction time during positive images by small (blue), average (green), and large (red) right hippocampal volume. The vertical bars represent confidence intervals.

Figure 4.

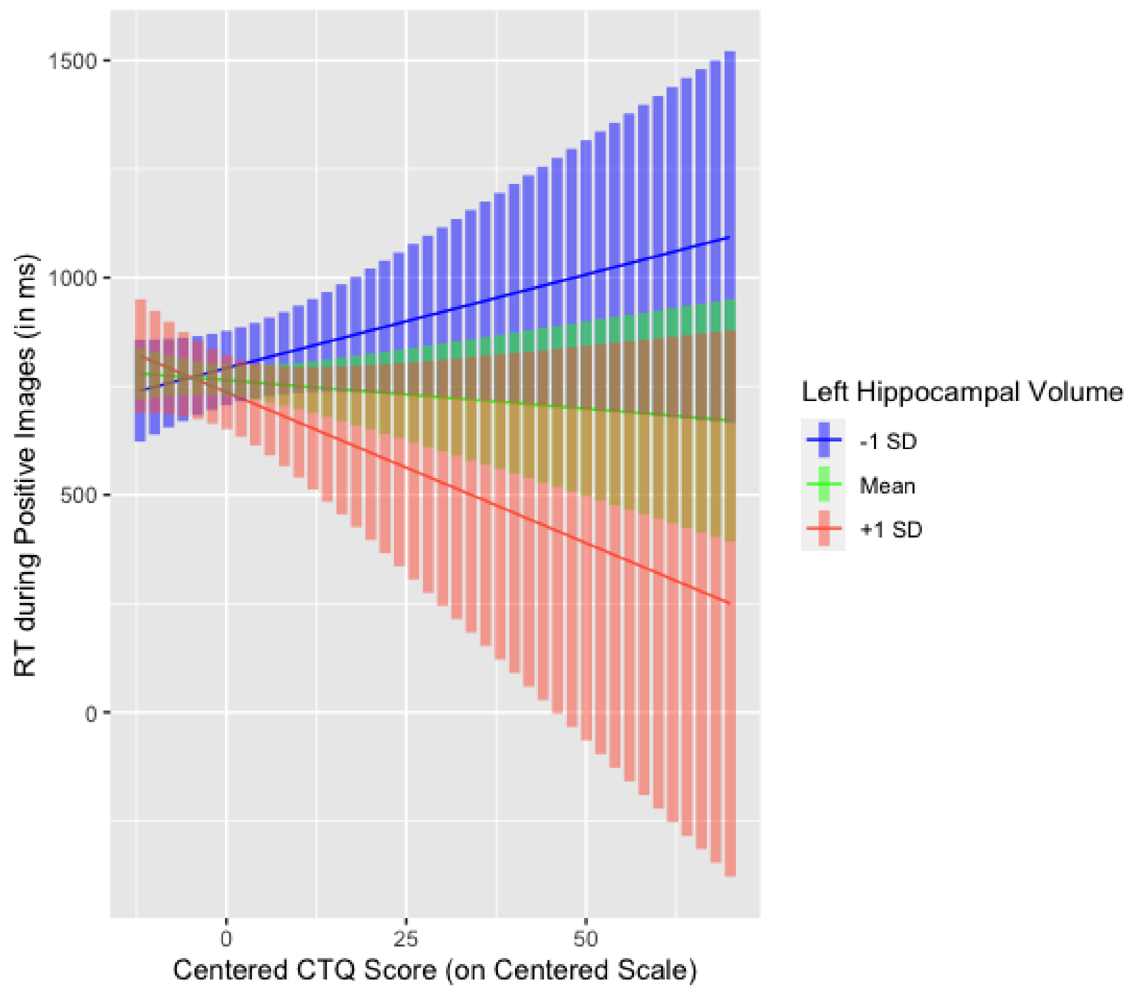
Reaction Time During Emotional Images as Functions of Maltreatment and Right Hippocampal Volume



Note. Relationship between centered CTQ score and reaction time during emotional images by small (blue), average (green), and large (red) right hippocampal volume. The vertical bars represent confidence intervals.

Figure 5.

Reaction Time During Positive Images as Functions of Maltreatment and Left Hippocampal Volume



Note. Relationship between centered CTQ score and reaction time during positive images by small (blue), average (green), and large (red) left hippocampal volume. The vertical bars represent confidence intervals.

Appendix A

Childhood Trauma Questionnaire

Instructions: In this questionnaire, you will be asked about your childhood experience in your family. Please read each statement and rate each of the items below by choosing 1 (Never true) to 5 (Very often true). Please give the answer which describes your childhood experience best.

	When I was growing up…	Never True	Rarely True	Sometimes True	Often True	Very Often True
1.	I didn't have enough to eat	1	2	3	4	5
2.	I knew that there was someone to take care of me and protect me	1	2	3	4	5
3.	People in my family called me things like "stupid," "lazy," or "ugly."	1	2	3	4	5
4.	My parents were too drunk or high to take care of the family	1	2	3	4	5
5.	There was someone in my family who helped me feel that I was important or special	1	2	3	4	5
6.	I had to wear dirty clothes	1	2	3	4	5
7.	I felt that I was loved	1	2	3	4	5
8.	I thought my parents wished I had never been born	1	2	3	4	5
9.	I got hit so hard by someone in my family that I had to see a doctor or go to the hospital	1	2	3	4	5
10.	People in my family hit me so hard that it left bruises or marks	1	2	3	4	5
11.	I was punished with a belt, a board, or a cord (or some other hard object).	1	2	3	4	5
12.	There was nothing I wanted to change about my family	1	2	3	4	5
13.	People in my family looked out for each other	1	2	3	4	5
14.	People in my family said hurtful or insulting things to me	1	2	3	4	5

15.	I believe that I was physically abused	1	2	3	4	5
16.	I got hit or beaten so badly that it was noticed by someone like a teacher, neighbor, or doctor	1	2	3	4	5
17.	I felt that someone in my family hated me	1	2	3	4	5
18.	People in my family felt close to each other	1	2	3	4	5
19.	Someone tried to touch me in a sexual way, or tried to make me touch them	1	2	3	4	5
20.	Someone threatened to hurt me or tell lies about me unless I did something sexual with them	1	2	3	4	5
21.	I had the perfect childhood	1	2	3	4	5
22.	Someone tried to make me do sexual things or watch sexual things	1	2	3	4	5
23.	Someone molested me	1	2	3	4	5
24.	I believe that I was emotionally abused	1	2	3	4	5
25.	There was someone to take me to the doctor if I needed it	1	2	3	4	5
26.	I had the best family in the world	1	2	3	4	5
27.	I believe that I was sexually abused	1	2	3	4	5
28.	My family was a source of strength and support	1	2	3	4	5

Appendix B

Edinburgh Handedness Inventory

Instructions: For each of the activities below, please indicate which hand you prefer for that activity. Some of the activities require both hands. In these cases, the part of the task or object for which hand preference is wanted is indicated in parentheses.

Which hand do you prefer to use in:

1. **Writing:**

☐	☐	☐	☐	☐	☐
Strongly prefer left	Prefer left	No preference	Prefer left	Prefer right	Strongly prefer right

2. **Drawing**:

☐	☐	☐	☐	☐	☐
Strongly prefer left	Prefer left	No preference	Prefer left	Prefer right	Strongly prefer right

3. **Throwing**:

☐	☐	☐	☐	☐	☐
Strongly prefer left	Prefer left	No preference	Prefer left	Prefer right	Strongly prefer right

4. **Scissors**:

☐	☐	☐	☐	☐	☐
Strongly prefer left	Prefer left	No preference	Prefer left	Prefer right	Strongly prefer right

5. **Toothbrush**:

☐	☐	☐	☐	☐	☐
Strongly prefer left	Prefer left	No preference	Prefer left	Prefer right	Strongly prefer right

6. **Knife (Without Fork):**

☐	☐	☐	☐	☐	☐
Strongly prefer left	Prefer left	No preference	Prefer left	Prefer right	Strongly prefer right

7. **Spoon**:

☐	☐	☐	☐	☐	☐
Strongly prefer left	Prefer left	No preference	Prefer left	Prefer right	Strongly prefer right

8. Broom (Upper Hand):

☐	☐	☐	☐	☐	☐
Strongly prefer left	Prefer left	No preference	Prefer left	Prefer right	Strongly prefer right

9. Striking Match (Match):

☐	☐	☐	☐	☐	☐
Strongly prefer left	Prefer left	No preference	Prefer left	Prefer right	Strongly prefer right

10. Opening Box (Lid):

☐	☐	☐	☐	☐	☐
Strongly prefer left	Prefer left	No preference	Prefer left	Prefer right	Strongly prefer right