THE IMPACT OF DIMENSIONS OF EXPERIENCE ON BEHAVIOR: EXAMINING THE ROLE OF DEPRIVATION AND THREAT IN EARLY CHILDHOOD

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ABSTRACT

Laura Machlin: The Impact of Dimensions of Experience on Behavior: Examining the Role of Deprivation and Threat in Early Childhood
(Under the direction of Margaret Sheridan)

Deprivation, defined as the absence of expected cognitive and social inputs, is associated with worse executive functioning. Threatening experiences, defined as the presence of atypical traumatic learning experiences, are associated with impaired fear learning processes. No prior work has examined the effects of deprivation and threat together outside of adolescence. The present study examines how deprivation and threat are associated with behavior in children 4-7 years old. Children (N = 63) completed executive functioning and fear conditioning tasks. To operationalize deprivation and threat, an index score was created from each relevant measure from child and parent report. Deprivation was associated with worse cognitive control. Threat was associated with greater attentional bias towards threat-related cues and greater generalization of physiological response during fear extinction. All analyses controlled for age, gender, IQ, and other experiences (deprivation or threat). Future work should examine neural mechanisms underlying behavioral changes associated with early adversity.

TABLE OF CONTENTS

LIST OF FIGURES vi

LIST OF TABLES vii

LIST OF ABBREVIATIONS viii

Introduction 1

- Deprivation 4
- Executive Functioning 6
- Exposure to Deprivation 7
- Institutionalization 7
- Low Socioeconomic Status (SES) 9
- Threat 11
- Exposure to Threatening Experiences 13
- Abuse 13
- Summary 16
- Current Study 18

Methods 19

- Participants 19
- Procedure 19

Measures 20
Deprivation Measures 20
Threat Measures 21
Inverse Efficiency 22
Executive Function Assessments 22
Fear Conditioning Data Acquisition and Analyses 24
Data Analysis 25
Statistical Analyses 27
Results 29
Sample Characteristics 29
Deprivation and Threat Correlations 29
Cognitive Control 30
Working Memory 30
Fear Acquisition and Extinction 31
Conclusions 34
Study Limitations and Future Directions 40
Summary 41
REFERENCES 65

LIST OF FIGURES

Figure 1. Proposed dimensions of experience: deprivation and threat 42

Figure 2. Sample item from the MNBS-CR 43

Figure 3. Sample item from the VEX-R 44

Figure 4. Cognitive control task.. 45

Figure 5. Working memory task 46

Figure 6. First block of fear conditioning task... 47

Figure 7. Histogram of deprivation dimension of experience 48

Figure 8. Histogram of threat dimension of experience 49

Figure 9. Partial regression plot of deprivation on cognitive control task performance 50

Figure 10. Partial regression plot of threat on fear extinction reaction time 51

Figure 11. Number of skin conductance responses to the CS+NR during fear extinction........... 52

Figure 12. Number of skin conductance responses to the CS- during fear extinction 53

LIST OF TABLES

Table 1. Means and standard deviations of sample characteristics. 54

Table 2. Correlations between measures of deprivation. 55

Table 3. Correlations between measures of threat 56

Table 4. Multiple regression analysis of cognitive control task 57

Table 5. Multiple regression analysis of working memory task 58

Table 6. Multiple regression analysis of fear acquisition behavioral performance 59

Table 7. Multiple regression analysis of fear extinction behavioral performance........................ 60

Table 8. Repeated measures ANOVA of fear acquisition number of SCRs 61

Table 9. Repeated measures ANOVA of fear acquisition mean skin conductance level 62

Table 10. Repeated measures ANOVA of fear extinction number of SCRs 63

Table 11. Repeated measures ANOVA of fear extinction mean skin conductance level............ 64

LIST OF ABBREVIATIONS

HPA	Hypothalamic-pituitary-adrenal
SES	Socioeconomic status
ADHD	Attention-deficit/hyperactivity disorder
CS+	Conditioned stimulus
UCS	Unconditioned stimulus
vmPFC	Ventromedial prefrontal cortex
CS-	Conditioned stimulus never paired with an UCS
KBIT-2	Kaufman brief intelligence test
MNBS-CR	Multidimensional neglectful behavior scale
HSQ	Home screening questionnaire
HOME	Home observation for the measurement of the environment
VEX-R	Violence exposure scale for children-revised
CTS-2	Conflict tactics scales
CAPI	Child abuse potential inventory
CS+R	Conditioned stimulus reinforced with the UCS
CS+NR	Conditioned stimulus non-reinforced without the UCS
CAPI	Child abuse potential inventory
ANOVA	Analysis of variance
PTSD	Post-traumatic stress disorder

Introduction

Since the influential Adverse Childhood Experiences study, there has been a veritable explosion of research linking early adversity with negative developmental outcomes such as risk for psychopathology (Felitti et al., 1998). Early adversity is defined as "experiences that are likely to require significant adaptation by an average child and that represent a deviation from the expectable environment" (McLaughlin, 2016). There is considerable evidence that early adversity is very common, impacting an estimated 50% of the US population across multiple epidemiological samples (Green et al., 2010; McLaughlin et al., 2012; McLaughlin, 2016). Early adversity in childhood is associated with a number of adverse health outcomes, including increased risk for psychopathology, heart disease, cancer, lung disease, liver disease, obesity, and self-rated health overall (Anda et al., 2005a; Felitti et al., 1998). Additionally, adverse childhood experiences show a dose-dependent relationship in which the number of adverse experiences relates to prevalence of and risk for the number of negative health outcomes (Anda et al., 2005a). In addition to risk for physical health, early adversity has a similar dose-dependent association with increased risk for psychopathology (Green et al., 2010).

Initial work on psychopathology focused on the relationship between early adversity and specific risk for depression, anxiety, alcoholism, drug abuse, and suicide attempts (Anda et al., 2005a; Chapman et al., 2004; Felitti et al., 1998). However, as more research has accumulated over time, the association between early adversity and psychopathology has been identified as largely nonspecific (Green et al., 2010; Kessler et al., 2010; McLaughlin et al., 2012). Children who have experienced early adversity are at higher risk for mood disorders, anxiety disorders, substance use disorders, and disruptive behavior disorders with similar strengths of association across psychological disorders (Green et al., 2010; Kessler et al., 2010; McLaughlin et al., 2012). In fact, experiences of early adversity may influence specific risk for psychological disorders through shared vulnerability to externalizing and internalizing symptoms (Keyes et al., 2012).

Prior work proposes that negative developmental outcomes and heightened risk for psychopathology associated with early adversity are the result of exposure to stress (Anda et al., 2005; Nurius, Green, Logan-Greene, & Borja, 2015). Within a stress accumulation model, early adversity is proposed to have additive effects on stress across the lifespan, which results in increased risk of psychopathology (Hostinar & Gunnar, 2013; Hostinar, Lachman, Mroczek, Seeman, & Miller, 2015). Maladaptive stress response to early adversity, or toxic stress, is defined as a strong, frequent, or prolonged activation of the body's stress responses system in the absence of buffering protection of a supporting, adult relationship (Shonkoff et al., 2012). The most widely studied biological mechanism for how early adversity impacts psychopathology is through alterations to the hypothalamic-pituitary-adrenal (HPA) axis, which produces cortisol in the context of stress (Cicchetti & Rogosch, 2001; Gunnar & Vazquez, 2001). Cortisol is a steroid hormone that binds with low affinity to glucocorticoid receptors throughout the brain and with high affinity to mineralocorticoid receptors in the amygdala and the hippocampus (Frodl & O'Keane, 2013; ter Heegde, De Rijk, & Vinkers, 2015). Once the system has been activated due to the experience of a stressor, negative feedback loops are triggered in multiple brain regions, including the hippocampus, to downregulate HPA axis activity.

To account for evidence of changes to the HPA axis from early adversity, multiple models have theorized pathways through which chronic stress from experiences of early adversity alters HPA axis functioning and influences risk for psychopathology. For example, the concept of allostatic load has provided a neurobiological model for the effect of stress on the brain and the body (McEwen, 1998; McEwen, 2000). Within this model, when an acute stressor occurs, HPA activation constitutes an adaptive response. However, chronic stressors can fundamentally alter HPA activation in ways that contribute to negative outcomes. HPA axis dysregulation from adverse childhood experiences results in “wear and tear” on the body from increased allostatic load (Juster, McEwen, & Lupien, 2010). When the HPA axis is chronically overactive, the theory postulates that a ‘domino effect’ will occur diminishing the individual’s ability to cognitively and physiologically respond to stress in the future (Juster et al., 2010). Other models, such as the adaptive calibration model and the biological sensitivity to context model similarly focus on HPA axis as the primary mechanism through which experience influences the brain and behavior (Boyce & Ellis, 2005; Giudice, Ellis, & Shirtcliff, 2011; Hostinar & Gunnar, 2013).

While animal studies in rodents and non-human primates have shown that early adversity results in hyperactive HPA axis functioning in adulthood (Meaney & Szyf, 2005; Meaney, Szyf, & Seckl, 2007; Plotsky & Meaney, 1993; Sanchez, 2006), there are more inconsistent findings across human studies on how early adversity impacts HPA functioning (Kudielka, Hellhammer, & Wüst, 2009; Simmons et al., 2015). The HPA axis alterations have not been able to predict risk for specific outcomes due to the lack of one-to-one relationship between adverse childhood experiences and discrete psychological disorders or differences in behavior. By focusing on the HPA axis as the primary mechanism between early adversity and changes to brain structure and function, prior models have implicitly suggested that different environmental experiences influence the brain through the same underlying mechanisms.

Given that experiences of early adversity broadly increase risk for psychopathology, it is vital to better understand how to differentiate those at risk for specific outcomes among children who have experienced early adversity. More specific neurobiological mechanisms tied to experience may be able to provide the link between early adverse experiences and risk for specific outcomes. Recently, a new theory has extended the framework for understanding the relationship between early adversity and later negative outcomes by distinguishing between different types of experiences.

Sheridan and McLaughlin have outlined a specific theoretical model differentiating between deprivation (the absence of expected cognitive and social learning experiences) and threat (the presence of atypical traumatic learning experiences) as differentially impacting brain structure and function (McLaughlin & Sheridan, 2016; McLaughlin, Sheridan, & Lambert, 2014; Sheridan & McLaughlin, 2014, 2016). Within the model, alterations to neurobiological processes based on dimensions of experience underlie differences in psychopathology. Deprivation and threat are theorized dimensions of experience that vary in frequency and severity (see Figure 1). Deprivation can be conceptualized as the result of low levels of parental interaction, reduced childhood exposure to complex language, or fewer opportunities for cognitive exploration or stimulation. Threat can be conceptualized as experiences including physical or sexual abuse, exposure to domestic violence, and direct exposure to community violence. I review current evidence for both dimensions of experience here.

Deprivation

Sheridan and McLaughlin have conceptualized deprivation as the absence of expected cognitive inputs, social inputs and a lack of complexity of inputs. Children with experiences of deprivation include children who have experienced institutionalization, physical neglect, or emotional neglect. Additionally, children who are raised in families with low socioeconomic status (SES) are at higher risk for the absence of expected inputs, including less exposure to language and cognitive stimulation in the home (Bradley & Corwyn, 2002; Hart & Risley, 1995). In this case, low socioeconomic status serves as a marker of risk for experiences of deprivation.

Substantial work from animal models has established a framework for how deprivation may shape neural structure and function. Rodents placed in deprived environments show decreases in brain volume, synapses and dendritic branching (Diamond, Rosenzweig, Bennett, Lindner, & Lyon, 1972; Würbel, 2001). Rodents with less cognitive stimulation in their environment show decreased cortical weight and cortical thickness (Diamond et al., 1972; Uylings, Kuypers, Diamond, & Veltman, 1978) These effects are partially reversible through exposure to cognitively stimulating environments following the period of deprivation (Diamond et al., 1972).

A mechanism through which early deprivation may alter neural structure and function in animals and humans is through synaptic pruning across development (Huttenlocher, de Courten, Garey, & Van der Loos, 1982). Synaptic pruning is the process of synapse elimination that occurs across childhood. Across development, the purpose of synaptic pruning is to remove unnecessary neural structures in the brain. Synapses that are not frequently used are more likely to be eliminated. The process of overproduction of synapses and synaptic pruning allows for flexibility of the developing brain (Tierney & Nelson, 2009). Early experience alters the pruning of synapses, which allows the brain to become more efficient for the current environment (Bick & Nelson, 2015). Within the process of synaptic pruning, different brain structures show distinct developmental trajectories for brain structure and function (Casey, Giedd, & Thomas, 2000; Gogtay & Thompson, 2010; Kolb et al., 2012). In particular, association cortex such as the prefrontal cortex, superior and inferior parietal cortex and superior temporal cortex have more prolonged developmental trajectories compared to primary sensory cortex (Gogtay et al., 2004; Huttenlocher, 1979). Therefore, experiences such as deprivation may have a greater impact on brain regions with longer developmental trajectories, such as association cortex, through the process of synaptic pruning.

Based on prior research on deprivation, children with lower levels of expected cognitive and social input would be predicted to have reductions in cortical thickness and surface area. Due to more extended developmental trajectories, children may show greater reductions in association cortex due to experience-dependent synaptic pruning which would continue to occur across a longer period of development. These differences in brain structure and function would be predicted to result in lower performance on executive functioning tasks. Below I review initial neural and behavioral evidence from children who have experienced institutionalization and poverty that supports these hypotheses.

Executive Functioning

Executive functions are defined as a set of control processes, linked to the prefrontal cortex of the brain, integral to the effortful deployment of cognitive resources for flexible, adaptive responding to shifting contingencies (McTeague, Goodkind, & Etkin, 2016; Miyake & Friedman, 2012). Three components of executive functioning have primarily been identified: updating (monitoring and refreshing working memory stores), inhibition (resisting prepotent responses), and shifting (switching between mental sets) (McTeague et al., 2016; Miyake & Friedman, 2012). Some researchers have also highlighted working memory, inhibition, and selective attention as components of executive functioning (Alvarez & Emory, 2006).

Exposure to Deprivation

Exposure to deprivation includes experiences such as institutionalization and neglect. Additionally, children who live in poverty are at increased risk for exposure to deprivation. Currently, 12.7% of the United States population lives below the poverty line (Bureau, n.d.). The poverty rate for children is even higher, with 18% of children living below the poverty line (Bureau, n.d.). Overall prevalence estimates indicate that 16% of children have experienced physical neglect while 18% of children have experienced emotional neglect worldwide (Stoltenborgh, Bakermans-Kranenburg, & Ijzendoorn, 2013). Worldwide, it is estimated that between 2 million and 8 million children are institutionalized (Dozier, Zeanah, Wallin, & Shauffer, 2012). To date, exposure to deprivation continues to impact young children both inside the United States and worldwide.

Institutionalization

Institutionalization is a profound experience of deprivation, including less interaction with caregivers, disturbances in attachment, fewer opportunities for social stimulation, and less exposure to cognitive stimuli (Nelson et al., 2007; Smyke, Dumitrescu, & Zeanah, 2002; Tottenham, 2012; Zeanah, Smyke, Koga, Carlson, & The Bucharest Early Intervention Project Core Group, 2005). These experiences are associated with decreased cognitive function, as measured by IQ, and language delays (Loman, Wiik, Frenn, Pollak, & Gunnar, 2009; Sheridan, Drury, McLaughlin, & Almas, 2010; Windsor et al., 2011; Windsor, Moraru, Nelson, Fox, & Zeanah, 2013). Furthermore, institutionalization is associated with worse executive functioning compared to healthy child controls (Bos, 2009). In addition, this decrement in performance on working memory and response inhibition tasks partially mediates the association between institutionalization and ADHD symptoms (Tibu et al., 2016).

These differences in behavior may be a result of changes in brain structure and function as a result of synaptic pruning. Consistent with this possibility, institutionalized children have decreased total grey matter volume and reductions in prefrontal, parietal and temporal cortical thickness (McLaughlin, Sheridan, Winter, et al., 2014; Sheridan, Fox, Zeanah, McLaughlin, & Nelson, 2012). There is mixed evidence for how institutionalization shapes brain structure in subcortical regions, such as the amygdala. While some research has indicated smaller amygdala volumes in institutionalized children (Hanson et al., 2015), others have demonstrated larger amygdala volumes in institutionalized samples (Mehta et al., 2009; Tottenham et al., 2010). There is evidence for differences in structural connectivity as well in institutionalized children, including reduced fractional anisotropy in the uncinated fasciculus, corona radiata, cingulum and interior longitudinal fasciculus (Bick et al., 2015; Eluvathingal, 2006; Hanson et al., 2013; Kumar et al., 2014). Thus, there is substantial evidence of alterations to brain structure associated with institutionalization.

As a model to understand early experiences of deprivation, institutionalized samples provide a unique opportunity to explore differences in brain structure associated with changes in behavior. For example, Kreppner and colleagues have proposed that inattention and overactivity may represent a deprivation-specific syndrome (Kreppner, O'Connor, Rutter, & Team, n.d.). Overall, research on institutionalized children suggests that deprivation results in cognitive difficulties and executive function deficits. However, institutionalization is a profound experience of deprivation: more research is needed to generalize research on institutionalization to more common, less severe experiences of deprivation.

Low Socioeconomic Status (SES)

Low socioeconomic status is a risk factor associated with higher experiences of deprivation and higher experiences of threat. Socioeconomic status is typically comprised of parental education, parental occupation, and family income (Bradley & Corwyn, 2002). Children with low socioeconomic status on average have less access to the same resources and experiences as other children. Children from low-income families are read to less frequently and have less access to a wide variety of important resources for cognitive development, such as books in their home, computers, or the ability to visit libraries or museums (Bradley, Corwyn, McAdoo, & García Coll, 2001; Evans, 2004). Children of low-income families receive less language input compared to their same-age peers (Hart & Risley, 1995). Overall, there is evidence that despite wide variability among children and families, children growing up in poverty have fewer cognitive opportunities compared to children of families with higher family income (Duncan & Brooks-Gunn, 1999).

Relatedly, children with low socioeconomic status have associated differences in language and behavior. Children of families with a low income-to-needs ratio have deficits in working memory that are partially mediated by cognitive enrichment in the home (Hackman, Gallop, Evans, & Farah, 2015). Noble and colleagues have demonstrated that a composite of SES comprised on parental education, income-to-needs ratio, and parental occupation is associated with deficits in language abilities and executive functioning (Noble, McCandliss, & Farah, 2007; Noble, Norman, & Farah, 2005). Some of the effects of low SES on cognition are mediated through differences in cognitive stimulation in the home, including the relationship between low SES environments and executive functioning (Hackman et al., 2015; Linver, Brooks-Gunn, & Kohen, 2002; Sarsour et al., 2011). In one review, Hackman and Farah suggest that the effects of poverty disproportionately impact language and executive functioning systems in comparison to other neurocognitive systems (Hackman & Farah, 2009). Children growing up in poverty and children who have experienced institutionalization show deficits on similar complex cognitive tasks, although institutionalization is associated with more profound behavioral differences. This body of research provides initial support that these behavioral deficits may be related to deprivation as a dimension of experience.

There is evidence that the underlying mechanism through which poverty impacts behavior is through alterations in prefrontal cortex structure and function. Children who are raised in families with low SES show reductions in cortical thickness and surface area in the prefrontal cortex (Jednoróg et al., 2012; Lawson, Duda, Avants, Wu, & Farah, 2013; Noble et al., 2015). These differences in cortical thickness have been associated with achievement test performance, likely indicative of broader cognitive functioning (Mackey et al., 2015). There is also evidence that children growing up in poverty have alterations in prefrontal cortex function, some of which has been explained by cognitive experiences such as language input (Raizada, Richards, Meltzoff, & Kuhl, 2008; Sheridan, Sarsour, Jutte, D'Esposito, & Boyce, 2012). Another body of work demonstrated differences in brain structure in other regions, including reduced grey matter volume in the hippocampus and the amygdala (Hanson, Chandra, Wolfe, & Pollak, 2011; Holz, Laucht, & Meyer-Lindenberg, 2015; Jednoróg et al., 2012; Luby, Belden, Botteron, & et al, 2013; Noble, Houston, Kan, & Sowell, 2012). Thus, future work needs to more systematically identify the components within the broad experience of poverty that are associated with differences in brain structure and function. Between the experiences of institutionalization and poverty, which are conceptualized within experiences of deprivation, there are consistencies in behavioral deficits and alterations to brain structure and function suggesting commonalities in how these experiences "get under the skin" to influence children's functioning.

Threat

Within the deprivation and threat model, threatening experiences are conceptualized as exposure to traumatic violence where one believes that oneself or a close other is in danger of being hurt badly or killed. Experiences on the threat dimension also differ in terms of severity, and include physical or sexual abuse, exposure to domestic violence or direct exposure to community violence. Prior research has often categorized these experiences within maltreatment. However, experiences of neglect would not fit within the threat dimension of experience because neglect does not include exposure to traumatic violence.

The deprivation and threat theory postulates that threatening experiences alter the neural circuitry underlying fear learning. Fear is an emotion caused by the belief that an environment is dangerous or threatening to the individual (Steimer, 2002). Fear learning occurs when an animal or human learns to associate a stimulus with threat, allowing for quick or defensive responses to threatening stimuli. Substantial work using animal models has explored how threatening experiences alter fear learning and shape brain structure and function. Below, I review fear learning paradigms and the evidence that early exposure to threat alters emotional functioning in animals and humans.

Fear Learning

Within this body of work and within human research, fear learning paradigms have been used to better understand the links between threatening stimuli and resulting neural activation, alterations to brain structure, and behavior. In fear learning paradigms, the subject is presented with an emotionally neutral conditioned stimulus (CS+), such as a light or tone, with an aversive or threatening unconditioned stimulus (UCS), such as an electric shock. After repeated pairings, as association is formed in which the CS+ elicits the behavioral and neurobiological responses associated with the UCS, which constitutes fear acquisition. Then, the CS is often paired with the absence of the UCS. Fear extinction occurs when the association between the CS and the absence of the UCS is learned by the subject (Phelps & LeDoux, 2005).

Animal research with rodents has identified that the amygdala plays a critical role in fear acquisition (Sevelinges et al., 2007; Thompson, Sullivan, & Wilson, 2008). The amygdala is essential to fear acquisition and the expression of the fear response following conditioning (Phelps & LeDoux, 2005). Lesion studies provide additional information about fear acquisition in humans. Patients with lesions to the amygdala do not show signs of fear acquisition, such as physiological responses of fear (Bechara, Tranel, Damasio, & Adolphs, 1995; LaBar, LeDoux, Spencer, & Phelps, 1995). Based on this body of work, the amygdala is required for fear acquisition and physiological responses to fear.

Fear extinction is the decrease in conditioned fear response after learning a new association between the CS+ and the absence of the UCS (Milad, Rauch, Pitman, & Quirk, 2006). Lesion studies in rats have found that the lesions to the ventromedial prefrontal cortex (vmPFC) impairs recall of fear extinction memories (Lebrón, Milad, & Quirk, 2004; Quirk, Russo, Barron, & Lebron, 2000). One study examining single-cell recording found that the infralimbic prefrontal cortex in rats, corresponding to the vmPFC in humans, responds to extinction recall (Milad & Quirk, 2002). Overall, animal work and human lesion studies have demonstrated the importance of the amygdala and vmPFC in fear acquisition and extinction processes.

Animal research has demonstrated that threatening experiences alter the structure and function of the amygdala. Threatening experiences in childhood in rats leads to changes in amygdala structure and function, including increased dendritic spines in the amygdala and associated anxiety and depression behaviors (Eiland, Ramroop, Hill, Manley, & McEwen, 2012). Based on animal research on experiences of threat, children who have experienced violence would be predicted to have alterations to amygdala function during fear acquisition, alterations to vmPFC function during fear extinction, and increased symptoms of psychopathology. During a fear acquisition and extinction paradigm, children with threatening experiences would be predicted to have differences in physiological reactivity to fear acquisition and extinction. Below I review initial evidence linking behavior and neural activity in individuals who have a history of exposure to threat that supports these hypotheses.

Exposure to Threatening Experiences

In population-based samples, 4-8% of individuals report experiencing physical abuse, 6% of individuals report sexual abuse and 8% of individuals report violence within their family (Green et al., 2010; McLaughlin et al., 2012). Physical abuse, sexual and family violence are all associated with mood disorders, anxiety disorders, substance use, and disruptive behavior (Green et al., 2010; McLaughlin et al., 2012). Overall, these experiences statistically account for 7-8% of all psychological disorders (McLaughlin et al., 2012).

Abuse

There are well-documented associations between exposure to threatening experiences and changes to brain structure (Andersen et al., 2008; De Bellis et al., 2002; Hanson et al., 2010). Abuse and witnessing domestic violence is associated with reductions in grey matter and white matter in a sociodemographically matched sample (De Bellis et al., 2002; Teicher & Samson, 2016). Additionally, there is evidence of specific reductions in volume in the orbitofrontal cortex (De Brito et al., 2013; Hanson et al., 2010), dorsolateral prefrontal cortex (Edmiston et al., 2011; Hanson et al., 2010), and ventromedial prefrontal cortex (Busso, 2016) associated with abuse. These reductions in volume may be driven by reductions in cortical thickness, with evidence of reduced thickness in the ventromedial prefrontal cortex associated with abuse (Gold et al., 2016). Abuse is associated with alterations to subcortical regions as well, including reduced amygdala and hippocampus volume (Hanson et al., 2015). Cumulatively, there is evidence that exposure to threat influences prefrontal brain structure and brain regions associated with fear acquisition and extinction processes.

Exposure to threatening experiences is associated with changes to behavior related to processing of emotion, and in particular threatening stimuli. Children with threatening experiences show heightened abilities to detect anger in facial expressions (Pollak & Kistler, 2002). After exposure to threat, children allocate more attention to angry faces, which mediates the relationship between physical abuse and negative affect (Gibb, Schofield, & Coles, 2008; McCrory, De Brito, & Viding, 2010; Shackman & Pollak, 2014; Shackman, Shackman, & Pollak, 2007). There is some evidence that children with threatening experiences are more attentive to fearful faces as well (Masten et al., 2008). Threatening experiences appear to alter sensitivity to threat-related information in the environment.

The mechanism through which exposure to threat may influence sensitivity to emotional information is through heightened amygdala activation following threatening stimuli. Exposure to threatening experiences in childhood is associated with heighted amygdala reactivity to threat-related emotional stimuli when stimuli are presented consciously and subconsciously (Dannlowski et al., 2012, 2013; McCrory et al., 2013). Children with exposure to family violence show increased amygdala reactivity in response to angry faces (McCrory et al., 2011). One quantitative meta-analysis has identified that maltreatment is associated with increased bilateral amygdala activation to emotional faces (Hein & Monk, 2016). While there is extensive research on differences in neural activation to emotional or threatening faces, there is little research investigating the neurobiological correlates of fear acquisition and extinction in children exposed to threat. Initial evidence suggests that threatening experiences alter responses to emotion stimuli and alter brain structure associated with fear acquisition and extinction. However, it is vital to identify if fear learning processes account for some of these differences in brain structure and behavior. By understanding the mechanisms through which children exposed to threat have alterations in brain structure and emotional learning identify and predict difficulties for children who have experienced threat, particularly in emotional contexts.

To date, there has been one study by McLaughlin and colleagues directly examining behavioral and physiological differences in fear conditioning and extinction associated with threat (McLaughlin et al., 2016). Children without maltreatment exposure showed physiological differences to the conditioned stimulus (CS+) compared to a control conditioned stimulus never paired with a UCS (CS-) during early conditioning. Maltreated children did not show differentiation during early conditioning in their physiological response. This work provides initial evidence that there are physiological differences as a result of maltreatment during a fear conditioning paradigm. In sum, current research on exposure to threat demonstrates associated alterations in brain structure, brain function and behavioral differences that influence sensitivity to threat-related stimuli and impair fear learning during a fear conditioning paradigm.

Summary

The literature reviewed provides support that depriving experiences result in lower performance on executive functioning and complex cognitive tasks. Separately, prior research supports the hypothesis that threatening experiences result in altered processing of threat-related stimuli and impaired fear learning during fear acquisition. In order to be able to differentiate between behavioral changes associated with deprivation and behavioral changes associated with threat, both dimensions of experience must be examined simultaneously. Sheridan, McLaughlin and colleagues have begun to examine depriving experiences and threatening experiences together to differentiate between associations with deprivation and associations with threat. Initial research has suggested that threat is associated with physiological reactivity in adolescence controlling for experiences of deprivation (Busso, 2016). When investigating deprivation and threat in the same model, threat was associated with automatic emotion regulation deficits in adolescence, while deprivation was associated with worse cognitive control (Lambert, King, Monahan, & McLaughlin, 2017). Finally, deprivation in adolescence has been associated with worse executive functioning when controlling for threatening experiences (Sheridan, Peverill, Finn, & McLaughlin, 2017). Overall, evidence has been accumulating supporting the deprivation and threat model with distinct dimensions of experience predicting behavior in adolescence. However, no studies have examined the impact of experiences of deprivation and threat on behavior in early childhood.

It is vital to understand the effects of threatening experiences and depriving experiences at an earlier age. Between birth and three years of age, vast changes in brain development occur that result in dramatic associated changes in behavior (Casey et al., 2000). Research focusing on early childhood can elucidate the underlying mechanisms through which these developmental changes in brain structure and function alter behavior. The deprivation and threat model predicts alterations in executive functioning and fear learning. Most research on executive functioning has focused on early childhood rather than adolescence (Best & Miller, 2010), which is likely because executive functioning shows rapid improvements across early childhood (Anderson, 2002; Davidson, Amso, Anderson, & Diamond, 2006). Across childhood, children also make significant gains in fear learning paradigms as well, in which older children show greater evidence of fear learning in fear conditioning and extinction paradigms (Glenn et al., 2011). Investigating the effects of deprivation and threat in early childhood has the potential to shed light on how dimensions of experience impact the development of executive functioning and fear learning as these abilities are beginning to emerge.

Additionally, by understanding the mechanisms of how dimensions of experience influence behavior in early childhood, it may be possible to intervene early to assist children who are likely to have impairments in executive functioning or fear learning. Educational interventions in early childhood have resulted in long-term gains in cognitive control, one component of executive functioning (Campbell, Pungello, Miller-Johnson, Burchinal, & Ramey, 2001). A diverse range of activities have been shown to improve children's executive functioning and training of executive function may help to avert the developmental trajectories of maladaptive behavior that begin in early childhood (Diamond & Lee, 2011). Due to the developmental trajectories that occur in early childhood, it is particularly important to study experiences of deprivation and threat early. The purpose of the current study is to identify how experiences of deprivation and threat alter early behavior.

Current Study

The current study examines the relationship between experiences of deprivation and threat on behavioral task performance in children 4-7 years old. The deprivation and threat model predicts that experiences of deprivation will be associated with worse performance on working memory and cognitive control behavioral tasks after controlling for threatening experiences. Second, experiences of threat will be associated with worse physiological differentiation between the CS+ and the CS- in a fear conditioning acquisition and extinction paradigm controlling for depriving experiences.

Methods

Participants

64 children ages 4-7 years old and a parent or legal guardian were recruited from Durham and Chapel Hill metropolitan area. Participants were recruited using listserv announcements, flyers, craigslist ads, and databases for participants. Parents provided written consent in accordance with the University of North Carolina Institutional Review Board. Children provided verbal assent if between the ages of four and six years old. Children provided written assent if seven years old. Exclusion criteria for participants included: (1) major medical conditions (e.g., HIV, cancer), (2) neurological illness (e.g., seizure disorders, migraines, multiple sclerosis), (3) factors limiting participant's ability to complete proposed research (e.g., English fluency), and (4) diagnostic history of psychosis, a pervasive developmental disorder (e.g., autism). Children were not excluded for other diagnoses of psychopathology or psychological symptoms. Of these participants, one participant was excluded for inability to complete any behavioral tasks. Thus, the final sample included 63 children.

Procedure

The present study was completed in one visit to the UNC campus at Howell Hall that lasted approximately three hours. Following informed consent procedures, parents of children in the study completed questionnaires assessing deprivation, threat, and symptoms of psychopathology. Children completed the KBIT-2 (Kaufman Brief Intelligence Test), interviews about experiences of deprivation and experiences of threat, behavioral tasks assessing working memory, cognitive control, and a fear conditioning acquisition and extinction paradigm. During the fear conditioning paradigm, skin conductance, behavioral measures, and self-report measures were collected.

Measures

IQ. IQ was assessed through the Kaufman Brief Intelligence Test (KBIT-2) which is a brief IQ measure composed of verbal and nonverbal cognitive abilities for individuals 4 to 90 years old. The verbal scale is composed of Verbal Knowledge and Riddles subtests. The nonverbal scale is composed of a Matrices subtest. The reliability of the composite IQ score from the KBIT is 0.93 in a normative sample (Bain & Jaspers, 2010).

Deprivation measures

Neglect. Neglect was assessed through the Multidimensional Neglectful Behavior Scale (MNBS-CR), a child interview measure (Kantor et al., 2004). The MNBS-CR is an interview for young children to assess neglect using cartoon-based items tailored to the participant's gender and the gender of their primary caregiver (Figure 2). The reliability of the neglect items ranges from 0.66 to 0.94 depending on the sample (Kantor et al., 2004). The present study assessed neglect using the emotional neglect, cognitive neglect, physical neglect, supervisory neglect, and abandonment items (44 items total).

Cognitive Stimulation. The level of age-appropriate scaffolded learning opportunities provided to the child was assessed using the Home Screening Questionnaire (HSQ) (Frankenburg & Coons, 1986). The home screening questionnaire is a parent-report measure based on the Home Observation for the Measurement of the Environment (HOME), an observational measure for use in children's homes to assess cognitive stimulation and emotional support in the home (Bradley, Caldwell, & Corwyn, 2003). The HOME and the HSQ identified the same children in need of support 86% of the time, suggesting that the HSQ may be used if home observation is not possible. The HSQ has good test-retest reliability in children above three years old (0.86) (Frankenburg & Coons, 1986). The current study utilized the sum of the HSQ with five items removed that assessed spanking and parental decision-making in the household, which were not conceptualized as a part of cognitive stimulation (56 items in original scale, 51 items utilized).

Parental Education. Parental education was assessed using the Macarthur Scale of Subjective Social Status (Adler & Stewart, 2007). Parental education was measured as the average of educational attainment for both primary caregivers of the child. If there was one primary caregiver, then the parental education of the one primary caregiver was utilized. Possible responses ranged from "Less than high school diploma" to "Professional degree".

Threat Measures

Violence Exposure. Exposure to violence was assessed using the Violence Exposure Scale for Children-Revised (VEX-R), a child interview measure (Fox & Leavitt, 1995). The VEX-R is a 21-item, cartoon-based interview used to assess young children's exposure to abuse, domestic violence and community violence (Figure 3). Responses are measured on a 4-point Likert scale. VEX-R has good internal consistency ranging from 0.80 to 0.86 (Kolko et al., 2010; Shahinfar, Fox, & Leavitt, 2000). The current study utilized the sum of the total items in which children reported on exposure to violence perpetrated by a teenager or an adult.

Partner Violence. Presence of domestic violence in the home was assessed using the Conflict Tactic Scales (CTS-2), a parent-report measure (Straus, Hamby, Boney-McCoy, & Sugarman, 1996). The CTS-2 consists of 39 items in five subscales: physical assault (12 items), psychological aggression (8 items), negotiation (6 items), injury (6 items) and sexual coercion (7 items). All subscales have good internal consistency (0.79 – 0.95) (Straus et al., 1996). The total sum of the physical assault, psychological aggression, injury, and sexual coercion subscales was used in the present study.

Physical Abuse. The likelihood of physical abuse was assessed using the Child Abuse Potential Inventory (CAPI), a parent-report measure (Milner, Charlesworth, Gold, Gold, & Friesen, 1988). The CAPI is a 160 item scale which screens for parental attitudes which indicate high risk for present or future physical abuse. Internal consistency with different populations ranges from 0.84 to 0.94 (Milner et al., 1988).

Inverse Efficiency

Behavioral task performance on the cognitive control and working memory tasks was assessed through inverse efficiency on the tasks. Inverse efficiency is a measure of behavioral performance that is commonly used on tasks that demonstrate a speed-accuracy tradeoff because the measure incorporates both speed and accuracy into one assessment of performance. Inverse efficiency can be calculated by dividing mean reaction time of correct responses by the proportion of correct responses (Bruyer & Brysbaert, 2011).

Executive Function Assessments

Cognitive Control. The Simon task assessing cognitive control is adapted from a prior cognitive control task for children (Kharitonova, Martin, Gabrieli, & Sheridan, 2013). In this task (Figure 4), children press a button on the same side of a screen if the stimulus is one color (congruent trials), and the opposite side from the stimulus if the stimulus is a different color (incongruent trials). On incongruent trials, children must inhibit a prepotent response (to press on the same side) in favor of a conflicting response (to press on the opposite side). This task has been successfully completed previously with young children (Kharitonova et al., 2013).

Cognitive control task performance is measured by inverse efficiency for incongruent trial blocks compared to inverse efficiency for congruent trial blocks.

Working Memory. The task assessing working memory is adapted from (Kharitonova, Winter, & Sheridan, 2015). In this task (Figure 5), children are shown a cue for 500 milliseconds (ms) to indicate the start of the trial. Then, they are shown a visual array of one or two circles within a 3 × 4 grid for 750 ms (encoding period). In the low-load condition, the child sees one circle on the screen. In the high-load condition, children see two circles to encode on the screen. Children hold this array in working memory for 1700 ms and then make a judgment about whether the color of a single shape is different or the same as the encoding phrase (probe). The probe is presented for 2000 ms. On 50% of trials, the color of the shape remained the same (match trials), while on the remaining 50% of trials, the color of the probe changed (nonmatch trials). Location of the probe stayed constant across the encoding and probe periods. This task has been successfully completed previously in young children (Kharitonova, Winter, & Sheridan, 2015). Working memory performance is operationally defined as inverse efficiency on the high-load trials of the working memory task compared to low-load trials.

Cognitive control and working memory task performance data acquisition and analyses. Task performance data for cognitive control and working memory tasks were collected using E-Prime Version 2.0. Task performance variables were extracted from E-Prime, exported into Microsoft Excel, and entered into SPSS Version 24. Descriptive statistics (i.e., mean and standard deviations) were calculated for all study variables. For the cognitive control task, three children were unable to complete the task for a total sample of 60 children. Participants were excluded from the cognitive control task if they performed below 50% accuracy on the congruent trials of the task. No children were excluded from the cognitive control task due to low performance. Participants were considered outliers if their task performance exceeded two standard deviations from the group means. In the cognitive control task, two children were excluded due to outliers for a final sample of 58 children.

For the working memory task, six children were unable to complete the task due to difficulty for a total of 57 children that completed the task. Participants were excluded from the working memory task if they performed below chance on a low load condition of the working memory task (below 50% accuracy). Using the exclusion criteria, five children were excluded from the working memory analyses for a sample of 52 children. Additionally, participants were considered outliers if their task performance exceeded two standard deviations from the group means. In the working memory task, three children were excluded due to outliers for a final sample of 49 children in working memory analyses.

Fear Conditioning Data Acquisition and Analyses

The present study uses a block design fear conditioning and extinction paradigm for young children. In the task, children will view two shapes (e.g.: blue square and orange diamond) one at a time on a computer screen (Figure 6). The two shapes are randomized across participants as the CS+, conditioned stimulus paired with an unconditioned stimulus (UCS), and the CS-, conditioned stimulus never paired with an unconditioned stimulus. Children will view 12 blocks of stimuli during fear acquisition: 4 blocks containing the CS+ reinforced (CS+R) with an aversive loud sound (UCS), 4 blocks of the CS+ non-reinforced without the UCS (CS+NR), and 4 blocks of the CS-. In each block, children will view 10 stimuli. In the blocks containing the CS+ and the UCS (CS+R), children will hear the UCS sound in 8 out of 10 trials. Before and after fear acquisition, children will report which shape was on the screen when they heard a sound. During fear extinction, children will view 8 blocks of stimuli: 4 blocks of the CS+NR and

4 blocks of the CS-. Then, children will report memory of which shape was associated with the sound. On 2/10 of the trials in all blocks, children will press to a probe to measure attention during the task.

Behavioral performance data for fear acquisition and extinction paradigm was collected using E-Prime Version 2.0. Skin conductance response data was collected using Mindware. Descriptive statistics were calculated for all study variables. For behavioral performance data, two children did not consent or were unable to complete the task for a total sample of 61 children. Due to technical problems, data from four children was not obtained or was unusable. Six children aborted the task during fear acquisition or fear extinction for a total of 51 children with complete behavioral data.

For skin conductance data, the ten participants excluded from behavioral data were also excluded from skin conductance analyses. Three additional children were excluded due to unusable skin conductance data due to technical problems. Three children did not provide consent to collect skin conductance data. Thus, 45 children were included in skin conductance analyses with complete data.

Data Analysis

The primary aims of the study are as follows: (Aim 1) the deprivation dimension of experience will predict performance on executive functioning tasks controlling for threatening experiences and (Aim 2) the threat dimension of experience will predict poor fear learning controlling for depriving experiences. Aim 1 was tested separately for two dimensions of executive function: cognitive control and working memory.

Fear learning is operationally defined with behavioral and physiological measures. Behavioral data is defined as reaction time to a cue on 2/10 of all trials during fear acquisition and fear extinction. Physiological arousal is measured by number of skin conductance responses and the mean skin conductance level during acquisition and extinction for each trial block (CS+R, CS+NR, and CS-).

Deprivation Measure. The deprivation dimension of experience score was derived from the sum of parent measures (parental education, HSQ) and child measures (MNBS-CR) assessing deprivation. First, the data from the HSQ and parental education was transformed. The total score for each child was subtracted from the maximum score possible on each measure so that for all measures, higher totals on the measure indicated a higher level of deprivation. Then, for each measure, each score was converted into a z-score compared to participants within the sample. The sum of the z-scores on each measure comprises the overall score on the deprivation dimension of experience. The deprivation variable was tested for violations of normality using the Shapiro-Wilks test indicating that the data were statistically normal ($p > .05$). Deprivation was also indicated to be normally distributed with a skewness of 0.4 ($SE = 0.3$) and kurtosis of 0.1 ($SE = 0.6$) (Figure 7).

Threat Measure. The threat dimension of experience score was comprised of a score derived from the sum of parent and child measures assessing threat: the VEX-R, the CTS-2, and the CAPI. For each measure included, the relevant score was converted into a z-score. The sum of the z-scores on each measure comprises the overall score on the threat dimension of experience. The threat dimension of experience was tested for violations of normality using the Shapiro-Wilks test indicating that the data was non-normally distributed ($p < .05$). Threat was also indicated to be non-normally distributed with a skewness of 1.8 ($SE = 0.3$) and kurtosis of 3.4 ($SE = 0.6$). Examination of the distribution of the threat dimension of experience revealed outliers with high values of threat relative to rest of the sample (Figure 8). Due to theoretical interest in children with high threat scores, these individuals were retained in analyses.

Statistical Analyses

Multiple linear regression models were used to predict task performance on executive functioning tasks. For the analysis of cognitive control task performance, the dependent variable was inverse efficiency on incongruent trials. Higher levels of inverse efficiency indicate slower reaction time and/or lower accuracy. Predictors included inverse efficiency on congruent trials, age, gender, IQ, the threat dimension of experience, and the deprivation dimension of experience. For the analysis of working memory task performance, the dependent variable was inverse efficiency on high-load trials. Predictors included inverse efficiency on low-load trials, age, gender, IQ, the threat dimension of experience, and the deprivation dimension of experience.

During the fear acquisition and extinction paradigm, questionnaire data, reaction time data and skin conductance data were collected. Descriptive statistics (i.e., mean and standard deviations) were analyzed for questionnaire variables. Descriptive statistics were analyzed for behavioral variables. Paired *t*-tests were used to analyze main effects of reaction time. Multiple linear regression models were used to predict reaction time separately during fear acquisition and fear extinction. In the fear acquisition model, the dependent variable was reaction time to the CS+NR during fear acquisition. Predictors included reaction time to the CS- during acquisition, age, gender, IQ, the threat dimension of experience, and the deprivation dimension of experience. In the fear extinction model, the dependent variable was reaction time to the CS+NR during fear extinction. Predictors included reaction time to the CS- during extinction, age, gender, IQ, the threat dimension of experience, and the deprivation dimension of experience.

Repeated-measures analysis of variance (ANOVA) models were used to predict skin conductance response during the fear acquisition and extinction paradigm. Physiological data was collected using Mindware. Skin conductance is measured through two electrodes attached to the palm of the non-dominant hand. Data are sampled at 1000 Hz. Data are filtered and smoothed using Mindware. All data was manually examined and edited for each participant. Using Mindware data analysis software, the number of skin conductance responses and the mean skin conductance level was collected for each trial type (CS+R, CS+NR, and CS-) across acquisition and extinction blocks.

Two models to predict skin conductance data in acquisition were utilized. In the first model, the dependent variable was the number of skin conductance responses across fear acquisition. In a second model, the dependent variable was the mean skin conductance level across fear acquisition. In the fear acquisition models, repeated measures included time for the four blocks of acquisition and CS type (CS- and CS+NR). Predictors included the threat dimension of experience, the deprivation dimension of experience, age, gender, and IQ. Then, two models were constructed to predict skin conductance response in extinction. In the first model, the dependent variable was the number of skin conductance responses across extinction. In the second model, the dependent variable was the mean skin conductance level across fear extinction. In the fear extinction models, repeated measures included time (four blocks of fear extinction) and CS type (CS- and CS+NR). Predictors included the threat dimension of experience, the deprivation dimension of experience, age, gender, and IQ.

Results

Sample Characteristics

In the sample, children ranged from four to seven years of age. The IQ of the sample represented a normal distribution of IQ with a mean of 99.6 and standard deviation of 15. The dimensional measures of deprivation and threat were constructed with a mean score of 0 from the sum of the z-scores of relevant measures. 36 children identified as female (56.3%) and 27 children identified as male (42.2%). Sample characteristics are presented in Table 1. Age, gender, and IQ were used as covariates in all analyses.

Deprivation and Threat Correlations

Correlations between measures of deprivation are presented in Table 2. Parental education was significantly correlated with the HSQ, which assesses cognitive stimulation in the home, and the MNBS-CR, which assesses child-reported neglect. The HSQ and MNBS-CR were not significantly correlated. Correlations between measures of threat are presented in Table 3. All measures of threat were significantly correlated with each other. Finally, correlations between the deprivation dimension of experience and the threat dimension of experience were examined. Results indicate that deprivation and threat were not significantly correlated in this sample ($r = 0.15$, p = ns). These results indicate that the impact of deprivation and the impact of threat can be analyzed within one model to examine behavioral task performance within this population.

Cognitive Control

Main Effects. Children responded with 84.2% accuracy on the task with 86.6% accuracy on congruent trials and 81.5% accuracy on incongruent trials. Children were more accurate on congruent trials than incongruent trials ($t = 3.75$, $p < .001$). Children completed trials overall in 721 ms on average with a mean of 697 ms to complete a congruent trial and a mean of 745 ms to complete an incongruent trial. Children were faster to complete congruent trials than incongruent trials ($t = -4.79$, $p < .001$). Children also performed significantly better on congruent trials than incongruent trials using the inverse efficiency measure ($t = -6.35$, $p < .001$).

Associations with Experience. A multiple regression model significantly predicted inverse efficiency of incongruent trials during the cognitive control task $F(6, 51) = 53.59$, p < .001, adj. $R^2 = .85$ (Table 4). As predicted, deprivation significantly predicted inverse efficiency of incongruent trials when controlling for inverse efficiency of congruent trials, age, gender, IQ, and threatening experiences ($\beta = 0.14$, $p < .05$, Figure 9. Children with higher levels of depriving experiences exhibited worse task performance on incongruent trials of the cognitive control task controlling for congruent trial performance, age, gender, IQ, and threatening experiences. Threatening experiences did not significantly predict cognitive control task performance. Age was significantly associated with task performance: older children performed better on incongruent trials with the above covariates ($\beta = -0.19$, $p < .05$). Gender did not have a significant effect on task performance. Higher IQ was associated with improved task performance on incongruent trials controlling for covariates ($\beta = -0.12$, $p < .05$).

Working Memory

Main Effects. Children responded with 78.3% accuracy on the task with 82.8% accuracy on low-load trials and 73.8% accuracy on high-load trials. Children were more accurate on low-load trials than high-load trials ($t = 6.18$, $p < .001$). Children completed trials overall in 1,399 ms on average with a mean of 1,355 to complete a low-load trial and a mean of 1,444 ms to complete a high-load trial. Children were significantly faster to complete low-load trials than high-load trials ($t = -5.92$, $p < .001$). Children also performed significantly better on low-load trials than high-load trials using the inverse efficiency measure ($t = -5.53$, $p < .001$).

Associations with Experience. A multiple regression model significantly predicted inverse efficiency of high-load trials during the working memory task $F(6, 42) = 27.91$ $p < .001$, adj. $R^2 = .77$ (Table 5). Deprivation was not significantly associated with inverse efficiency of high-load trials when controlling for inverse efficiency of low-load trials, age, gender, IQ, and threatening experiences ($\beta = -0.09$, p = ns). Threatening experiences did not significantly predict working memory task performance. Age was not significantly associated with working memory task performance. Gender did not have a significant effect on task performance. IQ was not associated with working memory task performance.

Fear Acquisition and Extinction

Descriptive Statistics. Following fear acquisition, 87% of children were able to distinguish between the CS+ and the CS- in a forced-choice question asking, "Which shape was on the screen when you heard a sound?" Following fear extinction, 82% of children were able to distinguish between the CS+ and the CS- using the same forced-choice question. Children responded with 83.9% accuracy to the cue during fear acquisition. Children responded 84.8% accuracy to the cue during fear extinction. There were no significant differences by CS type in accuracy during fear acquisition or fear extinction.   There were no significant differences by CS type in reaction time during fear acquisition or fear extinction across all participants.

Fear Acquisition Reaction Time. A multiple regression model significantly predicted reaction time during fear acquisition $F(6, 44) = 7.60$ $p < .001$, adj. $R^2 = .44$ (Table 6). Threat was not significantly associated with reaction time to the CS+NR when controlling for reaction time to the CS-, age, gender, IQ, and depriving experiences ($\beta = 0.01$, p = ns). Depriving experiences did not significantly predict reaction time during fear acquisition. Age was significantly associated with reaction time to the CS+NR during fear acquisition. Older children exhibited faster reaction time to the CS+NR when controlling for the CS-, gender, IQ, threatening experiences, and depriving experiences. Gender was not significantly associated with reaction time to the CS+NR during fear acquisition. IQ was not associated with reaction time to the CS+NR during fear acquisition.

Fear Extinction Reaction Time. A multiple regression model significantly predicted reaction time during fear extinction $F(6, 44) = 8.63$ $p < .001$, adj. $R^2 = .48$ (**Table 7**). Threat was significantly associated with reaction time to the CS+NR during extinction when controlling for reaction time to the CS- during extinction, age, gender, IQ, and depriving experiences ($\beta = -0.24$, $p < .05$) (Figure 10). Children with higher levels of threatening experiences were faster to respond to the CS+NR controlling for the reaction time to the CS-, age, gender, IQ, and depriving experiences. Depriving experiences did not significantly predict reaction time to the CS+NR during fear extinction. Age, gender, and IQ were not significantly associated with reaction time to the CS+NR during fear extinction.

Fear Acquisition Skin Conductance. A repeated measures ANOVA was run to determine the impact of the threat dimension of experience on the total number of skin conductance responses during fear acquisition over time (four blocks of acquisition) and CS type (CS-, CS+NR) (Table 8). No significant interactions between time, CS type, and Threat were observed. There was a significant main effect of age ($F(1, 39) = 4.5$, $p < .05$). Older children exhibited fewer skin conductance responses.

A repeated measures ANOVA was run to determine the impact of the threat dimension of experience on the mean skin conductance level during fear acquisition over time (four blocks of acquisition) and CS type (CS-, CS+NR) (Table 9). Again, in this model there were no significant interactions between time, CS type, and Threat. There was a significant main effect of age ($F(1, 39) = 7.92$, $p < .05$). Older children exhibited lower mean skin conductance levels.

Fear Extinction Skin Conductance. A repeated measures ANOVA was run to determine the impact of the threat dimension of experience on the total number of skin conductance responses during fear extinction over time (four blocks) and CS type (CS-, CS+NR) (Table 10). There was a statistically significant interaction of Time x CS Type x Threat ($F(3, 117) = 4.13$, $p < .01$) (Figure 11, Figure 12). Earlier in extinction, threat predicted number of skin conductance responses to the CS+NR controlling for age, gender, IQ, and number of responses to the CS-. There was a significant main effect of gender ($F(1, 39) = 2.1$, $p < .05$). Female children exhibited fewer skin conductance responses.

A repeated measures ANOVA was run to determine the impact of the threat dimension of experience on the mean skin conductance level during fear extinction over time (four blocks) and CS type (CS-, CS+NR) (Table 11). There were no significant interactions between time, CS type, and Threat for mean skin conductance response during extinction. There was a significant main effect of age ($F(1, 38) = 7.35$, $p < .05$). Older children exhibited lower mean skin conductance levels.

Conclusions

The present study examined associations between deprivation, threatening experiences, and behavior in early childhood. The study hypothesized that deprivation would be associated with impaired executive functioning (operationalized as cognitive control and working memory) controlling for threatening experiences. The results suggest that deprivation is associated with impaired cognitive control in early childhood. Children with higher levels of deprivation exhibited worse performance on incongruent trials of the cognitive control task controlling for congruent trials, age, gender, IQ and threatening experiences. Thus, children with more experiences of deprivation had more difficulty inhibiting a prepotent response in favor of another response.

Prior research has found that children raised in institutions, a severe experience of deprivation, demonstrated lower performance on inhibitory control tasks (Tibu et al., 2016). Similarly, young children from families with low socioeconomic status have shown deficits in inhibitory control (Noble et al., 2005; Sarsour et al., 2011). Therefore, the findings of the present study are consistent with an overall body of work that suggests deprivation in early childhood is associated with impaired inhibitory control. Prior work examining the deprivation and threat model has also found evidence that deprivation impacts inhibitory control in adolescence. Poverty was associated with impaired inhibitory control in adolescence when controlling for child abuse and exposure to community violence (Lambert et al., 2017). Deprivation has also been associated with problems related to executive function in adolescents when controlling for community violence and abuse (Sheridan et al., 2017). The present study contributes to a growing body of evidence for the specificity of experiences of deprivation in impacting inhibitory control by controlling for threatening experiences, which did not exhibit a significant effect on inhibitory control performance. Furthermore, the current study suggests that the specific effect of deprivation on inhibitory control begins in early childhood and continues to impact executive functioning through adolescence.

The study additionally hypothesized that deprivation would be associated with impaired working memory performance. The results of the present study suggest that deprivation is not associated with impaired working memory performance in early childhood, contrary to study hypotheses. In a previously institutionalized sample, children with a history of institutionalization demonstrated worse working memory performance at eight years old (Tibu et al., 2016). While children from families with low socioeconomic status have consistently shown executive functioning deficits, some studies have identified working memory deficits (Farah et al., 2006; Hackman et al., 2015; Noble et al., 2007), while others have not demonstrated a significant effect of socioeconomic status on working memory (Engel, Santos, & Gathercole, 2008; Noble et al., 2005). Prior work examining the deprivation and threat model has found that low socioeconomic status was associated with impaired working memory performance and inefficient neural recruitment during working memory tasks in adolescence (Sheridan et al., 2017). While there is some evidence that deprivation is related to working memory performance in prior research, there is mixed evidence on when this relationship occurs developmentally. Our results indicate that effects of deprivation on working memory may not be evident in early childhood.

Overall, the present study suggests that in early childhood, deprivation is associated with impairment in one component of executive functioning but not another. Deprivation may not be consistently associated with working memory deficits because working memory neural circuitry may not be adequately developed across early childhood. Prior work has suggested that the integrity of cortical and corticostriatal circuity is not adequately developed in children four years old (Luciana & Nelson, 1998). Some research has suggested that working memory components are present at four years old (Alloway Tracy Packiam, Gathercole, & Pickering, 2006). However, other studies have suggested that improvement of children's performance on visuospatial working memory tasks over time is dependent on recoding visually presented information into a phonological form (spontaneous rehearsal), a process which can be reliably used around eight years old (Gathercole, Pickering, Ambridge, & Wearing, 2004; Hitch, Halliday, Schaafstal, & Schraagen, 1988; Pickering, 2001). In contrast, children demonstrate inhibitory control at a substantially younger age. Preschoolers can successfully inhibit a prepotent response and continue to make dramatic improvements in speed and accuracy through approximately six years old (Anderson, 2002; Best & Miller, 2010). The current study suggests that deprivation does not exert an influence on working memory in children 4-7 years old. Since prior work suggests that deprivation is associated with working memory in adolescence, future work should identify the specific developmental timing in which deprivation begins to influence working memory systems. Conversely, substantial evidence suggests that deprivation has an impact on cognitive control both in early childhood and adolescence. The present study demonstrates that deprivation controlling for threat does exert an influence on cognitive control in early childhood, which is consistent with work in adolescence. This body of work suggests that experiences of deprivation may be impacting inhibitory control for children from early childhood through adolescence, highlighting a need to intervene for these children.

Next, the study hypothesized that threat would be associated with impaired fear learning processes during fear acquisition and fear extinction. Results indicate that threatening experiences are associated atypical fear learning during fear extinction but not during fear acquisition in early childhood. Little prior research has examined the impact of threatening experiences on fear learning in early childhood. One prior study in children 6-18 years old found that children who had experienced maltreatment failed to differentiate between the CS+ and the CS- during fear conditioning, suggesting poor discrimination between threatening cues and safety cues. The present study suggests that young children with threatening experiences may have atypical discrimination between the CS+ and CS- in fear extinction.

In the present study, children with higher levels of threatening experiences responded faster to cues during CS+ trials in extinction compared to children with lower levels of threatening experiences. Faster reaction time in CS+ trials during extinction suggests that children with more threatening experiences may have been more vigilant during CS+ trials compared to children with lower levels of threatening experiences. Behaviorally, this finding indicates that children with higher levels of threatening experiences demonstrated an attentional bias towards threat-related cues during fear extinction controlling for depriving experiences. Children with anxiety disorders have been shown to demonstrated a threat-related attentional bias across numerous studies (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007; Puliafico & Kendall, 2006). Prior work has also identified threat-related attention biases towards social threats in children diagnosed with post-traumatic stress disorder (PTSD) (Dalgleish, Moradi, Taghavi, Neshat-Doost, & Yule, 2001) and attentional biases towards social threats in children who have experienced physical abuse (Pollak & Tolley-Schell, 2003; Shackman et al., 2007). Threat-related biases towards threat have been similarly identified in adults diagnosed with PTSD (Fani et al., 2012). However, some studies have found that children have an attentional bias away from threat in children who have experienced maltreatment (Pine et al., 2005).

Prior work on threat-related attention biases have used substantially different behavioral measures, typically using a visual-probe or "dot-probe" paradigm rather than behavioral data from a fear conditioning and extinction paradigm (Dalgleish et al., 2001; Dalgleish et al., 2003; Pollak & Tolley-Schell, 2003). Therefore, there is no prior work with directly comparable findings. The current study demonstrated that children with higher levels of threatening experiences have a threat-related attention bias during fear extinction towards threat-related cues. The present study also provides initial evidence for the specificity of threat in impacting attentional bias during fear extinction by controlling for depriving experiences, which did not exhibit a significant effect on behavior. Future work should aim to replicate these initial findings.

Skin conductance data demonstrated that children with higher levels of threatening experiences had atypical physiological discrimination between the CS+ and the CS- measured by the number of skin conductance responses during fear extinction, resulting in a significant Time x CS Type x Threat interaction during fear extinction. Children with lower levels of threatening experiences initially show more skin conductance responses to the CS+NR during extinction and then habituate over time, suggesting that they are learning (measured by physiological response) that the CS+NR is a safe stimulus. The converse of this observation is that children with higher levels of threatening experiences initially show more skin conductance responses to the CS- during extinction and then habituate over time. This difference could be accounted for by if children with higher levels of threatening experiences may have generalized the fearful experience of fear acquisition to the CS+ and the CS-. The results suggest that children with higher levels of threatening experiences are experiencing fear overgeneralization measured by physiological arousal during fear extinction.

While there is only one prior study assessing the impact of threat on fear conditioning in children or adolescents, there is substantial prior research on adults with PTSD, and children and adults with anxiety disorders. Adults with PTSD have demonstrated higher physiological arousal measured by fear-potential startle to the CS-, or a safety cue (Jovanovic et al., 2010). Adults with PTSD have also shown reduced ability to discriminate between the CS+ and the CS- (Blechert, Michael, Vriends, Margraf, & Wilhelm, 2007). Among individuals with anxiety disorders broadly, there is substantial evidence of the failure to inhibit a fear response in the presence of the CS-, a safety cue (Duits et al., 2015). As described in the most recent meta-analysis on fear conditioning in anxiety disorders, this effect may represent an impaired ability to inhibit fear in the presence of safety cues or an increased tendency to generalize fear responses to safe stimuli resembling a danger cue (Duits et al., 2015) Higher levels of physiological arousal to the safety cue has also been associated with anxiety disorders in childhood (Jovanovic et al., 2014). Overall, the present study indicates through behavioral and physiological markers of fear learning that children with more threatening experiences have a threat-related attentional bias in extinction and overgeneralization of physiological response to the CS- during extinction.

Taken together, these findings support the specificity of deprivation in its association with cognitive control deficits and the specificity of threat in impaired fear learning processes during fear extinction. The findings also demonstrate the importance of measuring deprivation and threat individually in studies examining the effects of early adversity on behavior. Prior work on early adversity has typically measured all types of early adversity together, most commonly as a cumulative risk measure of the total number of experiences of early adversity.

Given the specificity of deprivation and threat in their influences on behavior in early childhood, combining all measures of early adversity together may mask the associations between dimensions of experience and behavior.

Additionally, the results suggest that deprivation and threat begin to impact children's behavior in early childhood, as early as preschool-age in the youngest participants in the sample. Therefore, the results suggest an early and extended developmental trajectory for how deprivation and threatening experiences influence behavior across childhood and adolescence. These results demonstrate a need for early intervention for children who have experienced deprivation and threat. The results predict different types of impairment in behavior based on the types of experiences that young children have faced. By understanding the relationship between dimensions of experience and behavior, future research can develop interventions for young children based on likely impairment associated with early adversity.

Study Limitations and Future Directions

No prior studies have explored the impact of the deprivation dimension of experience and the threat dimension of experience on behavior in early childhood. The study makes a novel contribution by examining early adversity as dimensions of experience in early childhood when the brain is rapidly developing, and by controlling for the other dimension of experience in all analyses. However, several limitations should be noted. First, these findings come from a small sample drawn from a single geographic location. Therefore, it is unknown how these findings would apply to larger samples across diverse geographical areas with a broader range of experiences of deprivation and threatening experiences. Second, age, gender, IQ, and the other dimension of experience (either deprivation or threat), were used as covariates in all analyses. In larger samples, there are additional covariates that would be recommended to account for other differences in children who have experienced early adversity, such as measures of prenatal exposure to illegal substances, prenatal maternal stress, nutrition, lead exposure, and other environmental toxic exposures. Third, the results of the present study are correlational: experiences of deprivation and threat were not manipulated. For that reason, strong causal arguments are not possible within this model. Finally, the present study did not follow families longitudinally and did not examine how deprivation and threat are related to brain structure and function. Future work should investigate the relationship between deprivation and threat in its influence on brain structure and function in early childhood.

Summary

In summary, this study documents that deprivation is associated with impaired cognitive control and that threatening experiences are associated with impaired fear learning processes in extinction for young children 4-7 years old. We provide evidence of these associations controlling for age, gender, IQ, and the other dimension of experience. The findings suggest that deprivation and threat have specificity in their impact of behavior in early childhood.

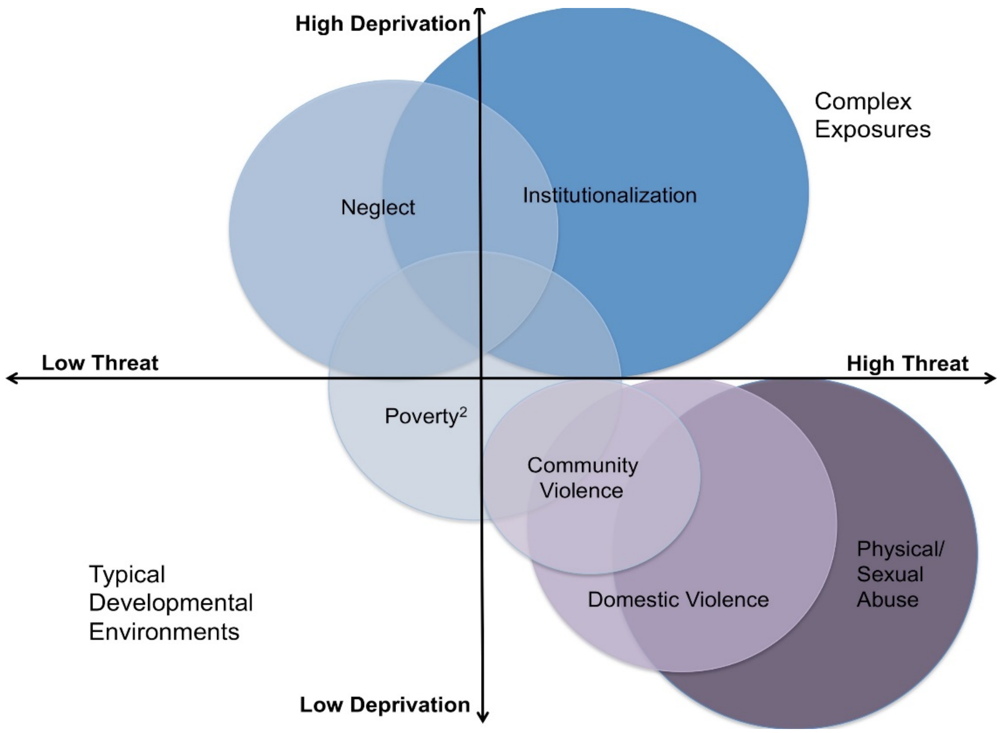

Figure 1. Proposed dimensions of experience: deprivation and threat.

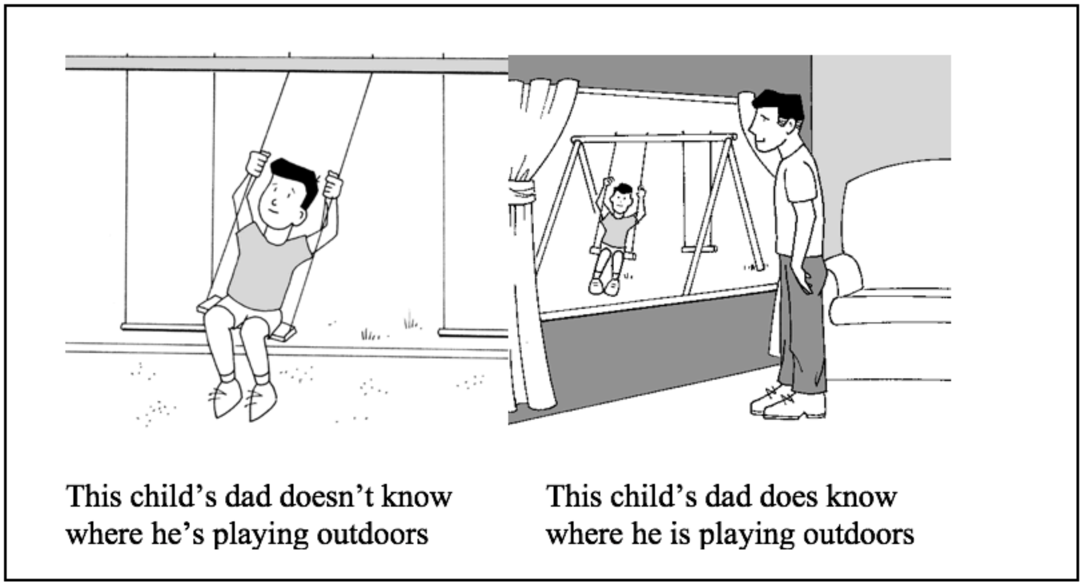

Figure 2. Sample item from the MNBS-CR.

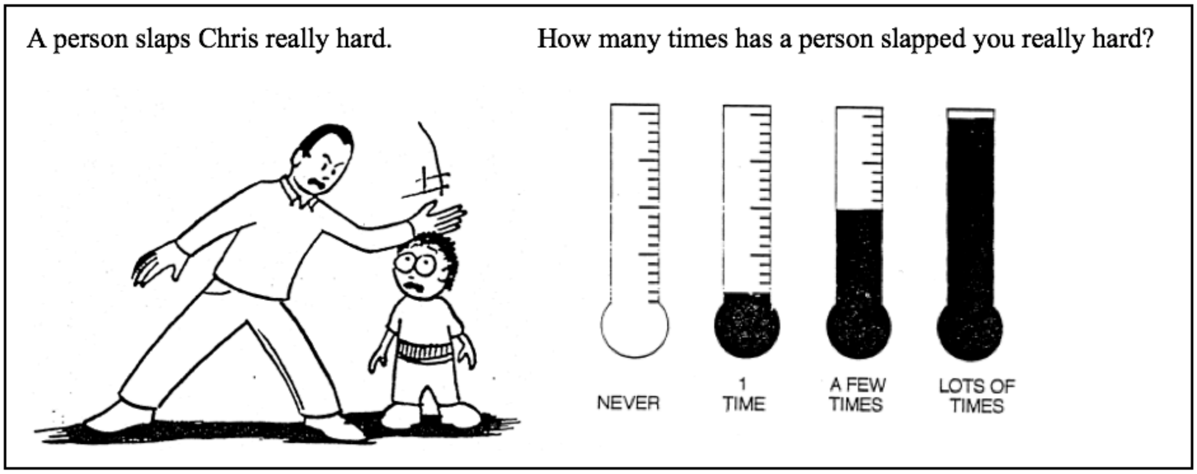

Figure 3. Sample item from the VEX-R.

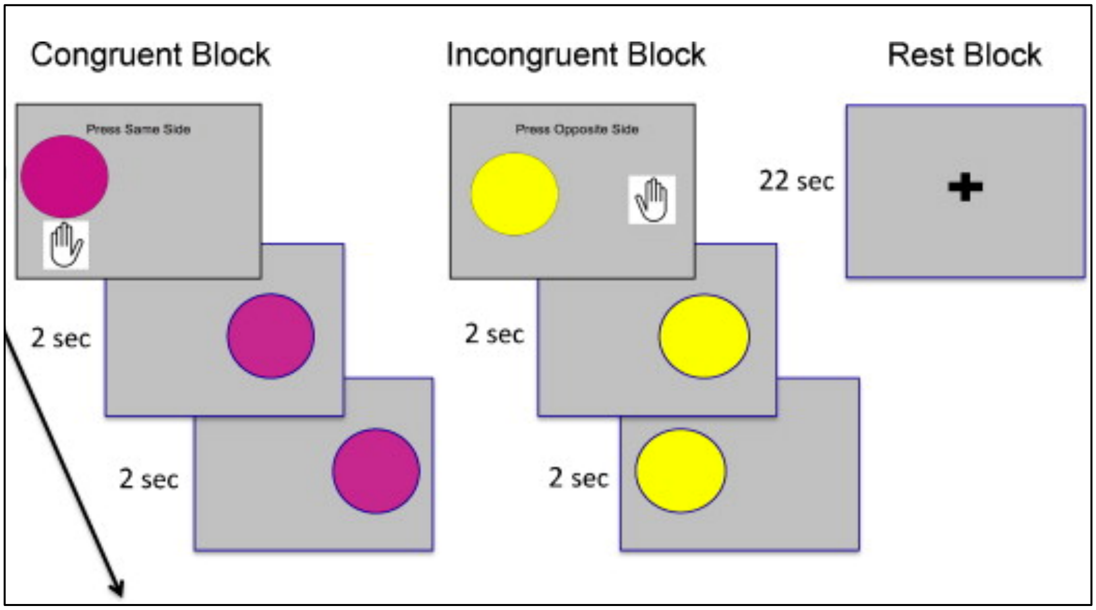

Figure 4. Cognitive control task.

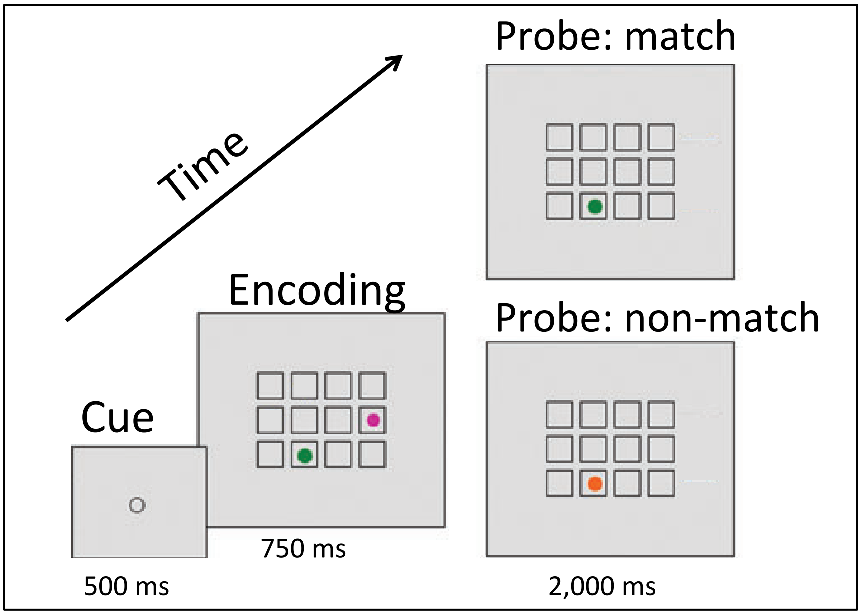

Figure 5. Working memory task.

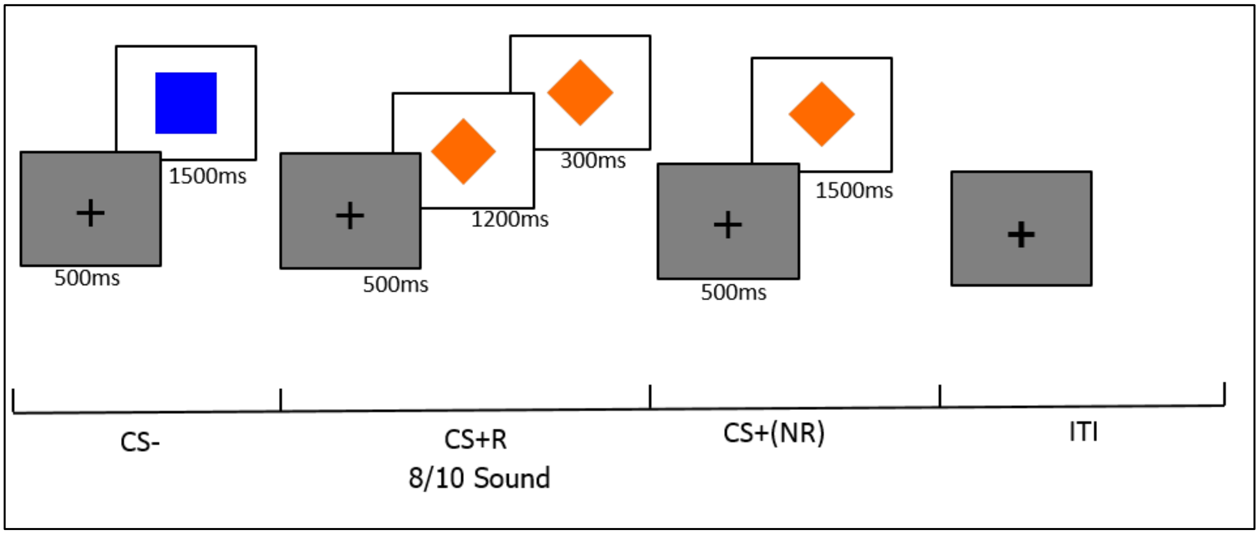

Figure 6. First block of fear conditioning task.

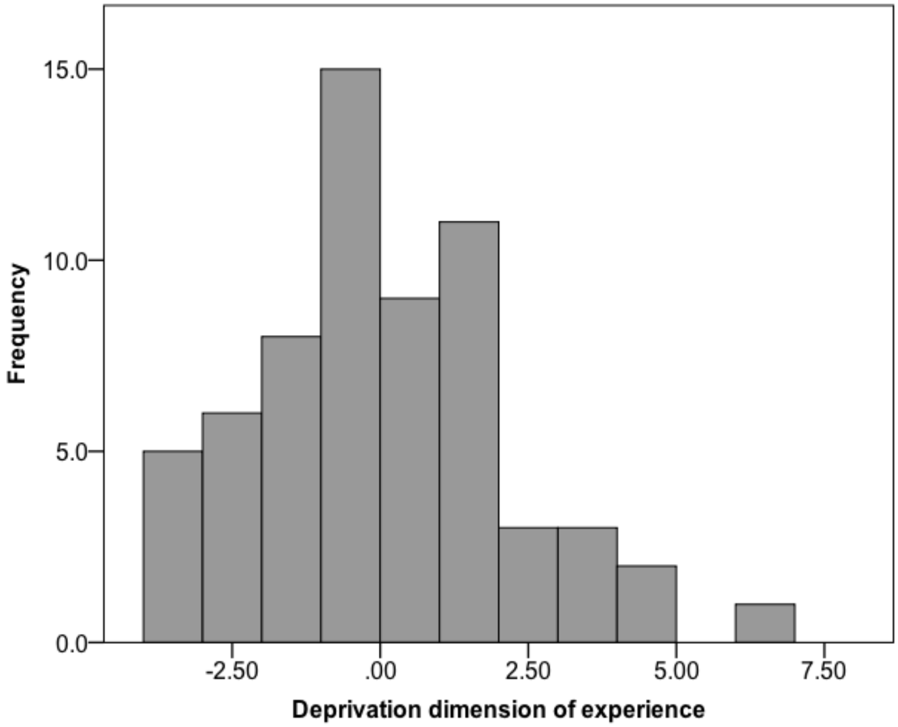

Figure 7. Histogram of deprivation dimension of experience.

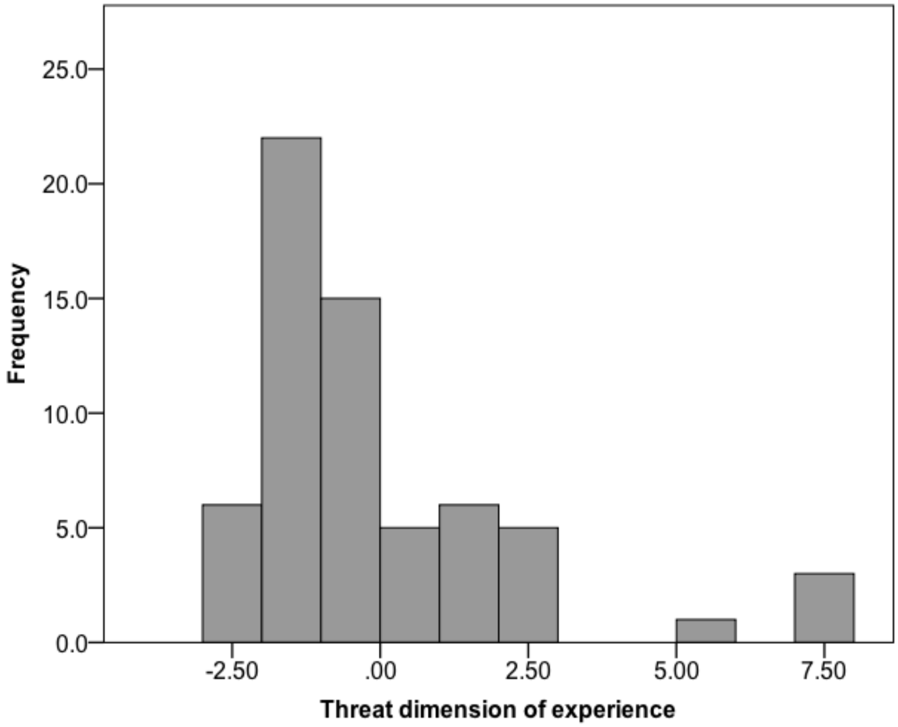

Figure 8. Histogram of threat dimension of experience.

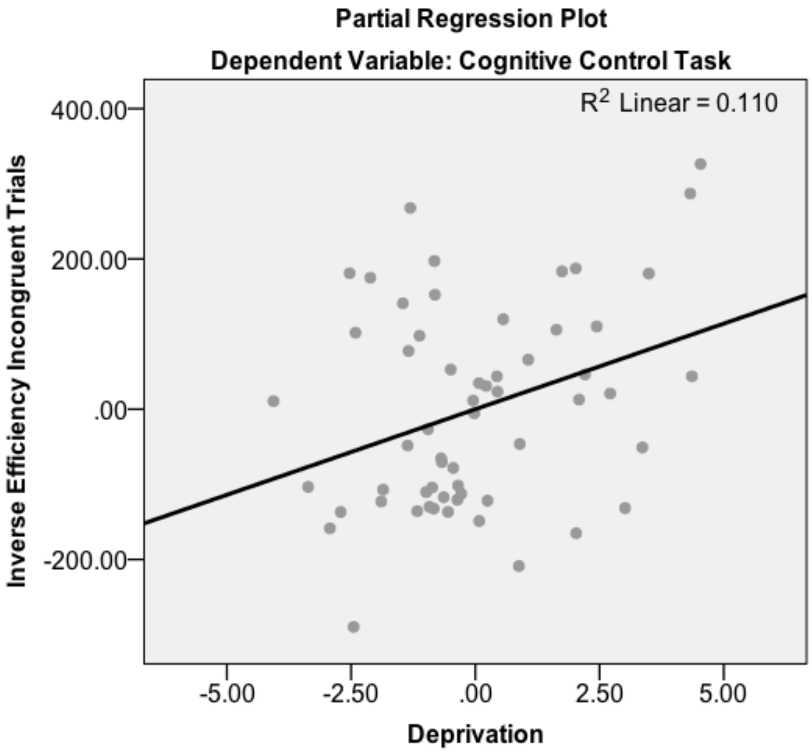

Figure 9. Partial regression plot of deprivation on cognitive control task performance

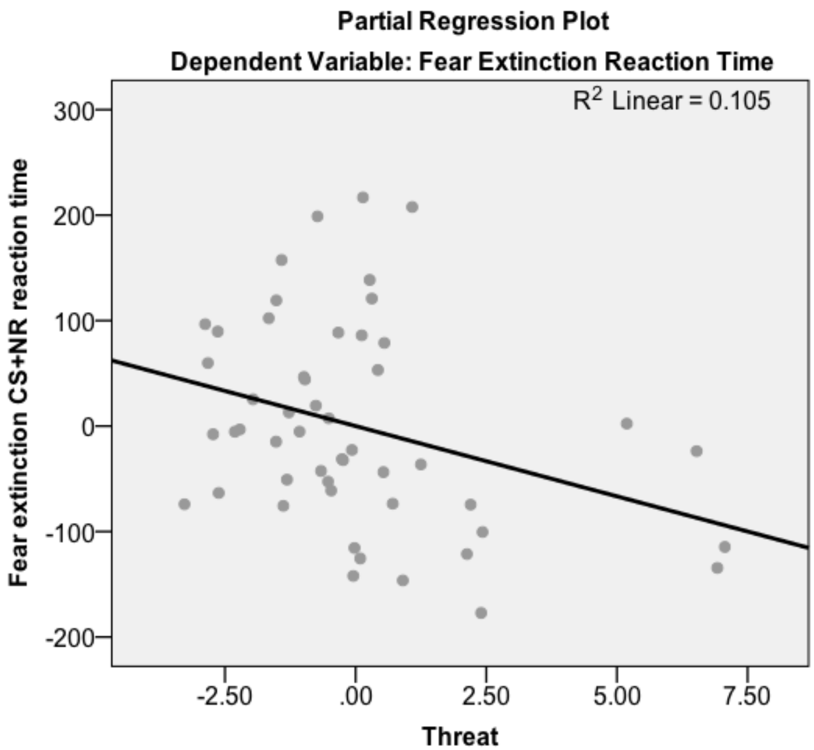

Figure 10. Partial regression plot of threat on fear extinction reaction time

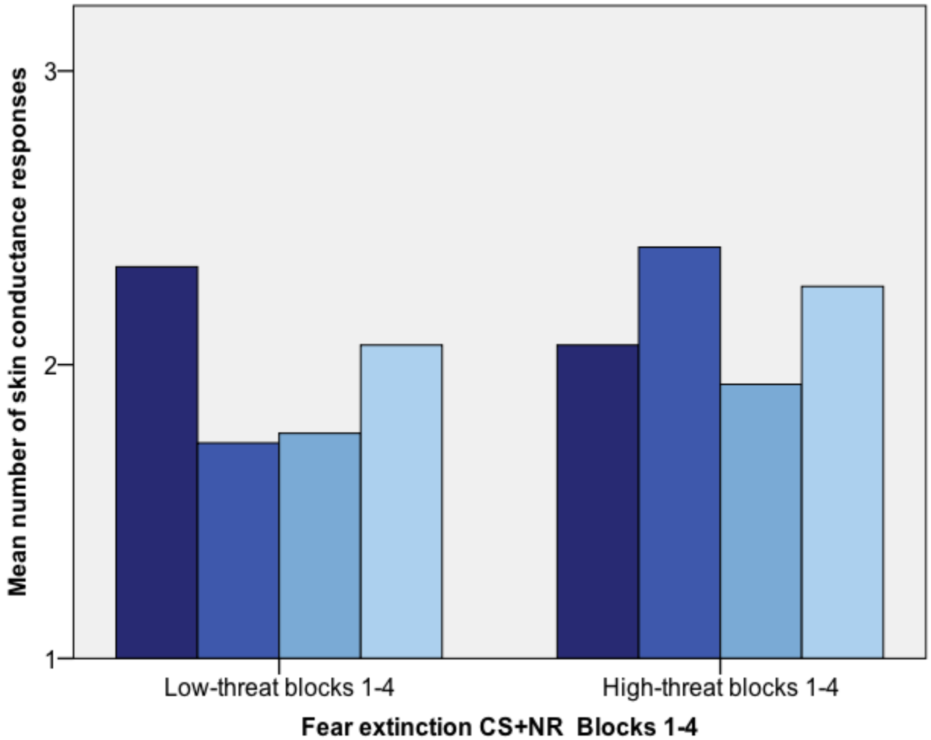

Figure 11. Number of skin conductance responses to the CS+NR during fear extinction

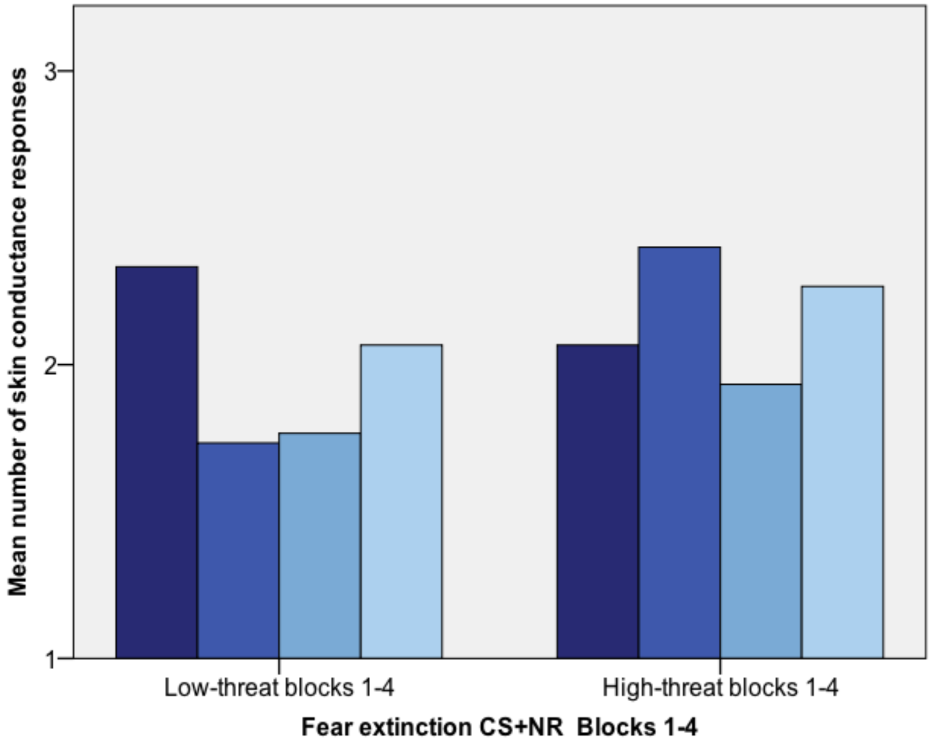

Figure 12. Number of skin conductance responses to the CS- during fear extinction

	Minimum	Maximum	Mean	SD
Age (months)	51	95	74.14	14.06
IQ	61	131	99.60	15.27
Deprivation	-3.9	6.1	0.0	2.2
Threat	-2.6	7.6	0.0	2.3

Table 1. Means and standard deviations of sample characteristics (N=63).

Variables	1	2	3
1. Multidimensional Neglectful Behavior Scale (MNBS-CR)	-		
2. Home Screening Questionnaire (HSQ)	-0.19	-	
3. Parental Education	-0.27*	0.36**	-

***p<0.05**

****p<0.01**

Table 2. Correlations between measures of deprivation (N=63).

Variables	1	2	3
1. Violence Exposure Scale for Children-Revised (VEX-R)	-		
2. Conflict Tactics Scale (CTS-2)	0.36**	-	
3. Child Abuse Potential Inventory (CAPI)	0.38**	0.50**	-

****p<0.01**

Table 3. Correlations between measures of threat (N=63).

Variables	***B***	***SE B***	**β**	***t***	***p***
Intercept	731.57	263.10		2.78	0.008
Inverse efficiency of congruent trials of cognitive control task	1.08	0.11	0.75	9.82	<0.001
Age	-4.74	1.87	-0.19	-2.54	0.014
Gender	48.98	38.16	0.07	1.28	0.205
IQ	-3.01	1.45	-0.12	-2.08	0.043
Deprivation	22.79	9.06	0.14	2.52	0.015
Threat	-5.29	8.03	-0.04	-0.66	0.513

Table 4. Multiple regression analysis of cognitive control task (N=58).

Variables	*B*	*SE B*	β	*t*	*p*
Intercept	169.17	562.37		0.30	0.765
Inverse efficiency of low-load trials of working memory task	0.96	0.09	0.82	10.39	<0.001
Age	-5.19	4.12	-0.10	-1.26	0.215
Gender	-30.35	99.97	-0.02	-0.30	0.763
IQ	6.27	4.03	0.12	1.56	0.127
Deprivation	-31.04	26.73	-0.09	-1.16	0.252
Threat	2.55	19.96	0.01	0.13	0.899

Table 5. Multiple regression analysis of working memory task (N=49).

Variables	***B***	***SE B***	**β**	***t***	***p***
Intercept	770.66	202.51		3.81	<0.001
Reaction time of CS- during fear acquisition	0.34	0.12	0.41	2.91	0.006
Age	-3.43	1.48	-0.31	-2.31	0.026
Gender	59.45	33.49	0.19	1.78	0.083
IQ	-0.46	1.20	-0.04	-0.38	0.704
Deprivation	-15.89	9.21	-0.21	-1.73	0.092
Threat	0.50	7.36	0.01	0.07	0.946

Table 6. Multiple regression analysis of fear acquisition behavioral performance (N=51).

Variables	*B*	*SE B*	β	*t*	*p*
Intercept	216.60	169.01		1.28	0.207
Reaction time of CS- during fear extinction	0.64	0.13	0.64	5.08	<0.001
Age	-0.47	1.18	-0.05	-0.40	0.691
Gender	-32.55	27.92	-0.12	-1.17	0.250
IQ	1.33	1.02	0.15	1.31	0.196
Deprivation	2.44	7.98	0.04	0.31	0.762
Threat	-13.33	5.86	-0.24	-2.28	0.028

Table 7. Multiple regression analysis of fear extinction behavioral performance (N=51).

Effect	*MS*	*df*	*F*	*p*	Greenhouse-Geisser
Time	2.49	3	1.10	0.353	0.341
CS	0.76	1	0.43	0.517	0.517
Time x CS	0.98	3	0.53	0.666	0.599
Time x Threat	0.60	3	0.26	0.851	0.779
Time x Deprivation	2.33	3	1.03	0.384	0.366
CS x Threat	1.37	1	0.77	0.386	0.386
CS x Deprivation	0.03	1	0.02	0.900	0.900
Time x CS x Threat	0.34	3	0.18	0.910	0.842
Time x CS x Deprivation	0.49	3	0.26	0.851	0.775

Table 8. Repeated measures ANOVA of fear acquisition number of SCRs (N=45).

Effect	*MS*	*df*	*F*	*p*	Greenhouse-Geisser
Time	1.09	3	0.30	0.823	0.745
CS	0.97	1	1.22	0.277	0.277
Time x CS	1.35	3	1.57	0.199	0.210
Time x Threat	1.24	3	0.35	0.791	0.714
Time x Deprivation	1.78	3	0.50	0.686	0.616
CS x Threat	0.06	1	0.08	0.782	0.782
CS x Deprivation	0.07	1	0.09	0.771	0.771
Time x CS x Threat	0.14	3	0.17	0.920	0.876
Time x CS x Deprivation	0.66	3	0.77	0.512	0.482

Table 9. Repeated measures ANOVA of fear acquisition mean skin conductance level (N=45).

Effect	*MS*	*df*	*F*	*p*	Greenhouse -Geisser
Time	0.97	3	0.77	0.511	0.493
CS	0.83	1	0.82	0.372	0.372
Time x CS	1.17	3	1.13	0.340	0.339
Time x Threat	1.43	3	1.14	0.336	0.332
Time x Deprivation	0.97	3	0.78	0.510	0.384
CS x Threat	0.79	1	0.78	0.382	0.382
CS x Deprivation	1.10	1	1.08	0.305	0.305
Time x CS x Threat	4.26	3	4.13	0.008	0.009
Time x CS x Deprivation	1.75	3	1.70	0.172	0.175

Table 10. Repeated measures ANOVA of fear extinction number of SCRs (N=45).

Effect	***MS***	***df***	***F***	***p***	**Greenhouse -Geisser**
Time	4.10	3	0.80	0.496	0.423
CS	0.29	1	0.52	0.474	0.474
Time x CS	2.05	3	1.39	0.249	0.255
Time x Threat	0.30	3	0.06	0.982	0.902
Time x Deprivation	5.42	3	1.06	0.370	0.337
CS x Threat	0.07	1	0.12	0.734	0.734
CS x Deprivation	0.31	1	0.57	0.456	0.456
Time x CS x Threat	1.38	3	0.94	0.425	0.398
Time x CS x Deprivation	1.63	3	1.11	0.350	0.337

Table 11. Repeated measures ANOVA of fear extinction mean skin conductance level (N=45).

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