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Christopher Anton Mark

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FUNCTIONAL NEAR-INFRARED SPECTROSCOPY AS A MECHANISM
FOR OBSERVING AND MEASURING NEUROLOGICAL EFFECTS OF
EXPERIENCED CHILD ABUSE AND ALCOHOL ABUSE

by

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A Dissertation

Submitted to the Graduate Faculty

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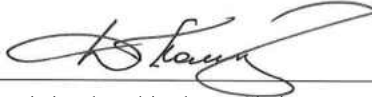
Doctor of Philosophy

Grand Forks, North Dakota

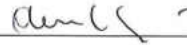
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2019

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This dissertation, submitted by Christopher Mark in partial fulfillment of the requirements for the Degree of Doctor of Philosophy from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.



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Title Functional Near-Infrared Spectroscopy as a Mechanism For Observing
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Christopher A. Mark
April 22, 2019

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ABSTRACT

Introduction: Previous research has shown cognitive and neurological dysfunction in adults with a history of child abuse. The purpose of the present study was to measure differences that exist in executive functioning skills, both cognitively and neurologically, between individuals who have been abused as children versus those who were not abused as children.

Methods: The present study recruited 84 students from the University of North Dakota (Females = 71) with an age range of 18-55 years of age ($M = 21.04$ years, $SD = 6.87$). The participants were administered several prescreening measures, including a measure of physical child abuse, emotional child abuse, and sexual child abuse. Based on responses to these measures, participants were assigned to either a no child abuse group or a child abuse group (mild or moderate-to-severe child abuse). Next, three measures of executive functioning skills were administered while functional near-infrared spectroscopy (fNIRS) data was collected.

Results: MANOVA results indicated that there were no significant differences on any of the combined cognitive dependent measures between the two abuse groups. However, follow-up univariate testing revealed a significant difference of commission error rates between the groups ($F(1,57) = 6.604, p = 0.013$ partial $\eta^2 = 0.104$) suggesting greater impulsivity in the child abuse group [provide means for each group here]. Additionally, fNIRS data revealed a statistically significant effect of group ($F(1, 69) = 2.934, p = 0.043$) across all executive functioning tasks with lower hemodynamic activation patterns observed in the prefrontal cortex of the child abuse group.

Additional tests showed these

differences existed only during measures of decision-making ($t(71) = 2.063, p = 0.043$).

Conclusion: Individuals who reported have been abused as children had decreased oxygenated blood flow to the medial prefrontal and orbitofrontal cortices during measures of decision making. Decreased oxygenated blood flow to the prefrontal cortex could explain poor decision-making skills that are common within this population. Furthermore, individuals reporting abuse during their childhood exhibited increased levels of impulsivity as compared to their non-abused counterparts.

CHAPTER I

INTRODUCTION

Many situations and experiences can influence an individual's ability to process information and function normally at a neurological level. Avoiding any major sources of neurological trauma, such as mild traumatic brain injury (mTBI) caused by a concussion, is imperative for both short-term and long-term well-being across many domains of one's life. However, alterations in one's healthy neurological functioning can occur through both physical and emotional abuse. For example, both child abuse (i.e., abuse experienced prior to the age of 18) and drug abuse can alter neurobiology at both a functional and developmental levels (Crews & Boettiger, 2009; Alper, Shah, Howard, John, & Pritchep, 2013). Furthermore, research has shown that physical, emotional, and sexual child abuse can serve as predictors for the likelihood and severity of substance use and dependence later in life (Lotzin, Haupt, von Schönfels, Wingenfeld, & Schäfer, 2016). Mandavia, Robinson, Bradley, Ressler, and Powers (2016) demonstrated that exposure to abuse in childhood can decrease an individual's ability to properly regulate emotions in adulthood, thus increasing the likelihood of substance use and dependence. Poor regulation on one's emotions is not just a cognitive abnormality. Positron emission tomography (PET) scans have shown that childhood maltreatment is associated with altered neural activity in adulthood within regions of the brain that are involved in executive functioning, cognitive control, and socioemotional processes (Insana, Banihashemi, Herringa, Kolko, & Germain, 2016). Likewise, electroencephalographic (EEG) activity has revealed that

asymmetry in frontal lobe functioning may serve as a marker for adults that experienced early life trauma (Peltola et al., 2014), as well as serve as an identifier for long-term (i.e., for a duration equal to or longer than 12 months) drug and/or alcohol abuse (Weiland et al., 2014). Finally, adult individuals who have been abused as children often experience psychological disorders, such as Depression. This may be the result of the over activity of neurobiological systems responsible for cortisol production, such as the hypothalamic-pituitary-adrenal axis (HPA axis), during critical periods of neural development that occur only during childhood and adolescence. (Lu, Gao, Huang, Li, & Xu, 2016).

While previous literature has explored the cause, predictors, relationship between, and treatment outcomes of substance use disorder (SUD) and child abuse, only specific risk factors are analyzed in each study. Thus, a complete picture of the association between abuse, both child and substance, and neurobiological outcomes is difficult to establish. Meta-analyses may reveal a more comprehensive understanding of the relationship between SUD and child abuse, but there is a significant dearth of studies that investigate neurocognitive functioning in the context of both factors (i.e. child abuse and drug abuse). The proposed study will analyze a wide array of both cognitive and neurological differences that exist between the abused and non-abused populations (both child and substance), as well as psychological and physiological identifiers of both child abuse and substance abuse. Several aspects are unique in the proposed study from previous research. The proposed study is novel, and aims to view neurological, cognitive, and physiological differences in individuals who present with drug abuse and child abuse, both independently and in conjunction. From a neurophysiological perspective, a novel functional measure of regional cortical blood flow will be used to obtain a precise and accurate perspective

on the neural underpinnings of the cognitive differences that exist between the proposed populations.

The most far-reaching impact of the proposed study will be the advancement in understanding the comorbidity of child abuse and various neurocognitive abnormalities. Currently, the causal relationship between child abuse and decreased neurocognitive functioning through one's life is not well understood. Many factors influence the development of substance abuse over one's lifetime, including moderate and severe abuse during periods of critical neural development that occur only during childhood. By utilizing neurological, physiological, and cognitive measures, it becomes possible to develop a more complete understanding of the substance abuse. Furthermore, the proposed study will shed light on the long-term effects of experiencing child abuse on neural and cognitive development and provide evidence for finding a strong association between child abuse and decreased neurocognitive functioning. More adequate and appropriate prevention and intervention methods could be developed if substance abuse is considered to develop over the course of one's life as a response to childhood trauma and stress.

Childhood Abuse and Maltreatment

Individuals who experience abuse (e.g., physical, psychological and/or sexual) as children, often experience acute and/or chronic, negative psychological and physiological outcomes later in life. Studies have shown that experiencing even moderate levels of abuse during childhood can leave an individual without the necessary skills to properly deal with stress during childhood and into adulthood. This, in turn, can lead to a predisposition for depression and a host of other mental illnesses (Suzuki et. al., 2014). With approximately 683,000 children abused and/or neglected in 2015 (National Children's Alliance, 2016) in the United States,

understanding the outcomes of abuse is imperative for the development of adequate prevention and intervention protocols. However, understanding these outcomes proves challenging, as abuse directed toward a child by a caregiver or other close adult, such as a coach or minister, can be present in a variety of forms.

Traditionally, child abuse can be classified as either physical, sexual, or emotional. Physical abuse in childhood occurs when an individual is physically harmed intentionally, either with or without an object, by a primary caregiver or other close adult (e. g., step-parent, aunt, minister, etc.). Childhood sexual abuse occurs when a child is used for any kind of sexual stimulation by any individual (e.g., parent, sibling, stranger, etc.). Emotional abuse in childhood occurs when a child's psychological well-being is damaged in some way by a caregiver or other close adult. This is usually done through humiliation, denial of affection or basic needs, etc. While physical and sexual abuse in childhood are generally easy to identify, emotional abuse is difficult to accurately identify, both for researchers and for abuse victims. Definitions of emotional abuse also vary depending on cultural context. As such, the proposed study will use only physical and sexual abuse as prerequisite criteria for inclusion of a participant in any of the child abuse groups. Emotional, or psychological, abuse will be used as exclusion criteria for the proposed study.

The outcomes of physical and sexual child abuse, both short-term and long-term, have been researched thoroughly. Romans, Martin, Anderson, Herbison, and Mullen (1995) found that abuse of any kind in childhood greatly increases the risk for psychopathology, sexual difficulties, decreased self-esteem, and interpersonal problems in adulthood. Additionally, the only major differences found between physical and sexual abuse outcomes were that sexual abuse had a greater association to sexual difficulties during adolescence and into adulthood as compared to

physical abuse (Romans et al., 1995). More recent studies have identified that, regardless of gender, childhood sexual abuse is associated with consistent increases in risk for issues related to overall mental health (e.g., suicidal ideations and attempts) and mental illnesses (i.e., depression, Post-Traumatic Stress Disorder, etc.) later in life, while childhood physical abuse has weaker and less consistent effects on mental health in adulthood (Fergusson, Boden, & Horwood, 2008). Whereas most studies agree on the negative mental health outcomes associated with childhood sexual abuse, there is disagreement on the long-term effects of childhood physical abuse. By using a longitudinal study, Springer, Sheridan, Kuo, and Carnes (2007) identified the experience of childhood physical abuse as a predictor for increased negative mental (e.g., high scores on standardized depression inventories) and physical (e.g., high blood pressure, higher rates of asthma, and multiple sclerosis) health outcomes decades into adulthood. Further research is required to understand the long-term negative health impact that childhood physical abuse may cause.

The Childhood Trauma Questionnaire (CTQ) is a widely used self-reported measure of all forms of childhood abuse. This measure has shown to be both valid and reliable when utilized with various populations, such as psychiatric patients, inmates, and adults in the general population (Dudeck et. al., 2015; Spinhoven et. al, 2014). Given that adults attending mental health clinics are more likely to have experienced childhood trauma and have a high likelihood of non-documented childhood trauma by mental health professionals, the use of a standardized questionnaire of childhood trauma assessment is recommended when working with individuals who were abused as children (Rossiter et. al., 2015).

While CTQ serves as the standard for quantifying abuse experienced in childhood, it cannot be used in an electronic format due to copyright concerns from the publisher. Instead, the

proposed study will utilize two separate measures of child abuse, each of which will identify either physical or sexual abuse. The Lifetime Report of Physical/Psychological/Sexual Abuse (LPAA, PALA, and SALA, respectively) was developed by the Longitudinal Studies of Child Abuse and Neglect (LONGSCAN) consortium (Runyan et al., 1998). This open consortium consists of groups of research who explore many critical issues pertaining to child abuse. The goal of LONGSCAN is to follow the children and their families over time until the children themselves become young adults in order to develop accurate measurement instruments of child abuse. These three retrospective measures of child abuse obtain the same basic information as the CTQ. Apart from identifying specific types of abuse, these measures also look to identify the perpetrator of the abuse, the age ranges at which the abuse occurred, the severity of the abuse (LPAA and PALA, only), feelings of personal responsibility for the abuse, and the degree of long-term impact of the abuse on the individual's life. Dubowitz et al., (2011) found the pattern of correlations between the factor scores (e.g., the physical needs of the child, emotional support available to the child, and how well the child is monitored by the parent(s)) of the three LONGSCAN measures, CPS reports, and measures of the parent-child relationship offered modest to moderate support for convergent validity between the CTQ and the LPAA, the PALA, and the SALA, indicating that is a suitable substitute in place of the CTQ.

Substance Dependence and Emotional Regulation

Substance dependence is a highly prevalent health and social issue that affected approximately 21 million Americans in 2010 (Substance Abuse and Mental Health Services Administration, 2011). Previous research has found that adult substance abuse may allow researchers to predict if an individual was abused as a child. It has been suggested that individuals who have been abused sexually as children do not develop healthy strategies for

regulating emotions, both internally and externally (Banducci, Hoffman, Lejuez, & Koenen, 2014). Abusers strip away both the physical and emotional protection traditionally afforded to a child, and increase the likelihood that said child will not be able to develop the proper coping strategies needed to process past abuse as an adult. This is one potential explanation for the increased rates of substance use disorders and psychiatric illnesses in individuals who experienced child abuse.

It is likely that emotional dysregulation begins in childhood and may be the result of the extreme stress and trauma associated with abuse during critical periods of emotional development, which occur only during childhood and adolescence. Studies have shown that all forms of child abuse are uniformly correlated with emotional dysregulation in adulthood, and that limited access to healthy emotional coping strategies are the most powerful predictor of psychopathology in adulthood (Jennissen, Holl, Mai, Wolff, & Barnow, 2016). Through structural equation modeling, Jennissen et al., (2016) also revealed that emotional dysregulation serves as a moderator between childhood abuse and psychopathology. Given that the population of individuals abused during childhood is generally unequipped with the necessary skills to process trauma, drugs and alcohol may be used by the victim as an alternative coping mechanism.

Mandavia et al. (2016) found that drug and alcohol use in adulthood are significantly correlated with child abuse, later life trauma, and emotional dysregulation. Furthermore, it was found that emotional dysregulation and other exposures to trauma, such as physical and/or sexual abuse, indirectly affect the relationship between child abuse and the likelihood of lifetime engagement in substance use (Mandavia et al., 2016). Of note in the above-mentioned study was the significance of the relationship between childhood emotional abuse and substance use in

adolescence and adulthood. While all three forms of child abuse were significantly associated with substance use in adolescence and adulthood, once physical and sexual abuse were accounted for, emotional abuse had a much stronger relationship to substance use (Mandavia et al., 2016). Finally, Weiland et al. (2014) demonstrated that individuals with a history of drug and/or alcohol abuse have smaller frontal cortical volumes of grey matter as compared to their non-drug abusing counterparts. Similar reductions in grey matter have been found in individuals that have experienced abuse in their childhood (Pelota et al., 2014). Much of the available literature either does not focus on the detrimental effects of emotional abuse in childhood, or has found that emotional abuse does not have a significant effect on lifetime outcomes of substance abuse once other factors are controlled for (e. g., gender, socioeconomic background, etc.). Further research is required to more adequately understand the relationship between child abuse, emotional regulatory strategies, and substance use disorders.

Executive Functioning Abilities of Abused Populations

Many studies have examined emotional regulation in terms of patterns of behavior and future mental health issues, but comparatively fewer studies have focused on the neurological deficits that child abuse can produce when it is experienced during critical periods of neurological development (i.e., approximately the first 10-15 years of life (Haartsen, Jones, & Johnson, 2016)). Frontal lobe dysfunction has been linked to excessively risky, impulsive behaviors and poor decision-making in drug users (Crews & Boettiger, 2009). The frontal lobes are responsible for abstract thinking, rule acquisition, planning and flexibility in responses including rule shifting, as well as initiating appropriate actions and inhibiting inappropriate actions. Naudé, du Preez, and Pretorius (2004) found a reduction in global executive functioning, including memory and verbal processing abilities, in a population of individuals that had been

abused as children. Additionally, they found that abused participants presented with symptoms such as depressed declarative memory, which is the conscious, intentional recollection of factual information from the long-term memory (Naudé, du Preez, & Pretorius, 2004). This was especially true of the individuals' semantic memories. Furthermore, they found that individuals who abuse substances have poor error detection and restoration rates, despite advanced levels of social knowledge (episodic memory) (Naudé, du Preez, & Pretorius, 2004).

McCroy and Viding (2015) reported that extreme stressors in early life could lead to atypical activation of various brain regions, including decreased activity in the prefrontal cortex. This lends further credence to the claim that early life stress, which is often in the form of child abuse and/or drug abuse in adolescence, can cause deficits in neurological function, brain development, and increase the likelihood of being diagnosed with at least one mental illness in adulthood.

A wide variety of tests and measures exist that look at an individual's functioning across multiple domains of executive functioning. The proposed study will specifically look at reasoning abilities, working memory span, and attention span. To accomplish this, electronic versions of the Wisconsin Card Sorting Task (WCST), the Operation Span Task (OSPAN), and the Connor's Continuous Performance Task (Connor's CPT) will be utilized to measure the executive functioning abilities, respectively. These tests measure reasoning and judgement skills, working memory, and attention span and impulsivity, respectively. A meta-analysis of studies using WCST found that effect sizes indicated significantly poorer decision-making performance for participants with frontal damage as compared to those with posterior brain damage (Demakis, 2003), making the WCST a sensitive instrument of frontal lobe function. Unsworth, Heitz, Schrock, and Engle (2005) found that an automated version of the OSPAN correlates well with

other measures of working memory capacity, and demonstrates high internal consistency and test-retest reliability. Performance on the Connor's CPT was found to differ significantly between children with and without ADHD (Bart, Raz, & Dan, 2014). Rueckert and Grafman (1996) showed that individuals who have frontal lobe lesions have slower reaction times when completing the Connor's CPT as compared to a control. This indicates that these individuals have deficits in sustained attention skills. Individuals who have a lesion on the right frontal lobe performed worse on this task as compared to those with a lesion on the left frontal lobe (Rueckert & Grafman, 1996).

Individuals who experienced child abuse score significantly lower on the WCST as compared to the non-abused population, indicating less cognitive flexibility (Spann et. al., 2012). Comparable results were found with the Connor's CPT when administered to individuals who had experienced child abuse. That is, this population exhibited decreased modulation and response times as compared to a normative sample (Miller et. al., 2015). While the OSPAN is not commonly used to test working memory in the child abuse population, individuals with a history of child abuse have been reported to show poorer outcomes on tests of working memory and information processing speed compared to normal controls (Lysaker, Meyer, Evan, & Marks, 2001). The OSPAN will be used in this study because of its ease of administration and availability in a computer-based format.

Neurological Measurement of Child and Drug Abuse

The mode of neurological measurement in the proposed study will be functional near-infrared spectroscopy (fNIRS). This technology emits near-infrared light that can penetrate the cerebral cortex by up to 3cm, and detects the absorption rate of said light. During tasks that illicit neuroactivation, such as executive functioning tasks, a hemodynamic response (i.e., differences

in blood flow to specific regions of the brain) is provoked. Oxygenated and deoxygenated blood are the dominant tissue absorbers in the infrared range of the light spectrum (Soul & Plessis, 1998). As such, areas of neuroactivation should show increased levels of oxygenated blood and decreased levels of deoxygenated blood. This data can then be compiled into a 3-dimensional image of real-time neural functioning. A detailed description of the technical operations of the instrument is provided below.

fNIRS is a relatively novel measurement technique in psychology. Thus, there is limited research available on its use specifically with individuals that have experienced child and/or drug abuse. However, studies have demonstrated association between an individual's default mode network (DMN) (i.e., networks of brain regions in which activity is highly correlated with each other, but not with other regions) and being subjected to early life stressors (Burghy et al., 2013). The DMN consists of the medial prefrontal cortex, posterior cingulate cortex, and superior temporal/inferior parietal cortex (Kim et al., 2010). The DMN is most active during restful, yet wakeful states, allowing for easy comparisons during cognitive tasks. Using fNIRS, Nakao et al. (2013) demonstrated that individuals abused in childhood more often made judgements based off external criterion as opposed to subjective preference. This could serve as partial evidence as to why child abuse victims are more prone to drug abuse. Experiencing extreme stress during crucial periods of development may both structurally and functionally alter brain development, leading to worsening cognitive and/or behavioral differences.

Little research has been conducted using fNIRS on drug dependent individuals. The primary application of fNIRS with drug abusing populations has been specifically with ecstasy polydrug users. While the proposed study is interested in individuals that abuse or have abused alcohol specifically, the impact of the above-mentioned studies will be reviewed. Roberts and

Montgomery (2015) found that while no behavioral differences were observed between ecstasy polydrug users and controls, the ecstasy polydrug user group had significant changes in oxygenated blood concentration in the left dorsolateral prefrontal cortex and the left medial prefrontal cortex during a word fluency task. This is indicative of needing an increased workload (i.e., mental effort) to successfully complete the task (Roberts & Montgomery, 2015; Mandrick, Peysakhovich, Rémy, Lepron, & Causse, 2016). These results may indicate that increased activation of the prefrontal cortex may serve as a compensatory neurological mechanism. fNIRS is a relatively novel technology and will provide information about the specific areas and intensity of activity in prefrontal cortex, as well as advance the current literature by providing a new method of observing the potential impact of various forms of abuse that may compound over one's lifetime.

Present Study

Previous research provides useful information on the relationship between child abuse, drug abuse, and potential physical and psychological outcomes of this abuse in adulthood. However, controlling for child and drug abuse histories within the same study will allow for a more accurate view of their respective long-term effects. More specifically, this project will attempt to find evidence that may explain neurological differences between abused (physical, psychological, and sexual child and/or drug abuse) and non-abused populations. As such, the proposed study aims to explore the impact of abuse on cognition by using neurological imaging techniques. Nakoa et al., (2013) identified important differences in prefrontal cortex activation between abused and non-abused human samples using fNIRS.

The primary objective of the present study is to empirically test whether child abuse and/or drug abuse have an impact on normative cognitive functioning in adulthood. There are

three primary hypotheses. First, it is hypothesized that the dual-abuse group that has experienced both moderate-to-severe levels of physical and/or sexual child abuse, as determined by the LPAA and/or SALA, and score in the moderate or high range of drug abuse and identify alcohol as their primary substance of abuse, as determined by the Texas Christian University Drug Screen (TCUDS-V; see “*Instruments*” for a detailed description), will have significantly lower levels of executive functioning (i.e., decision-making skills, sustained attention, and working memory abilities) as measured by the WCST, the Connor’s CPT, and the OSPAN Task, as compared to both single abuse and non-abused groups (H_{1a}). Second, it is hypothesized that there is no significant difference between single abuse groups (i.e., only child or drug abuse) on any measures of executive functioning. That is, no significant differences are predicted between the child abuse only group and the alcohol abuse only group on the WCST, the Connor’s CPT, or the OSPAN Task (H_{1b}). Thirdly, it is hypothesized that the non-abused group will have the highest levels of executive functioning as determined by the WCST, the Connor’s CPT, and the OSPAN Task as compared to all abuse groups (H_{1c}).

The secondary objective of the present study is to empirically test whether child abuse and/or drug abuse has an impact on neurological functioning. Following this, there are three secondary hypotheses. First, it is hypothesized that groups that have experienced both moderate to severe levels of physical and/or sexual child abuse, as determined by the LPAA and/or the SALA, and score in the moderate or high range of drug abuse and identify alcohol as their primary substance of abuse, as determined by the TCUDS-V, will have significantly higher levels of prefrontal cortical activation during measures of executive functioning when compared to both the single abused and non-abused groups (H_{2a}). Second, it is hypothesized that there is no significant difference in cortical activation during measures of executive functioning between the

child abuse only group and the alcohol abuse only group (H_{2b}). Finally, it is hypothesized that the non-abused group will have the lowest level of cortical activation during executive functioning tasks (H_{2c}). All data pertaining to the secondary hypotheses will be measured using fNIRS.

CHAPTER II

METHODS

Participants

The proposed study will consist of four groups of thirty (30) individuals. A total of 120 participants are proposed to be recruited. Participants were assigned to one of the following groups based on responses to an online prescreening questionnaire (see below): child and drug abuse; child abuse only; drug abuse only; and no abuse. The number of participants needed for this study was determined using a power analysis conducted using G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009; see the Power Analysis section below). All participants were adults living in the Greater Grand Forks area (i.e., Grand Forks, North Dakota and East Grand Forks, Minnesota) who were also students at the University of North Dakota. Both men and women were recruited with no preference given to one sex over the other. Participants were 18 years of age or older. They were recruited using the University of North Dakota Sona system, and flyers posted on bulletin boards in UND's Psychology Department. The Lifetime Report of Physical Abuse (LPAA), the Lifetime Report of Sexual Abuse (SALA), the Lifetime Report of Psychological Abuse (PALA), the Texas Christian University Drug Screen (TCUDS-V), the Prospective and Retrospective Memory Questionnaire (PRMQ), and a demographic questionnaire were administered to UND psychology students seeking credit for research participation through an online prescreen using Qualtrics. The demographic questionnaire was asking the participant's age, sex, ethnicity, highest level of education, employment status, and socioeconomic status of primary caregiver(s) during childhood and adolescence. The Total

PRMQ scale was used to validate the participants' memory. The Retrospective PRQM scale was used to validate participants' recollection of childhood abuse.

Group inclusion was based on LPAA/SALA and TCUDS-V responses. Individuals scoring in the moderate-to-severe range (see "Instruments" for specific range criteria) on the LPAA and/or the SALA, having this abuse take place between the ages of 5 and 17, and the last occurrence of abuse being greater than or equal to one year ago, qualified for inclusion in the child abuse groups. Individuals scoring in the moderate-to-high range (see "Instruments" for specific range criteria) on the TCUDS-V and identifying alcohol as the main substance of abuse qualified for inclusion in the drug abuse groups. Individuals who meet both above-mentioned criteria qualified for inclusion in the child and drug abuse group. Individuals who did not meet either of the above-mentioned criteria qualified for inclusion in the no abuse group.

Group exclusion were based on PALA and TCUDS-V responses. Individuals who scored in the moderate-to-severe range on the PALA, but did not score in the moderate-to-severe range of the LPAA or SALA were excluded from the study, as they indicated experiencing psychological abuse, which the proposed study did not aim to measure. Individuals who scored in the moderate-to-high range on the TCUDS-V, but identified any drug other than alcohol as their substance of abuse were not eligible for the in-laboratory portion of the study. Individuals who scored lower than a 10 on the Retrospective subscale (see describing below) of the PRQM were not eligible to participate. This is because their ability to accurately recall past child abuse is considered to be unreliable for the purposes of the current study.

Instruments

Demographic Questionnaire

The primary purpose of the demographic questionnaire was to obtain the descriptive statistics of the acquired sample. The demographic questionnaire was brief, consisting of only seven questions. Participants were asked to provide their current age, sex, gender, ethnicity, academic year, grade point average (GPA), the status of their parent's marital status, and an estimate of their average household income during childhood (ages 5-17). If any answer other than "still married" is given on the question pertaining to marital status, follow up questions pertaining to the time of separation and/or death of a parent were asked. The question pertaining to household income had also secondary questions asking if any major shift in household income occurred during the participant's childhood of which he/she was aware of.

Independent Variables

Childhood Abuse Questionnaire

The Lifetime Report of Physical Abuse (LPAA) and the Lifetime Report of Sexual Abuse (SALA) are childhood abuse scales designed to assess a young adult's self-reported history of lifetime abuse (respectively for each scale) and harsh parenting. The LPAA and the PALA consist of twelve behavioral stem items that ask if the individual has ever experienced a specific parent or caregiver to be physically/psychologically abusive or displayed harsh behaviors towards it during its childhood. Positive endorsements trigger follow-up items assessing the frequency of occurrence, perpetrator, and injury outcomes (but only for the LPAA). For the SALA, 11 stem items ask about specific sexually abusive caregiver behaviors; four of these items have gender-specific wording for boys or girls. After a participant completed all appropriate stem items, follow-up items assessed the frequency of occurrence and perpetrator(s). For the purposes of the proposed study, only scores of the stem questions for both two scales were used to assign an individual to a specific group, with a possible maximum score of 24.

Individuals with a score of 0 were assigned to the “no child abuse group”. Individuals with a score between 1 and 3 were excluded from participation, as these scores fall within the mild range of experienced abuse. Individuals with a score of 4 or greater (with a score of 4 indicating “moderate abuse”, and a score of 5 or greater indicating “severe abuse”) were assigned to either the “child abuse only” group or the “child abuse and substance abuse” group, with the latter assignment depending on TCUDS-V scores (see below for detailed description). Research has found that the self-reporting of past child abuse by adult experiencers often leads to a more accurate determination of the type and severity of abuse that has been experienced, as opposed to determinations made by protective organizations such as Child Protective Services (CPS) (Barnett, Manly, Cicchetti, 1993; Everson et al., 2008).

Drug Use Questionnaire

Childhood physical abuse severity is associated with an earlier initiation into drug use by the abused individual. Any level of substance abuse is associated with more extensive lifetime and recent polydrug use by the individual that experienced abuse as a child (Darke & Torok, 2014). The Texas University Drug Screen V (TCUDS-V), which is an updated version of the TCUDS-II, screens for mild to severe substance use disorder. This self-administered questionnaire serves to quickly identify individuals with a history of moderate to heavy drug use or dependency. This scale asks questions about specific drugs used by the individual, as well as the ways in which drug use has affected the individual’s personal and professional life in the past 12 months. Psychometric criteria for this instrument have been established, particularly focusing on its internal consistency (Knight, 2002). The sensitivity of the TCUDS-V makes it particularly useful in minimizing inappropriate treatment referrals for drug users (Knight, Simpson, & Hiller, 2002).

Prospective/Retrospective Memory

The Prospective and Retrospective Memory Questionnaire (PRMQ; Smith, Della Sala, Logie & Maylor, 2000) was developed to provide a self-report measure of prospective and retrospective memory slips in everyday life. The PRMQ is a 5-point Likert scale measure ranging from “Never” to “Very Often” and consisting of 16 items. Numerical scores are assigned to these responses (e.g., 1 = “Never”, 2 = “Rarely”, 3 = “Sometimes”, 4 = “Often”, 5 = “Very Often”), and scores range from 16 to 80. These items are designed to measure prospective versus retrospective memory slips, slips in short-term versus long-term memory, and self-cued versus environmentally-cued memory slips. Self-cued memories are those that an individual remembers without any external cues. Environmentally-cued memories are those that are triggered by some external stimuli. A total memory score is also provided. The PRMQ is a useful tool for measuring normative memory functioning, as the total measure of memory scale has demonstrated internal consistency ($\alpha = .89$, 95% CI = .88-.90). The PRMQ has also demonstrated reliability for young, middle-aged, and old populations (prospective memory subscale $\alpha = .85$; retrospective memory subscale $\alpha = .84$) (Gonda et al., 2010). For the purposes of the proposed study, only the measures of total and retrospective memory are used. The Total PRQM scale is used as a way of measuring normative memory functioning prior to in-laboratory data collection, while the Retrospective PRQM scale provides evidence that a participant’s recollection of experienced abuse is accurate. Normative Total PRMQ statistics have been identified as $M = 38.88$, $SD = 9.15$ in a study consisting of 551 adults from the general population (Females = 344, Males = 207) (Crawford et al., 2003). As such, participants with a Total PRQM score between 29.73 and 48.03 qualified for inclusion in the in-laboratory portion of the proposed study. Normative Retrospective PRQM statistics have been identified as $M =$

18.69, $SD = 4.98$ in a study consisting of 551 adults from the general population (Females = 344, Males = 207) (Crawford et al., 2003). As such, participants with a Retrospective PRQM score between 13.71 and 23.67 qualified for inclusion in the in-laboratory portion of the proposed study. The total, prospective, and retrospective scales of the PRMQ have shown to be reliable measures of memory ($\alpha = .89, .84, \text{ and } .80$, respectively). While this measure does not directly test working memory, it provides the researchers with an information pertaining to a participant's memory prior to in-laboratory data collection, as well as allow the researcher to exclude individuals with below average memory capabilities.

Dependent Variables

Spatial Neurological Imaging

Functional near-infrared spectroscopy, or fNIRS, is a method of hemodynamic neuroimaging that measures neuroactivation and metabolic rate based on near-infrared light reflected by oxygenated (oxy-Hb) and deoxygenated (deoxy-Hb) red blood cells in the cortices. In a dark environment, light is emitted through light-emitting diodes (i.e., sources) connected to a skull cap that a participant wears during data acquisition. The light is reflected at different rates by oxy-Hb and deoxy-Hb and measured by detectors that are positioned near the diodes. The skullcap array was organized for the frontal lobe based on the International 10-20 system. This difference in blood oxygenation, as measured by the difference between oxy-Hb and deoxy-Hb, corresponds to either increased or decreased metabolic rate in the brain region being monitored, thus indicating areas of either greater or lesser cognitive activation during task completion. The use of fNIRS as a neuroimaging technique has continually shown to be both valid and reliable (Ferrari & Quaresima, 2012) through simultaneous recording in conjunction with both functional magnetic resonance imaging (fMRI) and positron emission tomography (PET).

The proposed study used the NIRScout, produced by NIRx Optical Imaging. This equipment is non-invasive, user-friendly, and multi-modal compatible. The NIRScout provides real-time images of cortical functionality. The current system is fitted with 8 LED infrared sources and 4 detectors, producing a total of 32 measurement sites. This provides sufficient spatial resolution of imaging of the prefrontal cortex. Corresponding scalp locations of the sources and detectors were arranged in a prefrontal montage optimized by NIRX, which is based on the International 10-20 system. The frontal source channels were placed in the F2, Fpz, F3, and F4 locations, while the intermediate source channels were placed in the AF3, AF4, AF7, and AF8 locations. The detector channels were placed in the Fp1, Fp2, F1, and F2 locations. This arrangement allowed for a total of 32 measurement sites localized specifically over the prefrontal cortex. The available sources and detectors allowed for high-resolution spatial imaging of the activation of the prefrontal region of the cerebral cortex of the frontal lobe during completion of tasks that specifically measure cognitive function that take place in said brain area.

All physiological data was collected using NIRStar, a fNIRS data acquisition software produced by NIRx. NIRStar is designed to function as a multiplatform instrument to support the investigation objective of the present study. NIRStar provided system control and real-time display capabilities that maximized the investigational opportunities accessible with the NIRScout. Lastly, the physiological data was analyzed using nirsLAB. nirsLAB is a fNIRS analysis software developed by NIRx. This software offers a sufficient statistic parametric mapping environment that is suited for use in the present study. The nirsLAB's graphic user interface (GUI) based toolboxes provided the resources needed to edit and explore the neurophysiological data collected using the NIRScout.

Attention and Impulsivity Task

The Connor's Continuous Performance Task (Connor's CPT) is a psychological measure of sustained/selective attention and impulsivity. During a 16-minute task, of which the first two minutes are training, participants were shown a series of letters in the center of a computer screen that appear briefly and are present at variable intervals. Participants were instructed to click the right mouse button for every letter they see except for the letter "X". When an "X" is shown, they were not to respond in any way. There are 11 dependent measures that fall into three broader categories. These categories are: "inattention", "impulsivity", and "vigilance". "Inattention" includes number of omissions, number of commissions, hit reaction time (HRT), HRT standard error, variability, detectability, HRT inter-stimulus interval (ISI) change, and hit standard error ISI change. "Impulsivity" includes number of commissions, HRT, and preservations. "Vigilance" includes HRT block change and Hit stand error block change. The Connor's CPT exhibits both validity and split-half reliability, as it has satisfactory accuracy in terms of both false negatives and false positives (Connor & Lyon, 2015).

Working Memory Tasks

Working memory is an essential aspect of executive functioning wherein information is stored, manipulated, and processed. Developed by Turner and Engle (1989), the Operation Span Task (OSPAN) can assess an individual's general working memory capacity. In this task, participants verified a simple math problem (e.g., "Is $(4/2)-1=1$?") while they also read and memorized a series of letters after the operation. After a series of operation-word pairs have been presented, participants were asked to recall the letters, in order, that followed each operation. The number of operation-word strings in a sequence was increased and decreased during the task to measure the participant's operation span. Operation span measures predict verbal abilities and reading comprehension even though the subjects were solving mathematical problems. For the

purposes of this experiment, an automated, computerized version of OSPAN was administered. This version of OSPAN correlates well with other measures of working memory capacity and has both good internal consistency and test-retest reliability (Unsworth, Heitz, Schrock, & Engle, 2005).

Reasoning Task

The Wisconsin Card Sorting Task (WCST) is a classic measure of one's executive functioning. Namely, it is used as a measure of the selective feature of attention, and can reflect a variety of cognitive impairments. A computerized version was employed in this study. This task consisted of four stimulus cards and 128 response cards. The test proceeded through several shifts in a set (sorting principles) that varied along three dimensions (color, form, and number). Successful performance on the WCST required the participant first to determine the correct sorting principle based on computer feedback, and then to maintain this sorting principle or set. The WCST dependent measures included: number of trials administered, trials to complete the first category (the number of trials to make 10 consecutive correct responses), total number of categories achieved, total number/percentage correct, failure to maintain set (interruption of the correct sorting strategy after five consecutive correct responses have been made), perseverative errors/responses (responses that would have been correct under the previous sorting rule) and their corresponding percentages, total number of errors, total number of correct trials, conceptual level responses (consecutive correct responses occurring in runs of three or more), and the mean overall difference in the percentage of errors calculated for each completed category.

Procedure

Informed consent was obtained in the form of an electronic signature from each participant prior to the completion of any measures. Given the sensitive nature of the

questionnaires (i.e., child abuse and drug abuse), participants were provided with phone numbers and website addresses pertaining to mental health resources so that they may seek counseling if desired. Participants were also provided with the contact information of the researchers. Once informed consent was obtained, participants completed an online prescreen, which was administered through SONA. The prescreen consisted of five questionnaires: the Lifetime Report of Physical Abuse (LPAA), the Lifetime Report of Psychological Abuse (PALA), the Lifetime Report of Sexual Abuse (SALA), the Texas Christian University Drug Screen – V (TCUDS-V), and a demographic questionnaire. Participants were assigned to one of four groups based on responses provided during the prescreening procedure. Those groups were: no child or drug abuse, child abuse only, drug abuse only, and both child and drug abuse.

Next, eligible participants were invited to participate in the in-laboratory portion of the study. No questions regarding any form of abuse were asked during this portion of the study. Written informed consent was obtained from each participant prior to any testing. Next, the neurophysiological equipment was properly placed on the participant and calibrated to ensure proper data collection. The fNIRS optode array was arranged over the prefrontal lobes using a configuration that is optimized for data collection specifically of the prefrontal cortex.

Participants then completed the Wisconsin Card Sorting Task, the Conner's Continuous Performance Task, and the Operation Span Task. These tasks were counterbalanced between participants using a Latin Square design. Start and end markers were inputted by the researcher in the neuropsychological data to denote the start and stop time of each of the three tasks. Upon completion of the tasks, fNIRS data acquisition ended, and the measurement tool was removed from the participant. The entire session took approximately one hour of each participant's time.

Statistical Analyses

All hypotheses (see “Present Study”) of the proposed study were evaluated using the SPSS software according to the following guidelines. The hypotheses of the first objective of the proposed study (i.e., H_{1a} , H_{1b} , and H_{1c}) were evaluated using a 2x2 two-way between groups analysis of variance (ANOVA). Assumptions for normality of distribution and equality of variance were tested for prior to conducting the ANOVA. Child abuse assignment and/or drug abuse assignment served as the independent variables of interest, and both contained two conditions (no abuse vs. moderate-to-high abuse). Main effects and interaction effects were analyzed between the groups on overall correct responses on the WCST, error omission rate of Connor’s CPT, and the total correct letters recalled and math questions answered on the OSPAN Task. The hypotheses of the second objective of the proposed study (i.e., H_{2a} , H_{2b} , and H_{2c}) were evaluated using a 2x2 two-way between groups ANOVA. Assumptions for normality of distribution and equality of variance were tested for prior to conducting the ANOVA. Child abuse assignment and drug abuse assignment served as the independent variables of interest, and both contained two conditions (no abuse vs. moderate-to-high abuse). Main effects and interaction effects were analyzed between the groups on total cortical activation during each of the three experimental tasks. This was accomplished through analysis of the fNIRS data.

A power analysis for the experiment was performed using G*Power 3.1. Based on the minimum acceptable power of .80, four groups, a single numerator degree of freedom, and a medium-to-large effect size of $d = .35$, a total sample size of approximately 120 participants (30 per group) was needed. A medium-to-large effect size is justified in this experiment, as the relationship between deficits in executive functioning and early life maltreatment has been demonstrated in previous research (DePrince, Weinzierl, & Combs, 2009). A meta-analysis of the WCST and brain damage revealed larger effect sizes for individuals who have experienced

damage to the frontal lobe as compared to individuals who have suffered damage to non-frontal regions of the brain (Demakis, 2003). Mowinckel et al (2015) calculated the average effect sizes for different decision-making domains and the Connor's CPT through meta-analysis. They found these two variables show robust small to medium effect sizes.

Vasilevski and Tucker (2015) examined whether maltreated adolescents exhibited cognitive deficits across several cognitive domains and found that maltreated groups showed significant impairments on measures of executive function and attention, working memory, learning, visuospatial function and visual processing speed, with effect sizes ranging from $d = .54$ – $d = .81$. Another study found medium effect sizes ($d = .30$) when looking at executive functioning as a function of familial exposure to trauma (DePrince, Weinzierl, & Combs, 2009). An expected effect size of $d = 0.35$ is reasonable given previous findings.

Previous literature has documented the short-term and long-term repercussions of alcohol deficits within the domain of cognition. Attention, working memory, speed of processing, visuospatial abilities, executive functions, impulsivity, learning, memory and verbal fluency have all been shown to be impaired in alcoholism (Beatty et al. 2000; Davies et al. 2005; Noël et al. 2007b; Pitel et al. 2009). Meta-analyses have allowed a greater degree of specificity regarding which cognitive functions are more susceptible to impairment due to alcohol abuse, and to how duration of abstinence affects cognitive recovery. Starvo, Pelletier, and Potvin (2012) found moderate impairment across 11 cognitive domains during short-term abstinence, as well as moderate impairment across 10 domains during intermediate term abstinence. These areas include working memory ($d = 0.532$), attention ($d = 0.699$), problem solving ($d = 0.534$), and inhibition/impulsivity ($d = 0.460$). This provides further evidence for the expected effect size of $d = 0.35$ in the proposed study.

CHAPTER III

RESULTS

Due to the nature of the collection of cognitive and neurological data as separate metrics (i.e., cognitive and neurological data could not be analyzed simultaneously) results for cognitive and neurological data will be reported independent of one another. Demographic characteristics of the cognitive and neurological samples are included in Table 1 and Table 2, respectively.

Cognitive Data

For the cognitive analyses, participants were a total of 84 University of North Dakota students, the majority of whom were female ($n = 71$) and had an average age of 21.04 years ($SD = 6.87$). The average child abuse score for these participants was 3.43 ($SD = 5.89$; out of a maximum possible score of 36), while the average drug abuse score (as measured by the Texas Christian University Drug Screen (TCUDS-V)) was 0.167 ($SD = 0.618$; out of a possible score of 13). Given that only two participants in the sample were identified as experiencing any form of substance abuse, drug abuse was removed as a group from all statistical analyses. A series of five one-way Multivariate Analyses of Variance (MANOVAs) were performed. This method of analysis was chosen over the originally proposed 2x2 two-way between groups ANOVA to control for inflated Type I error with multiple tests ($n = 18$). The independent variable of “Child Abuse Level” (which consisted of 2 levels: no child abuse and child abuse) was the same for all of the tests, while dependent variables were specific to each test. The use of a dichotomous child abuse group independent variable is supported by an exploratory analysis of the distribution of the sample, which revealed that the 56% of individuals identified a score of ‘0’ (i.e., no child

abuse), while the remaining 44% of individuals had at least the score of '1' (i.e., child abuse). Furthermore, only the primary hypothesis (i.e., that individuals who have experienced childhood trauma as classified by the LPAA, the PALA, and the SALA would have a lower level of executive functioning as measured by WCST, the Connor's CPT, and the OSPAN, when compared to those who experienced no childhood trauma) of the current study was tested. Since our abuse groups comprised only 2 levels instead of originally proposed 4, secondary hypotheses were not tested.

A one-way MANOVA was conducted to determine the effect of child abuse on the dependent measures associated with the WCST. These dependent measures were: the total number of correct answers, preservative errors, the summation of the failure to maintain the present set, and the total number of incorrect answers. Data were first transformed to eliminate outliers. A univariate analysis was first used to identify outliers. This was accomplished through the use of boxplots, with any data point falling outside the 99% score distribution (i.e., beyond 2.69 standard deviations) on each dependent variable being removed. Next, multivariate outliers were identified using the critical value associated with Mahalanobis Distance ($\chi^2 = 7.82, df = 3, p = 0.05$). Levene's Test for Equality of Variance revealed unequal variances among groups within the summation of failure to maintain set dependent variable of the WCST dependent measure [$F(1, 60) = 5.586, p = 0.021$]. All other dependent variables of the WCST dependent measure had equal variance among groups (see Table 3). Box's M Test ($Box's M = 5.688, p = 0.0874$) was nonsignificant for the WCST dependent measure, indicating the need to use Wilk's Lambda when interpreting MANOVA results. Bartlett's Test of Sphericity was also significant ($\chi^2(9) = 254.029, p < 0.001$), which indicates that a MANOVA is warranted for the variables of interest. MANOVA results indicate that child abuse group [Wilk's Lambda = 0.933, $F(1,60) = 1.019, p =$

0.405 partial $\eta^2 = 0.067$] does not significantly affect the combined dependent variable of the WCST. However, secondary univariate follow-up tests revealed that the summation of failure to maintain present set [$F(1,60) = 3.069, p = 0.085$ partial $\eta^2 = 0.049$] was the only variable showing marginal significance on the combined dependent variable of the WCST. Multivariate and univariate effect sizes were small. No other dependent measures within the MANOVA were significantly different between the two abuse groups on the WCST. Table 4 presents the adjusted group means for the four dependent measures contained in the MANOVA by child abuse group. Table 5 presents the one-way MANOVA results for the WCST dependent variable.

A one-way MANOVA was conducted to determine the effect of child abuse on the dependent measures associated with the Connors CPT count data. These dependent measures were: the omission error count for the CPT Part 1, the commission error count for the CPT Part 1, the omission error count for the CPT Part 2, and the commission error count for the CPT Part 2. Data were first transformed to eliminate outliers. A univariate analysis was first used to identify outliers. Next, multivariate outliers were identified using the critical value associated with Mahalanobis Distance ($\chi^2 = 7.82, df = 3, p = 0.05$). Levene's Test for Equality of Variance revealed unequal variances among groups within the Part 2 omission error count of the Connors CPT count data dependent measure [$F(1, 60) = 6.800, p = 0.011$]. All other dependent variables of the Connors CPT count data dependent measure had equal variance among groups (see Table 6). Box's M Test ($Box's M = 16.355, p = 0.127$) was nonsignificant for the Connors CPT count data dependent measure, indicating the need to use Wilk's Lambda when interpreting MANOVA results. Bartlett's Test of Sphericity was also significant ($\chi^2(9) = 51.119, p < 0.001$), which indicates that a MANOVA is warranted for the variables of interest. MANOVA results indicate that child abuse group [Wilk's Lambda = 0.860, $F(1,60) = 2.326, p = 0.067$ partial $\eta^2 = 0.140$]

does not significantly affect the combined dependent variable of the Conners CPT count data. However, secondary univariate follow-up tests revealed that the commission error count for the Conners CPT Part 1 [$F(1,60) = 3.822, p = 0.055$ partial $\eta^2 = 0.060$] was the only variable in the combined DV that showed marginal significance. These effect sizes were again small. No other dependent measures within the MANOVA on the Conners CPT count data showed statistically significant difference between the two groups. Table 7 presents the adjusted group means for the four dependent measures contained in the MANOVA by child abuse group. Table 8 presents the one-way MANOVA results for the Conners CPT count dependent variable.

A one-way MANOVA was conducted to determine the effect of child abuse on the dependent measures associated with the Conners CPT rate data. These dependent measures were: the omission error rate for the CPT Part 1, the commission error rate for the CPT Part 1, the omission error rate for the CPT Part 2, and the commission error rate for the CPT Part 2. Data were first transformed to eliminate outliers. A univariate analysis was first used to identify outliers. Next, multivariate outliers were identified using the critical value associated with Mahalanobis Distance ($\chi^2 = 7.82, df = 3, p = 0.05$). Levene's Test for Equality of Variance revealed unequal variances among groups within the Part 1 omission error rate of the Conners CPT rate data dependent measure [$F(1, 57) = 6.197, p = 0.016$]. All other dependent variables of the Conners CPT rate data dependent measure had equal variance among groups (see Table 9). Box's M Test ($Box's M = 6.517, p = 0.815$) was nonsignificant for the Conners CPT rate data dependent measure, indicating the need to use Wilk's Lambda when interpreting MANOVA results. Bartlett's Test of Sphericity was also significant ($\chi^2(9) = 226.524, p < 0.001$), which indicates that a MANOVA is warranted for the variables of interest. MANOVA results indicate that child abuse group [$Wilk's Lambda = 0.867, F(1,57) = 2.079, p = 0.096$ partial $\eta^2 = 0.133$]

does not significantly affect the combined dependent variable of Conners CPT rate data. However, secondary univariate follow-up tests revealed that the commission error rate for the Conners CPT Part 1 [$F(1,57) = 6.604, p = 0.055$ partial $\eta^2 = 0.104$] was the only variable in the combined DV that showed significance. This effect sizes were small-to-medium. No other dependent measures within the MANOVA showed statistically significant differences between the groups. Table 10 presents the adjusted group means for the four dependent measures contained in the MANOVA by child abuse group. Table 11 presents the one-way MANOVA results for the Connors CPT rate dependent variable.

A one-way MANOVA was conducted to determine the effect of child abuse on the dependent measures associated with the OSPAN numbers data. These dependent measures were: math speed errors, math accuracy errors, and total math errors. Data were first transformed to eliminate outliers. A univariate analysis was first used to identify outliers. Next, multivariate outliers were identified using the critical value associated with Mahalanobis Distance ($\chi^2 = 5.99, df = 2, p = 0.05$). Levene's Test for Equality of Variance revealed equal variances among groups within the OSPAN numbers dependent measure (see Table 12). Box's M Test could not be computed, as there were fewer than two non-singular cell covariance matrices. Likewise, Bartlett's Test of Sphericity could not be computed, as the error SSCP matrix was singular. As such, Pillar's Trace was used when interpreting MANOVA results. MANOVA results indicate that child abuse group [Pillar's Trace = 0.042, $F(1,69) = 1.475, p = 0.236$ partial $\eta^2 = 0.042$] does not significantly affect the combined dependent variable of OSPAN numbers data. However, secondary univariate follow-up tests revealed that math accuracy errors [$F(1,69) = 2.99, p = 0.88, \text{partial } \eta^2 = 0.042$] was the only variable on the combined DV that showed marginal significance. These effect sizes were small. Table 13 presents the adjusted group means

for the three dependent measures contained in the MANOVA by child abuse group. Table 14 presents the one-way MANOVA results for the OSPAN numbers dependent variable.

Neurological Data

For the neurological analyses, conducted separately from cognitive analysis, usable data was available for 71 participants, the majority of whom were female ($n = 58$) and had an average age of 20.14 years ($SD = 3.926$). The average child abuse score for these participants was 2.739 ($SD = 4.981$; out of a maximum possible score of 36), while the average drug abuse score (as measured by the Texas Christian University Drug Screen (TCUDS-V)) was 0.167 ($SD = 0.637$; out of a possible score of 13). Given that only two participants in the sample were identified as experiencing any form of substance abuse, drug abuse was removed as a group from all statistical analyses.

Raw data collected using the fNIRS is initially in the form of near-infrared wavelengths. Hemodynamic analyses, however, are conventionally done using concentration of oxygenated, deoxygenated, and/or total blood concentration. Unit conversion from wavelength to hemoglobin concentration was accomplished through a series of pre-processing procedures that included checking of the raw signal, truncation (i.e., removing time that does not contain information pertinent to the executive functioning tasks completed by the participant), spike artifact removal (i.e., the removal of sudden spikes of oxygenated blood within the data that are unrelated to actual brain activity), the removal of discontinuities (i.e., correction for moments in which the sources and/or detectors of the fNIRS do not make sufficient contact with the scalp), and the application of a frequency filter (i.e., a pass through a filter which removes experimentally irrelevant frequency bands). Next, the data was automatically transformed from wavelength data

into hemodynamic states (i.e., data containing information pertaining to hemoglobin concentration in response to neural activity) using in-built software functions.

Once pre-processing was finished, Statistical Parametric Mapping (SPM) was completed on each participant's pre-processed data file. SPM refers to the construction and assessment of spatially extended statistical processes used to test hypotheses about functional imaging data. SPM is completed first at the within-subject level (i.e., level 1), then at the between-subject level (i.e., level 2). SPM level 1 analysis requires certain parameters to be set, including specifying a basis function and specifying the experimental conditions. The basis function is a mathematical model that is used to account for the physiological fact that hemodynamic response to a change in neural activity is not perfectly synchronized for that activity. For the purposes of the present study, the canonical hemodynamic response function (hrf) was used, as it serves as the default basis function when performing group-level analysis of fMRI data (Steffener, Tabert, Reuben, & Stern, 2010). The experimental conditions (i.e., the executive functioning tasks) were also a specified parameter for SPM level 1 analyses.

After SPM level 1 (within-subjects) was completed for all participant data, SPM level 2 analyses (between-subjects) could be completed. First, the number of groups and individuals within those groups was specified. Next, the SPM level 1 results of each individual participant were selected for their corresponding groups. Given that the experimental tasks were counterbalanced between participants, they must be rearranged within the data so that software compares the correct tasks between groups. An F-contrast matrix was then constructed. This contrast allows the statistical software to perform the equivalent of a univariate analysis of variance (ANOVA) across all the executive functioning tasks between the child abuse and no child abuse groups. This test identifies any significant differences between the groups across all

experimental tasks. A t-contrast matrix was then used to identify potential difference within specific tasks, as well as the direction of those differences. These contrasts allow the statistical software to perform the equivalent of a two-sample t-test across each executive functioning task between the child abuse and no child abuse groups.

There was a statically significant main effect of group [$F(1, 69) = 2.934, p = 0.043$] across completion of all executive functioning tasks. This was signified by the F-contrast (see Figure 1). These differences exist only between the S5/D2 sensor and detector pair (see Figure 2). Additional t-contrast revealed that there was a statistically significant effect of group [$t(71) = 2.063, p = 0.043$] during the WCST (see Figure 3). Furthermore, the t-contrast revealed that the child abuse group had a decreased hemodynamic response during the WCST as compared to the no child abuse group (see Figure 4). These differences exist only between the S5/D2 sensor and detector pair. Anatomically, these areas correspond to the medial prefrontal cortex (mPFC) and the orbitofrontal cortex (OFC).

Additional t-contrast revealed marginally significant differences in hemodynamic response between groups during the OSPAN. These t-contrasts revealed that there was a marginally significant effect of group [$t(71) = 1.839, p = 0.071$] during the OSPAN (see Figure 5). Furthermore, the t-contrast revealed that the child abuse group had a decreased hemodynamic response during the OSPAN as compared to the no child abuse group (see Figure 6). These differences exist only between the S6/D3 sensor and detector pair. Anatomically, this area corresponds to the dorsolateral prefrontal cortex (dlPFC).

Additional t-contrast revealed marginally significant differences in hemodynamic response between groups during other Part 2 of the Conners CPT. Additional t-contrasts revealed that there was a marginally significant effect of group [$t(71) = 1.777, p = 0.081$] during Part 2 of

the Conners CPT (see Figure 7). Furthermore, the t-contrast revealed that the child abuse group had a decreased hemodynamic response during Part 2 of the Conners CPT as compared to the no child abuse group (see Figure 8). These differences exist only between the S6/D3 sensor and detector pair. Anatomically, this area corresponds to the dorsolateral prefrontal cortex (dlPFC).

CHAPTER IV

DISCUSSION

Due to constraints on time and data acquisition during part two of the current study, only fNIRS and data from the three executive functioning tasks, along with abuse scores acquired from the three primary child abuse questionnaires were analyzed. The measure that was not analyzed was the Prospective and Retrospective Memory Questionnaire (PRQM).

Significance of Cognitive Findings

Individuals that were not abused as children selected an incorrect card more often during completion of the WCST as compared to their abused counterparts. While this result was only marginally significant and the effect size was small, it is important to consider the implications given the significant neurological findings during completion of the WCST (discussed below). This is a component of the WCST, which specifically measures reasoning and decision making. Earlier research into the long-term effects of child abuse found no significant differences between abused and non-abused populations in regard to either cognitive or neurological differences (Mark, Poltavski, Petros, & King, 2018). Additionally, Perna and Kiefner (2013) found differences between child abuse victims and their non-abused counterparts on the WCST, but only for the categories of maintenance of set and preservative errors. A possible explanation for the marginally significant results in the present study may be that individuals that were abused in their childhood have developed cognitive coping mechanisms that allow them to make accurate decisions more quickly than their non-abused counterparts, but a different area of the brain is involved the neurological aspect of completing these responses.

The present study was only actively imaging the outer 3cm of the prefrontal cortex. Other areas of the brain are also involved in decision making and judgement, such as the anterior cingulate cortex (Brown & Alexander, 2017), which is a deep brain structure whose activity cannot be measured using fNIRS.

Although the hemodynamic response of the non-abuse group during the WCST demonstrates comparatively increased cortical activation, their poor performance on the WCST may also be explained as a spurious, non-significant finding. The present study may have lacked sufficient power to detect minute cognitive difference between the abuse and non-abuse groups due to a relatively small sample size. Future research should focus on larger samples of individuals that can be assigned to more clearly defined child abuse groups.

While the results of the WCST were marginally significant, there was a significant difference between abuse groups on the dependent variable of commission error rate during Part 1 of the Conners CPT. The difference was in the predicted direction with the abuse group showing more error of commission compared to the non-abuse group. Commission error rate refers to the rate at which individuals provided a response when an “X” was not present. The Conners CPT is often used as a tool for diagnosing Attention Deficit Hyperactivity Disorder (ADHD), which is a psychiatric diagnosis that is more common among individuals that were abused during their childhood (Sanderud, Murphy, & Elklit, 2016). The present study did not collect any data pertaining to psychiatric diagnoses of the sample, much less information pertaining to symptomology of undiagnosed psychiatric disorders. Commission error rate is also a specifically adequate measure of impulsivity that can be measured regardless of ADHD or other psychiatric illness status. Shaked et al., (2019) found commission errors and response time

to be useful and stable measures of sustained attention and impulsivity relative to the omission error component of the Conners CPT.

Research has demonstrated that childhood maltreatment (i.e., childhood abuse or neglect) is associated with heightened self-reported trait impulsivity (e.g., Li et al., 2012; Roy, 2005). However, given that impulsivity is multidimensional (Lynam, Smith, Whiteside, & Cyders, 2006), child abuse may show specificity with respect to particular aspects of impulsivity. Sujan, Humphreys, Ray, and Lee (2014) demonstrated that laboratory-based measures of impulsivity suggested that individuals with a history of child abuse showed significantly less impulsivity and risk-taking than individuals without abuse histories. However, these laboratory-based measures may be influenced by hypervigilance or in the moment actions, self-report measures may assess more general behaviors related to real-world impulsivity and risk-taking.

Following the marginally significant WCST results, dependent variables within the Conners CPT and OSPAN were also marginally significant. There was a significant difference between abuse groups on the dependent variable of commission error count during Part 1 of the Conners CPT, but these results just fall short of statistical significance. This is similar to the significant findings of commission error rate during Part 1 of the Conners CPT. When both results are taken in conjunction, there is strong evidence for the hypothesis that that experiencing child abuse increases an individual's impulsivity, causing reactions when stimuli are not present.

The marginally significant difference of the average number of math accuracy errors during completion of each block of the OSPAN is interesting, as individuals in the no child abuse group made more math accuracy errors on average as compared to the child abuse group. Working memory and early life stress, of which child abuse can be a major stressor, is associated with decreased working memory (Pechtel & Pizzagalli, 2011), yet this relationship is not well

documented within neuroimaging literature. The OSPAN results in the present study are likely due to the convenience sample that was used, which was comprised of undergraduate psychology students a relatively small sample size, and unequal distribution of participants between the abuse and non-abuse groups. Future research should include the use of clinical samples, larger sample sizes as well as an equal distribution of individuals within child abuse groups.

Significance of fNIRS Findings

A significant difference in cortical blood flow was found between individuals who had not experienced child abuse versus those who had experienced moderate-to-high levels of child abuse in and between Brodmann's Area's (BA) 10 and 11. Secondary analyses revealed these differences to exist only during the completion of the WCST. Specifically, individuals who had experienced child abuse had decreased cortical blood flow to these parts of the prefrontal cortex during the WCST as compared to their non-abused counterparts.

BA 10, which is part of the medial prefrontal cortex (mPFC), is the anterior-most portion of the prefrontal cortex (PFC), while BA 11 is part of the orbitofrontal cortex (OFC). Research suggest that BA 10 is believed to be involved in strategic memory recall, as well as various other executive functions (Ramnani & Owen, 2004). BA 11 is involved in decision making, the processing of rewards, encoding new information to long-term memory, and reasoning (Rogers et al., 1999; Frey & Petrides, 2000; Kringelbach & Rolls, 2004). The mPFC is a functional brain region important for producing adaptive behavior when circumstances change, confidence in one's decision making, and fear generalization (Bang & Flemming, 2018; Sharp & Killcross, 2018; Spalding, 2018). The OFC is a functional brain region shown to play a crucial role in reward-guided learning and decision making, especially for impulsive choice procedures (Rushworth et al., 2011).

The above evidence may provide an explanation for why differences in these areas of the prefrontal cortex were not found during completion of the other executive functioning tasks, as they do not specifically measure decision-making and reasoning abilities. Engagement of the mPFC has been associated with the WCST (Shirayama, et al., 2010), and poor WCST performance has been associated with the orbitofrontal cortex deficits (Chung et al., 2013). This was the only significant finding in regard to fNIRS data and childhood abuse groups in the present study.

The significant neurological results of the present study are consistent with previous research on the topic with groups of typical children versus those at risk for the development of developmental coordination disorder (DCD) (Koch, Miguel, & Smiley-Oyen, 2018). Koch, Miguel, and Smiley-Oyen (2018) showed that both groups performed with similar accuracy on the Stroop Task and the WCST, but their underlying neural activation differed. The high and sustained activation of the PFC the DCD group experienced during the WCST may serve as a compensatory effort to maintain response accuracy (Koch, Miguel, & Smiley-Oyen, 2018). This partially supports the primary hypothesis, insofar that more abused individuals did display characteristics of atypical neural activation, which is indicated by increased blood flow to the prefrontal cortex, while also displaying nonsignificant to marginally significant difference during cognitive measures of executive function.

A number of brain structures have been implicated as encoding rewarding and punishing outcomes, including the mPFC and OFC. Jessup and O'Doherty (2014) found evidence that the lateral OFC, a subsection of the OFC, shows increased activity when encoding informational signals that distinguish rewarding or punishing outcomes, but the level of activation is the same between rewarding and punishing outcomes. The mPFC, however, was found to respond to

informational signals about outcomes in a manner that differentiated rewarding from punishing outcomes (Jessup & O’Doherty, 2014). This supports the results of the present study, as individuals that were abused as children had less active mPFC and OFC during a decision-making task as compared to their non-abused counterparts. This decreased level of activity in the face of decision-making may be explained by stress these individuals experienced during their childhood when making decision that may or may not have resulted in abuse from their parent(s) or caregiver(s). Chronic exposure to this kind of situation may result in permanent atypical activation patterns of the mPFC and OFC. Research in this area is still needed to make informed conclusions the relationship between child abuse and long-term neurological function.

There were marginally significant neurological findings during completion of the OSPAN. The child abuse group experienced marginally significantly less neural activity while completing the OSPAN as compared to the no child abuse group. This difference was only present around BA 46, which corresponds to the dorsolateral prefrontal cortex (dlPFC). Among other executive functioning roles, the dlPFC exerts executive top-down control over other working memory related brain areas (Gazzaley & Nobre, 2012). As such, decreased activation of this brain area in the child abuse group supports the hypotheses of the present study, as it may signify atypical functioning associated to experienced child abuse. Phillip et al., (2016) demonstrated that early life stress is associated with impaired neurobehavioral performance and changes in brain activation, suggesting recruitment of additional cognitive resources during working memory in tasks in those that experienced early life stress. Phillip et al., (2016), however, used fMRI technology, allowing them to gain a level of spatial resolution that is not possible with fNIRS. The limitations of the imaging technology used in the present study, as well

as a small sample size, likely accounts for the lack of significant neurological findings during the OSPAN task.

Finally, there were marginally significant neurological findings during completion of Part 2 of the Conners CPT. The child abuse group experienced marginally significantly less neural activity while completing the OSPAN as compared to the no child abuse group. This difference was only present around BA 46, which corresponds to the dorsolateral prefrontal cortex (dlPFC). Along with a role in working memory, the dlPFC plays a role in attention control and sustained attention (Bishop, 2009; Bishop, Duncan, Brett, and Lawrence, 2004). As such, a decreased hemodynamic response in this brain area in the child abuse group, which signifies decreased neural activity, supports the hypotheses of the present study. This may indicate atypical functioning associated to experienced child abuse. Lim et al., (2016) demonstrated that participants with a history of child abuse displayed significantly reduced activation relative to healthy controls during challenging attention tasks, but only in typical attention regions including the dlPFC. This study, however, also monitored the neural activation of deep brain structures in conjunction with the dlPFC, as fMRI was the neuroimaging technique utilized. The limitations of fNIRS, as well as a small sample size, likely accounts for the lack of significant neurological findings during Part 1 of the Conners CPT in the present study.

The identification of significant neurological results with simultaneous nonsignificant and marginally significant cognitive results may, on the surface, appear counterintuitive. However, physiological measures of neurological activity may be more sensitive to subtle differences between abuse groups than cognitive measures. fNIRS has been identified as a particularly sensitive measure of neurological activity, specifically for measuring increased functional connectivity of interhemispheric dlPFC during cognitively demanding tasks

(Fishburn, Norr, Medvedev, & Vaidya, 2014). As such, fNIRS is equipped to identify cognitive state differences at a neurological level, while executive functioning measures are not fully equipped to identify the subtle differences between abuse groups that were observed in the present study. Additionally, individuals that experienced abuse during and throughout their childhood may have learned to compensate cognitively for the neurological deficits that developed in response to the abuse they suffered. This could potentially explain the lack of cognitive differences between abuse groups in the present study.

Study Limitations

There were some statistical limitations in the present study. Multivariate analysis of variance is fairly sensitive to violations of its underlying assumptions. Levene's Test for Equality of Error Variance between the groups was significant for the omission error rate during the Conners CPT Part 1, the omission error count during the Conners CPT Part 2, as well as the summation of failure to maintain set during the WCST. This signifies that the error variance between the two groups for each dependent measure was not similar. At the same time the assumption of homoscedasticity of covariance matrices between each pair of dependent variables was maintained as Box's Test of Equality of Covariance Matrices was nonsignificant for all MANOVA's, with the exception of the OSPAN in which number-based measures served as the dependent variable. As such, the assumption of homoscedasticity was met for four out of five MANOVAs. Additionally, Bartlett's Test of Sphericity was significant for all MANOVAs performed, again with the exception of the OSPAN in which number-based measures served as the dependent variable. This indicates that at least one of the intercorrelations between dependent measures within each of the five MANOVAs was non-zero, which suggests that the selected dependent variables are related and the MANOVA approach was warranted.

A more significant limitation to the present study is the small obtained sample size. While the proposed sample size was 120 individuals, spanning 4 abuse groups, our final sample included 84 participant data points in cognitive analyses and only 71 participant data points in hemodynamic assessments spanning 2 abuse groups. In the latter analyses there were 29 individuals in the abuse group and 42 individuals in the non-abuse group. This falls somewhat short of the required sample size for the abuse group ($n=30$, to detect a medium-to-large effect size). However, these sample sizes are based on a medium-to-large effect size ($d = 0.35$). For the cognitive analyses, groups sizes varied based on the elimination of univariate and multivariate outliers from the statistical analysis ($n = 59$ to $n = 71$).

Future Directions

There are several directions that the current study can continue in regard to data analysis and connections of the negative effects of child abuse to varying domains of functioning. Data from the Prospective and Retrospective Memory Questionnaire have not yet been analyzed. If the findings of previous research hold true, then this data should further support the findings of the current study, insofar that individuals abused during childhood maltreatment is associated with the impairment of memory (Lin et al., 2017). Lin et al., 2017 also found the severity of maltreatment to be positively associated with the severity of impairment of both prospective and retrospective memory. Along with PRMQ data, additional information for the child abuse questionnaires (e.g., the abuser, ages that abuse occurred, number of times abuse occurred, etc.) has yet to be analyzed.

fNIRS is a novel technology that has not previously been used to image the brains of individuals that have experienced abuse during their childhood years. Traditionally, diffusion tensor imaging (DTI) is used. DTI is an MRI-based neuroimaging technique which makes it

possible estimate the location, orientation, and anisotropy (i.e., the property of being directionally dependent) of the brain's white matter tracks. DTI, as well as all other MRI-based technologies, allow researchers to collect data on deep brain structures. For example, Rinne-Albers et al., (2016) found that early trauma exposure affects the development of the corpus callosum, which may play a role in the pathophysiology of PTSD in adolescents.

MRI-based technology is especially useful when studying child abuse in children directly, as the PFC is not yet fully developed. fNIRS was used in the present study as access to MRI-based technology was not possible. Additionally, the number of sources and detectors that could be used in the present study was minimal. Regardless, the present study did have significant neurological findings. This study serves as evidence for the utility of fNIRS in child abuse research. Future studies should explore the technology in measuring differential cortical blood flow between various child abuse groups.

Originally, the present study proposed to explore the long-term effects of alcohol abuse on neurological and cognitive functioning, both independently and in conjunction with child abuse. This was not feasible after a preliminary analysis, as only one individual in the obtained sample identified experiencing any levels of alcohol abuse. This was not expected, as alcohol and/or drug use is heightened among adult survivors of childhood sexual, physical, and emotional abuse (Windom & White, 1997; Mokma, Eshelman, & Messman-Moore, 2002; Miron, Orcutt, Hannan, & Thompson, 2014). Previous research also indicates that individuals that have experienced either child abuse, alcohol abuse, and/or drug abuse may experience neurological and cognitive abnormalities (Risher et al., 2015; Woods et al., 2016). Future research should focus on the association between experienced child abuse and drug and/or alcohol abuse and their impacts on cognitive and neurological functioning. Future research into

the long-term outcomes of child abuse should also collect information of diagnosed psychiatric disorders, as well as behavioral data that may aid in identifying symptomology of undiagnosed disorders.

Social desirability bias must also be considered when dealing with sensitive topics, such as alcohol abuse and child abuse. Haberecht et al. (2014) found that socially desirable responses on self-report measures may depend on school education, with untruthful, yet socially desirable response rates being higher among individuals with higher school education. Social desirability bias also represents a significant threat to the validity of self-reported alcohol use and harm measures. Davis, Thake, and Vilhena (2010) found consistent associations between social desirability bias and self-reported alcohol consumption such that those more concerned with how they are perceived report 20% to 33% less consumption and are about 50% less likely to report risky drinking. Following this, the low self-report rates of alcohol misuse and abuse may be due to the obtained sample providing socially desirable responses.

Outside of the current study, future research should also focus on individuals who have experienced mild levels of abuse. The present study treated child abuse as a dichotomous variable, but child abuse exists on a spectrum between and within the forms of physical, psychological, and sexual. It may be possible that experiencing relatively small amounts of one type of abuse as a child will have no lasting impact on individuals in adulthood, while small amounts of other kinds of abuse will have a lasting impact. There is currently not enough research in this area to make any substantial claims. Future research should also focus on the interaction of child abuse and drug use. While there is much evidence on the negative psychological effects of drug use (Pentz & Riggs, 2013), less research has been conducted on child abuse as a direct predictor for drug use as an adult. Banducci et al. (2014) found that

abused individuals who have been abused as children are at a particularly high risk for SUD.

However, the best ways in which to help this population in terms of therapy and treatment is still unknown.

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TABLES

Table 1. Demographics of Age, Child Abuse, and Drug Abuse for Cognitive Sample.

Characteristic (<i>N</i> = 84)	Sample Size (n)	Valid Percent of Sample Size (%)
Age (<i>M</i> = 21.04, <i>SD</i> = 6.870)		
18	23	27.4
19	27	32.1
20	16	19.0
21	6	7.1
22	1	1.2
23	2	2.4
27	1	1.2
28	1	1.2
35	1	1.2
40	1	1.2
44	1	1.2
55	2	2.4
N/A	2	2.4
Sex		
Female	71	84.5
Male	13	15.5
Child Abuse Group (<i>M</i> = 1.884, <i>SD</i> = .879)		
No Abuse	47	56.0
Abuse	37	44.0

Table 2. Demographics of Age, Child Abuse, and Drug Abuse for Neurological Sample.

Characteristic (N = 71)	Sample Size (n)	Valid Percent of Sample Size (%)
Age (M = 20.14, SD = 3.926)		
18	21	29.6
19	23	32.4
20	14	19.7
21	4	5.6
22	2	2.8
23	2	2.8
27	2	2.8
28	1	1.4
35	1	1.4
44	1	1.4
Sex		
Female	60	84.5
Male	11	15.5
Child Abuse Group (M = 1.884, SD = .879)		
No Abuse	42	59.2
Abuse	29	40.8

Table 3. Levene's Test of Equality of Error Variance for the WCST Dependent Measure.

	F	df1	df2	p-value
Total Correct Answers	0.168	1	60	0.683
Preservative Errors	.199	1	60	0.657
Summation of Failure to Maintain Set	5.586	1	60	0.021
Total Incorrect Answers	.229	1	60	0.634

Tests the null hypothesis that the error variance of the dependent variables is equal across groups.

Table 4. Unadjusted Group Means for the Four Dependent Measures Contained in the WCST MANOVA by Child Abuse Group.

<u>Dependent Variable</u>	<u>Child Abuse Level</u>	<u>Mean</u>	<u>Standard Deviation</u>	<u>N</u>
Total Correct Answers	No Abuse	34.84	2.351	37
	Abuse	34.20	2.598	25
	Total	34.58	2.453	62
Preservative Errors	No Abuse	5.11	1.776	37
	Abuse	5.56	2.002	25
	Total	5.29	1.868	62
Summation of Failure to Maintain Set	No Abuse	0.57	0.689	37
	Abuse	0.28	0.542	25
	Total	0.45	0.645	62
Total Incorrect Answers	No Abuse	12.27	3.338	37
	Abuse	12.84	3.738	25
	Total	12.5	3.515	62

The above table provides the unadjusted means, standard deviations, and retained sample size for the dependent variables that construct the dependent measure of the WCST. These values are provided for all levels of the independent variables of child abuse group (i.e., no child abuse and child abuse).

Table 5. One-Way MANOVA Results for the WCST Dependent Variable.

Source	Dependent Measure	df	F-ratio	p-value	Partial Eta ²	Observed Power
Child Abuse Level	Total Correct Answers	1	1.009	.319	.017	.167
	Preservative Errors	1	.872	.354	.014	.151
	Sum. Failure to Maintain Set	1	3.069	.085 [^]	.049	.407
	Total Incorrect Answers	1	.388	.536	.006	.094

The above table present the data of importance from the One-Way MANOVA performed on the WCST dependent measure. No data reached the level of significance of $p < .05$. Marginally significant data is denoted with the symbol “[^]”.

Table 6. Levene’s Test of Equality of Error Variance for the Conners CPT Count Data Dependent Measure.

	F	df1	df2	p-value
Omission Error Count (Part 1)	0.709	1	60	0.403
Commission Error Count (Part 1)	2.341	1	60	0.131
Omission Error Count (Part 2)	6.800	1	60	0.011
Commission Error Count (Part 2)	1.398	1	60	0.242

Tests the null hypothesis that the error variance of the dependent variables is equal across groups.

Table 7. Unadjusted Group Means for the Four Dependent Measures Contained in the Conners CPT Count Data MANOVA by Child Abuse Group.

<u>Dependent Variable</u>	<u>Child Abuse Level</u>	<u>Mean</u>	<u>Standard Deviation</u>	<u>N</u>
Omission Error Count (Part 1)	No Abuse	1.06	1.205	34
	Abuse	0.75	1.143	28
	Total	0.92	1.178	62
Commission Error Count (Part 1)	No Abuse	0.59	0.857	34
	Abuse	1.11	1.227	28
	Total	0.82	1.064	62
Omission Error Count (Part 2)	No Abuse	1.12	1.274	34
	Abuse	0.68	0.863	28
	Total	0.92	1.121	62
Commission Error Count (Part 2)	No Abuse	0.88	0.977	34
	Abuse	0.64	0.826	28
	Total	0.77	0.913	62

The above table provides the unadjusted means, standard deviations, and retained sample size for the dependent variables that construct the dependent measure of the Conners CPT Count data. These values are provided for all levels of the independent variables of child abuse group (i.e., no child abuse and child abuse).

Table 8. One-Way MANOVA Results for the Conners CPT Count Data Dependent Variable.

Source	Dependent Measure	df	F-ratio	p-value	Partial Eta ²	Observed Power
Child Abuse Level	Omission Error Count (Part 1)	1	1.057	.308	.017	.173
	Commission Error Count (Part 1)	1	3.822	.055 [^]	.060	.486
	Omission Error Count (Part 2)	1	2.412	.126	.039	.333
	Commission Error Count (Part 2)	1	1.058	.308	.017	.173

The above table present the data of importance from the One-Way MANOVA performed on the Conners CPT Count data dependent measure. No data reached the level of significance of $p < .05$. Marginally significant data is denoted with the symbol “ ^ ”.

Table 9. Levene’s Test of Equality of Error Variance for the Conners CPT Count Rate Dependent Measure.

	F	df1	df2	p-value
Omission Error Rate (Part 1)	6.197	1	57	0.016
Commission Rate Count (Part 1)	2.484	1	57	0.121
Omission Error Rate (Part 2)	0.498	1	57	0.483
Commission Rate Count (Part 2)	.506	1	57	0.506

Tests the null hypothesis that the error variance of the dependent variables is equal across groups.

Table 10. Unadjusted Group Means for the Four Dependent Measures Contained in the Conners CPT Rate Data MANOVA by Child Abuse Group.

<u>Dependent Variable</u>	<u>Child Abuse Level</u>	<u>Mean</u>	<u>Standard Deviation</u>	<u>N</u>
Omission Error Rate (Part 1)	No Abuse	0.0094	0.0092	34
	Abuse	0.0100	0.0131	25
	Total	0.0097	0.0109	59
Commission Error Rate (Part 1)	No Abuse	0.0017	0.0027	34
	Abuse	0.0037	0.0033	25
	Total	0.0026	0.0031	59
Omission Error Rate (Part 2)	No Abuse	0.0125	0.0132	34
	Abuse	0.0102	0.0134	25
	Total	0.01153	0.0132	59
Commission Rate Count (Part 2)	No Abuse	0.0025	0.0026	34
	Abuse	0.0021	0.0024	25
	Total	0.0023	0.0025	59

The above table provides the unadjusted means, standard deviations, and retained sample size for the dependent variables that construct the dependent measure of the Conners CPT Rate data. These values are provided for all levels of the independent variables of child abuse group (i.e., no child abuse and child abuse).

Table 11. One-Way MANOVA Results for the Conners CPT Rate Data Dependent Variable.

Source	Dependent Measure	df	F-ratio	p-value	Partial Eta ²	Observed Power
Child Abuse Level	Omission Rate Count (Part 1)	1	0.036	.849	.001	.054
	Commission Rate Count (Part 1)	1	6.604	.013*	.104	.714
	Omission Rate Count (Part 2)	1	0.448	.506	.008	.101
	Commission Rate Count (Part 2)	1	0.293	.590	.005	.083

*The above table present the data of importance from the One-Way MANOVA performed on the Conners CPT Count data dependent measure. Significant data ($p < .05$) is denoted with the symbol “ * ”.*

Table 12. Levene’s Test of Equality of Error Variance for the OSPAN Numbers Dependent Measure.

	F	df1	df2	p-value
Math Speed Errors	0.059	1	69	0.808
Math Accuracy Errors	1.692	1	69	0.198
Total Math Errors	0.204	1	69	0.653

Tests the null hypothesis that the error variance of the dependent variables is equal across groups.

Table 13. Unadjusted Group Means for the Three Dependent Measures Contained in the OSPAN Numbers MANOVA by Child Abuse Group.

<u>Dependent Variable</u>	<u>Child Abuse Level</u>	<u>Mean</u>	<u>Standard Deviation</u>	<u>N</u>
Math Speed Errors	No Abuse	0.76	0.888	41
	Abuse	0.77	0.935	30
	Total	0.76	0.902	71
Math Accuracy Errors	No Abuse	2.95	1.746	41
	Abuse	2.17	2.069	30
	Total	2.62	1.915	71
Total Math Errors	No Abuse	3.71	2.003	41
	Abuse	2.93	2.100	30
	Total	3.38	2.066	71

The above table provides the unadjusted means, standard deviations, and retained sample size for the dependent variables that construct the dependent measure of the OSPAN Numbers data. These values are provided for all levels of the independent variables of child abuse group (i.e., no child abuse and child abuse).

Table 14. One-Way MANOVA Results for the OSPAN Numbers Dependent Variable.

Source	Dependent Measure	df	F-ratio	p-value	Partial Eta ²	Observed Power
Child Abuse Level	Math Speed Errors	1	0.002	.962	.000	.050
	Math Accuracy Errors	1	2.990	.088 [^]	.042	.400
	Total Math Errors	1	2.483	.120	.035	.343

The above table present the data of importance from the One-Way MANOVA performed on the OSPAN Numbers dependent measure. No data reached the level of significance of $p < .05$. Marginally significant data is denoted with the symbol “^”.

Table 15. Levene’s Test of Equality of Error Variance for the OSPAN Letters Dependent Measure.

	F	df1	df2	p-value
Sum. of Perfectly Recalled Letter Sets	0.216	1	65	0.644
Sum. of All Letters Recalled	0.330	1	65	0.568

Tests the null hypothesis that the error variance of the dependent variables is equal across groups.

Table 16. Unadjusted Group Means for the Two Dependent Measures Contained in the OSPAN Letters MANOVA by Child Abuse Group.

<u>Dependent Variable</u>	<u>Child Abuse Level</u>	<u>Mean</u>	<u>Standard Deviation</u>	<u>N</u>
Sum. of Perfectly Recalled Letter Sets	No Abuse	36.55	18.88	38
	Abuse	44.28	18.73	29
	Total	39.90	19.07	67
Sum. of All Letters Recalled	No Abuse	55.82	13.16	38
	Abuse	60.38	13.87	29
	Total	57.79	13.56	67

The above table provides the unadjusted means, standard deviations, and retained sample size for the dependent variables that construct the dependent measure of the OSPAN Letters data. These values are provided for all levels of the independent variables of child abuse group (i.e., no child abuse and child abuse).

Table 17. One-Way MANOVA Results for the OSPAN Letters Dependent Variable.

Source	Dependent Measure	df	F-ratio	p-value	Partial Eta ²	Observed Power
Child Abuse Level	Sum. of Perfectly Recalled Letter Sets	1	2.771	.101	.041	.375
	Sum. of All Letters Recalled	1	1.888	.174	.028	.273

The above table present the data of importance from the One-Way MANOVA performed on the OSPAN Numbers dependent measure. No data reached the level of significance of $p < .05$, nor did any data attain marginal significance.

FIGURES

SPMF Image: F-statistic map for Hboxy

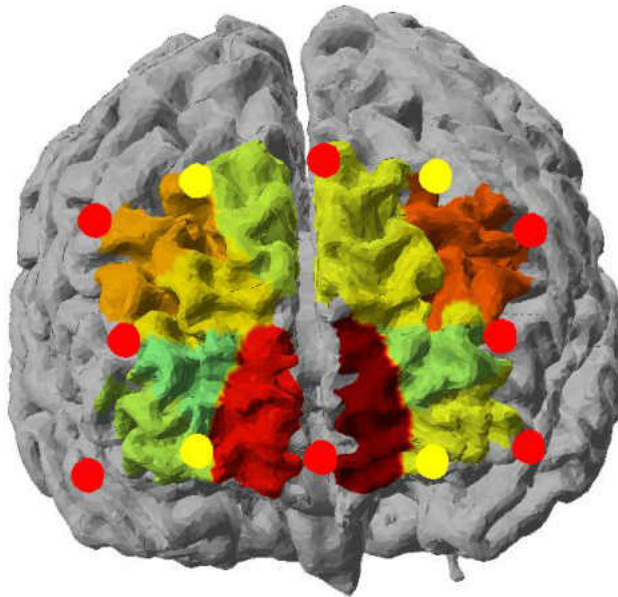


Figure 1. Overall Hemodynamic Differences Between Abuse and Non-Abuse Groups Across all Executive Functioning Tasks. *The red and yellow dots represent the sources and detectors, respectively. The redder an area of the brain is, the more different the abuse groups. The F-contrast does not specify specific group differences.*

Thresholded SPMF Image: p-value = 0.043 for Hboxy

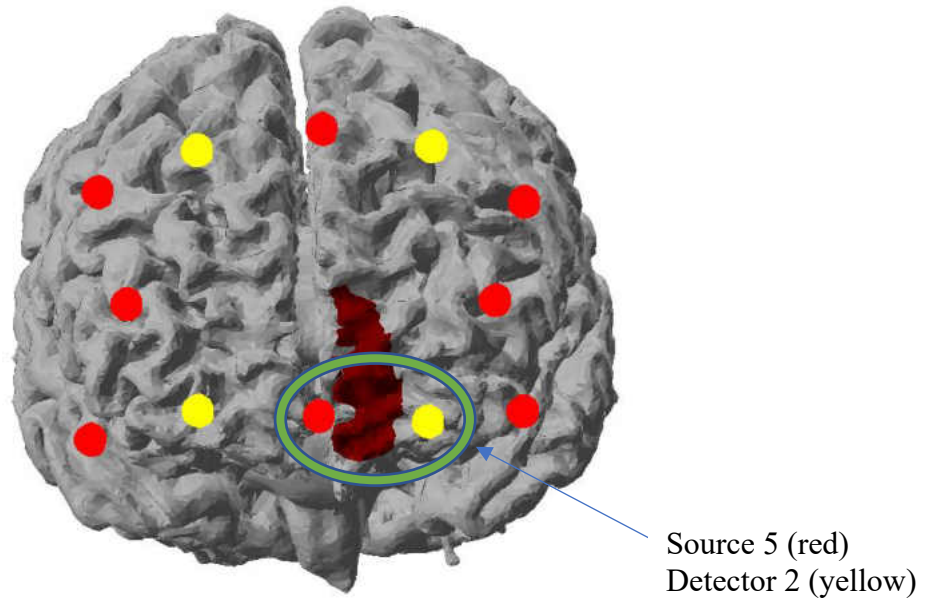


Figure 2. Threshold Differences Between Abuse and Non-Abuse Groups Across All Executive Functioning Tasks. *The red and yellow dots represent the sources and detectors, respectively. The red area represents the area of the brain with significantly different ($p = 0.043$) hemodynamic response (i.e., blood flow) between the child abuse and no child abuse groups.*

SPM Image: t-statistic map for Hboxy

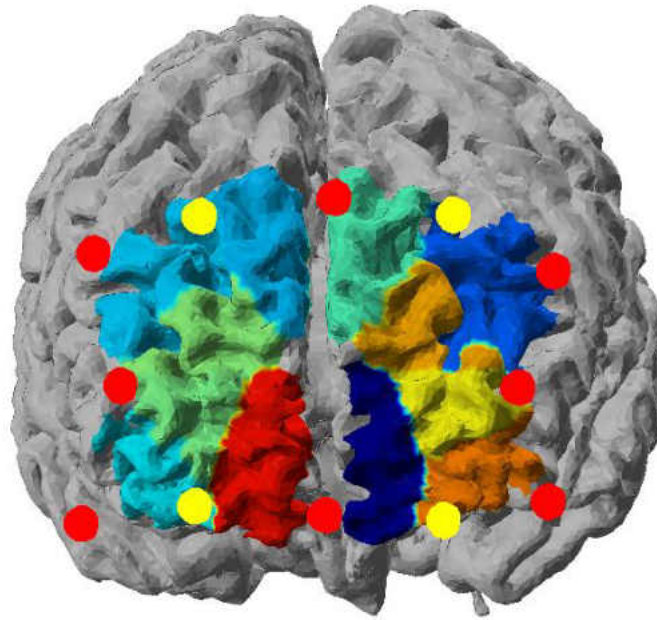


Figure 3. Overall Hemodynamic Differences Between Abuse and Non-Abuse Groups During the WCST. *The red and yellow dots represent the sources and detectors, respectively. The bluer an area of the brain is, the lower the level of hemodynamic response in the corresponding brain area in the child abuse group as compared to the no child abuse group over the course of the WCST.*

Thresholded SPMt Image: p-value = 0.043 for Hboxy

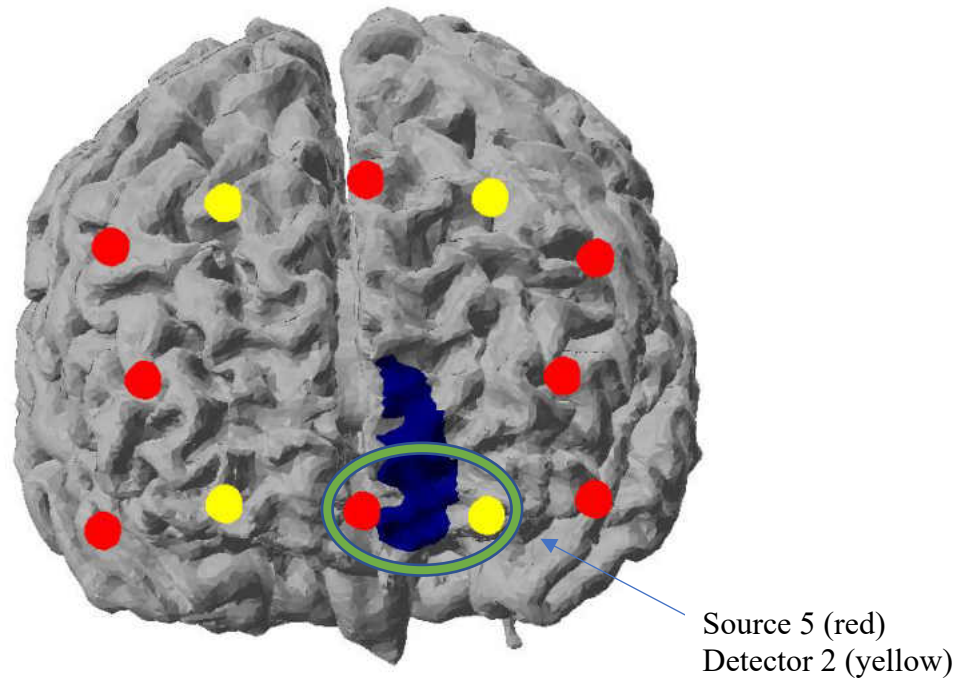


Figure 4. Threshold Differences Between Abuse and Non-Abuse Groups During the WCST. *The red and yellow dots represent the sources and detectors, respectively. The blue area represents the area of the brain with a significantly lower ($p = 0.043$) hemodynamic response (i.e., blood flow) in the child abuse group as compared to the no child abuse group over the course of the WCST.*

SPM Image: t-statistic map for Hboxy

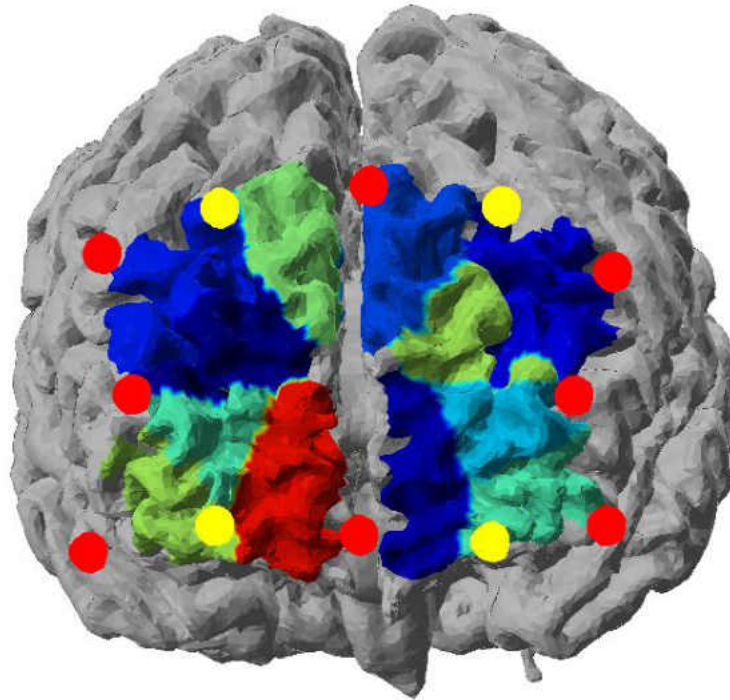


Figure 5. Overall Hemodynamic Differences Between Abuse and Non-Abuse Groups During the OSPAN. *The red and yellow dots represent the sources and detectors, respectively. The bluer an area of the brain is, the lower the level of hemodynamic response in the corresponding brain area in the child abuse group as compared to the no child abuse group over the course of the OSPAN.*

Thresholded SPMt Image: p-value = 0.071 for Hboxy

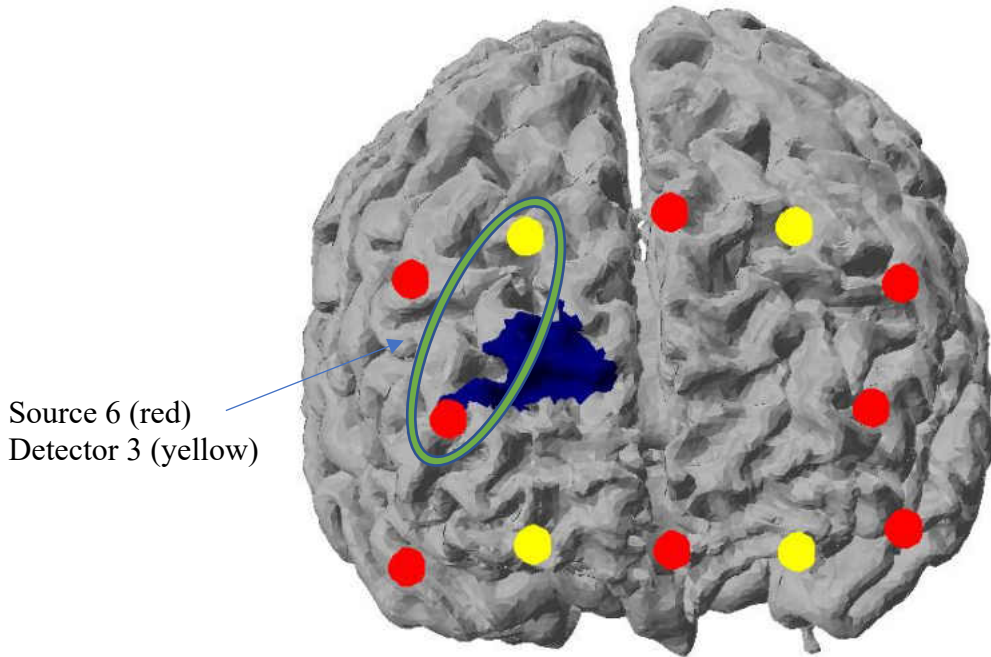


Figure 6. Threshold Differences Between Abuse and Non-Abuse Groups During the OSPAN. *The red and yellow dots represent the sources and detectors, respectively. The blue area represents the area of the brain with a marginally significantly lower ($p = 0.071$) hemodynamic response (i.e., blood flow) in the child abuse group as compared to the no child abuse group over the course of the OSPAN.*

SPMt Image: t-statistic map for Hboxy

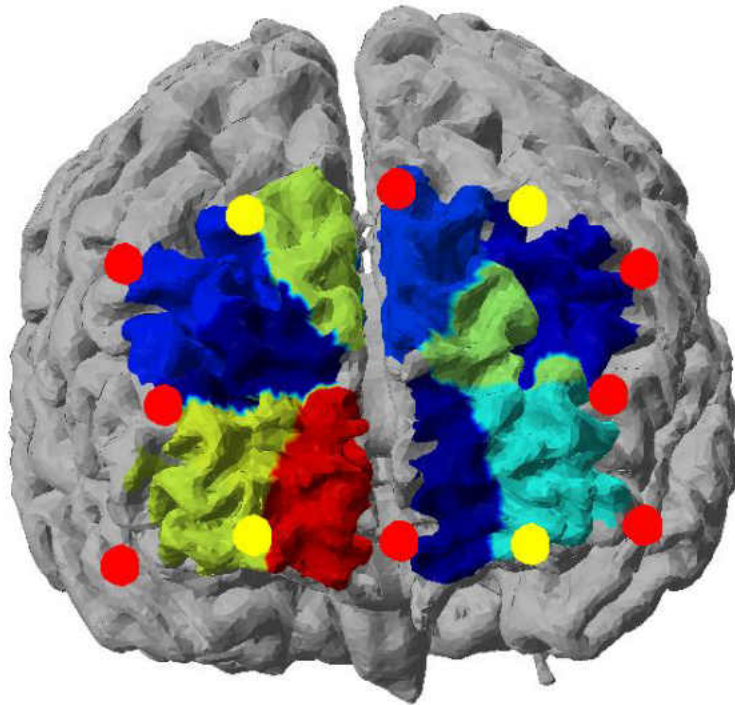


Figure 7. Overall Hemodynamic Differences Between Abuse and Non-Abuse Groups During Part 2 of the Conners CPT. *The red and yellow dots represent the sources and detectors, respectively. The bluer an area of the brain is, the lower the level of hemodynamic response in the corresponding brain area in the child abuse group as compared to the no child abuse group over the course of Part 2 of the Conners CPT.*

Thresholded SPMt Image: p -value = 0.081 for Hboxy

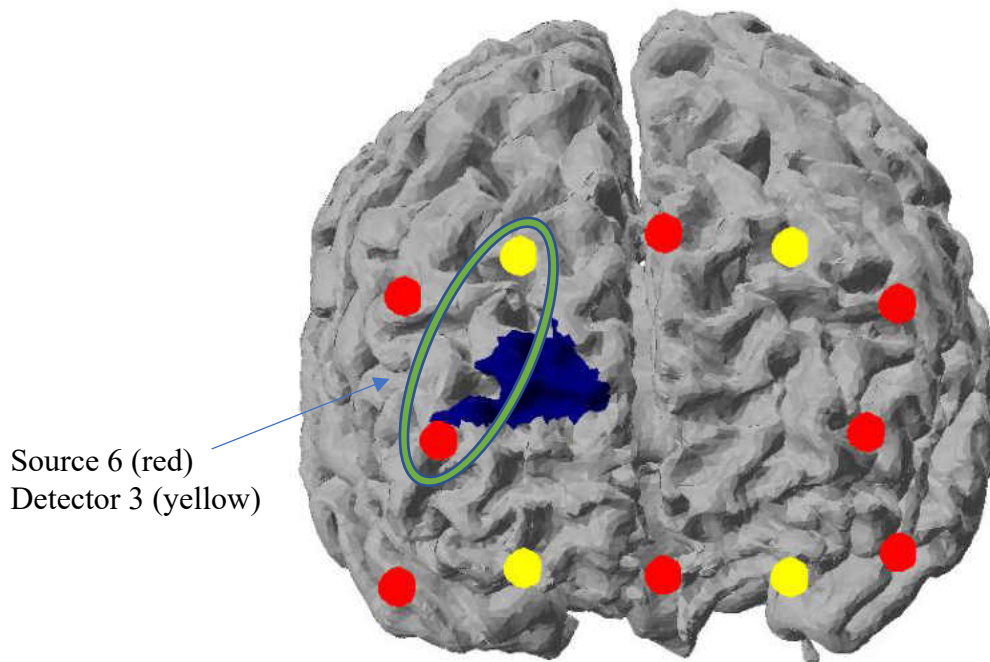


Figure 8. Threshold Differences Between Abuse and Non-Abuse Groups During Part 2 of the Conners CPT. The red and yellow dots represent the sources and detectors, respectively. The blue area represents the area of the brain with a marginally significantly lower ($p = 0.081$) hemodynamic response (i.e., blood flow) in the child abuse group as compared to the no child abuse group over the course of Part 2 of the Conners CPT.