Differential executive functioning in young adulthood as a function of experienced child abuse

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ABSTRACT

Introduction: Previous research has shown cognitive 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 between individuals who have been abused as children versus those without the history of childhood abuse.

Methods: The present study recruited 43 students from the University of North Dakota (33 women) between ages 18 and 23 years of age. 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 grouped into a no-child-abuse group, a mild-child-abuse group, or a moderate-to-severe child abuse group. All participants were administered measures of executive functioning that included the Wisconsin Card Sorting Task, the Operation Span Task, and the Connors Continuous Performance Task with a simultaneous recording of electroencephalographic activity using a wireless 9 channel EEG system.

Results: There was a statistically significant main effect of child abuse group (no child abuse vs. moderate-to-high child abuse) for the EEG-derived probability of cognitive workload during the OSPAN. Beta bandwidths for individuals in the drug abuse group, which served as a covariate, were also found to be significantly attenuated during the Connors CPT.

Conclusion: Individuals that have been abused as children must use significantly more mental effort to complete executive functioning tasks as compared to their non-abused counterparts. Increased neurological effort could be used to explain poor decision-making skills that are common within the population.

1. Introduction

Individuals who experience trauma and maltreatment in childhood often experience acute and/or chronic, negative psychological and physiological effects later in life. Studies have shown that experiencing even moderate levels of trauma can leave an individual without the necessary skills to properly deal with stress, which, in turn, can lead to emotional dysregulation, impulsivity and a predisposition for a host of mental illnesses including depression and Attention-Deficit-Hyperactivity Disorder (Velotti and Garofalo, 2015; Suzuki et al., 2014; Nanni et al., 2012; Marusak et al., 2015; Retz-Junginger et al., 2015).

A fair amount of research has also focused on the association of childhood abuse with drug use and abuse. Adults with substance use disorders (SUDs) report higher rates of child abuse than adults without SUDs (Banducci et al., 2014a, 2014b). While the use of drugs and alcohol could function as a coping mechanism to deal with trauma, the fact that this population has an overall higher level of impulsivity increases the odds of drug use later in life (Sergentanis et al., 2014). Poor executive functioning skills may also increase an individual’s chance of initiating drug use. Pentz and Riggs (2013) demonstrated that effective executive functioning skills were the major predictor of lower substance use during adolescence.

Research has also shown that experiencing traumatic events as a child can lead to a host of deficits in executive functioning. For example, Naudé et al. (2004) found a reduction in global executive functioning, which included memory and verbal processing abilities, in a population of individuals who were placed in a “Place of Safety” due to child abuse. Additionally, they found that abused subjects presented with symptoms such as depressed explicit-declarative memory (especially semantic memory), as well as poor error detection and restoration, despite advanced levels of social knowledge (episodic memory). Similarly, Pandey (2011) found working memory impairments in abused children compared to their non-abused counterparts. Additionally, Mothes et al. (2015) found that the number of instances of child abuse significantly impacted executive functioning during adolescence.

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Abuse experienced during childhood can come in three major forms; physical abuse, psychological/emotional abuse, and sexual abuse. The majority of available research concerning child abuse does not consider potential differential outcomes based on the type of abuse experienced by an individual. Instead, the three primary varieties of child abuse are collapsed into a singular type of event experienced during childhood. Research that does distinguish between the three primary types of child abuse have found that number of abuse types and severity of abuse interact to predict greater levels of trauma symptomatology in adulthood (Wind and Silvnen, 1992; Clemmons et al., 2007). Thus, it is the interaction between type of abuse and severity of that abuse that determine outcomes in adulthood, as opposed to type of abuse alone. Furthermore, physical and psychological abuse are often experienced in conjunction with one another (Briere and Runtz, 1990). Thus, teasing apart the subtle differences between these abuse types is difficult outside of large samples. Finally, the similarities between the three primary forms of child abuse in terms of their association with negative adult outcomes is more apparent than any differences; though there was a trend for sexual abuse to be particularly associated to sexual problems, emotional abuse to low self-esteem, and physical abuse to marital breakdown (Mullen et al., 1996).

Various psychiatric conditions are often associated with not only behavioral and emotional deficits, but also with neurological deficiencies. Early life stress (not necessarily linked to child abuse) has shown to be associated with structural anomalies in the corpus callosum in children and the hippocampus in adults (Rogers and De Brito, 2016). Moreover, the authors of the aforementioned study also reported that extreme stressors in early life could lead to atypical activation of several brain regions, including decreased activity in the prefrontal cortex.

Indeed, Ito et al. (1993) reported that of children admitted to psychiatric hospitals, 54% of abused children presented with brain-wave abnormalities compared to only 27% of non-abused children. Cook et al. (2009) demonstrated that those with childhood trauma had significantly higher EEG coherence (which is the degree of association between 1 s time periods during data collection) in the frontal, central, temporal, and parietal areas as compared to those with either only adulthood trauma or no past trauma. These long-term neural correlates of childhood appear to suggest information processing differences, as well as demonstrating the lasting impact child abuse has on neuronal connectivity (Cook et al., 2009).

A study conducted by Miskovic et al. (2010) found that maltreated youths exhibited more left hemisphere EEG coherence than the control youths, suggesting a suboptimal organization of cortical networks, as well as reduced frontal (anterior) interhemispheric coherence. This conclusion was reached by analyzing resting regional EEG intra- and interhemispheric α-band (7.5–12.5 Hz) coherence. Alpha waves, however, are not the only bandwidth that can serve as a marker for behavioral and emotional problems as a function of past child abuse. Black (2004) found that theta waves play a role in the brain functioning of individuals who have experienced childhood sexual abuse. Prior to this research, the alpha bandwidth was the primary focus of research and treatment. Alper et al. (2013) found that individuals with histories of abuse in childhood had significantly greater EEG power than controls in the theta frequency range (3.51–7.41 Hz). They posited that EEG theta power may be a correlate of childhood exposure to abuse (Alper et al., 2013). Loo et al. (2009) explored the difference in electrical activity of the frontal lobe in individuals with ADHD. This research found both a decrease in alpha power and an increase in beta power in ADHD adults compared to the controls. These patterns of frontal and parietal activation indicated increased cortical arousal during completion of the attention task (see “Instruments for further elaboration” in the ADHD group.

Abnormal beta bandwidths may also serve as way to identify an individual at risk for alcoholism. Rangaswamy et al. (2004) found that males with a high risk for alcoholism had higher low beta power (measured as 12.5 Hz–16 Hz) and high-risk females had increased mid and high beta power (midrange beta power was measured from 16 to 20 Hz, while high range beta power was measured from 21 to 28 Hz) compared to low risk participants.

With the growing availability of state-of-the art systems of neurophysiological monitoring it now becomes possible to correlate cognitive deficits attributed to traumatic childhood experiences with EEG-derived cognitive metrics of cognitive workload, low ms high engagement, and distractibility. Such indexes are typically derived using individual subjects’ EEG profile recorded during completion of standardized neuropsychological benchmark tasks. Cognitive workload refers to the amount of mental effort required to complete a cognitive task, and in turn-key automated EEG systems is outputted as a probability of high cognitive workload. Workload is the relationship between the resources required to carry out a task and the resources available to, and hence supplied by, the operator (Wickens and Tsang, 2015). Engagement is a subjective state linked to vigilance, which includes energetic arousal, intrinsic motivation, motivation for success and concentration. Task engagement is seen as an index of availability of attentional resources and may be expressed in the form of probabilities for high and low engagement (Kamzanova et al., 2014). Distractibility is the condition of being sidetracked during completion of a cognitive task. Such metrics are more easily associated with cognitive resource allocation and are typically based on complex algorithms involving multiple bandwidths recorded over specific cortical sites. For example, Berka et al. (2007) the researchers validated cognitive state metrics based on the automated output of a wireless EEG system B-Alert X-10 by Advanced Brain Monitoring (ABM) using a combination of multi-level cognitive and vigilance tasks, objective performance metrics such as reaction time, and percentage of correct responses and subjective ratings to assess the perceived level of effort. Since the original study by Berka et al. (2007) ABM’s algorithms have been validated with a number of cognitive tests (e.g. Stroop (Sciarini et al., 2014)), physical and social states (e.g. sleep deprivation, Westbrook et al., 2004; team collaboration, Stevens et al., 2009) and populations (e.g. athletes, Štišić et al., 2014).

It thus becomes possible to use metrics of cognitive state to assess executive function in those with and without a history of child abuse and comorbidity with drug abuse. Better understanding of the unique needs of this population from the neuro-cognitive perspective may drive development of better treatment strategies, behavioral/educational interventions and help monitor their progress. In the present study we utilized EEG-derived metrics of cognitive state as well as traditional EEG bandwidths to describe differences in executive functioning between those with and without a history of child abuse while controlling for a history of drug abuse. Based on previous literature, the objective of the present study is to provide preliminary evidence of a neural correlates between experiencing abuse in childhood and diminished executive functioning in young adulthood. It was hypothesized that individuals who experienced either moderate or severe childhood trauma would have a lower level of executive functioning compared to those who experienced no or low levels of childhood trauma (H1). Secondly, it was hypothesized that individuals who had experienced either a moderate or severe childhood trauma would exhibit higher beta, and theta power, as well as lower alpha power in the frontal regions of the brain (H2) suggesting greater cortical activation, which would be consistent with higher workload and lower engagement during completion of executive function tasks indicative of inefficient cognitive processing (H3).

2. Methods

2.1. Participants

A total of 43 students (33 women) from the University of North Dakota participated in the study as part of the research requirement introduced in conjunction with some of the participants’ undergraduate psychology classes. The average age of participants was 19.6 years.
The convenience sample was recruited using the University of North Dakota online participant recruitment system, SONA. The participants first completed an online screening for a history of childhood abuse as well as drug use and abuse. Based on their scores, eligible individuals were grouped according to the following criteria: those who had experienced no childhood abuse (n = 19), low levels of abuse (n = 10) or those who had experienced moderate-to-severe childhood abuse (n = 14). Inclusion into these groups was based on the total score of stem questions positively endorsed on the Lifetime Report of Physical Abuse (LPAA), the Lifetime Report of Psychological Abuse (PALA), and the Lifetime Report of Sexual Abuse (SALA) scale (LONGSCAN) with a maximum possible score of 36. An exploratory analysis of the distribution of the sample scores revealed that the bottom 50% of the sample had a score of 0 (no history of abuse). The range of scores between the 50th and 75th percentiles consisted of individuals with scores ranging from 1 to 3 (i.e., mild abuse). Finally, those falling between the 75th and 100th percentile had scores ranging from 4 to 11 (i.e., moderate-to-high abuse). All research protocols were approved by the University of North Dakota Institutional Review Board. All participants provided informed consent to both parts of the study: electronic consent for the online screening and written consent for the in-lab cognitive and neurophysiological assessment.

2.2. Instruments

2.2.1. Childhood Abuse Questionnaire

The Lifetime Report of Physical Abuse (LPAA), the Lifetime Report of Psychological Abuse (PALA), 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. They were developed by the Longitudinal Studies of Child Abuse and Neglect (LONGSCAN) consortium. Dubowitz et al. (2011) found that the pattern of correlations between the factor scores (i.e., physical needs, emotional support, and parental monitoring) of the three LONGSCAN measures, Child Protective Services reports, and measures of the parent–child relationship offered modest to moderate support for convergent validity of the three aforementioned scales.

2.2.2. Drug Use Questionnaire

Childhood physical abuse severity is associated with an earlier initiation into drug use. Any level of abuse is associated with more extensive life-time and recent polydrug use (Darke and Torok, 2014). The Texas Christian 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 dependence. Psychometric criteria for this instrument have been established, particularly focusing on its internal consistency (Knight et al., 2002). The sensitivity of the TCUDS-V makes it particularly useful in minimizing inappropriate treatment referrals for drug users (Knight et al., 2002). For the purposes of this study, a drug use score served as a covariate during statistical analyses.

2.2.3. Physiological measurements

A B-Alert X-10 wireless EEG system by ABM was used to assess participants’ brainwave activity within the 1–40 Hz range. The system has a sampling rate of 256 Hz and acquires nine channels of monopolar EEG recordings with a linked mastoid reference. The EEG channels correspond to electrode positioning according to the standard International 10–20 system and include sensor sites in the frontal (Fz, F3 and F4), central (Cz, C3 and C4) and parietal-occipital (POz, P3, and P4) regions. B-Alert Acquisition software (B-Alert Live) consists of several modules that allow the user to acquire, store, view, and analyze physiological signals acquired by the wireless system. The system automatically transforms the data producing both global and channel-specific power spectral density values (PSDs) for 1 Hz bins as well as along traditional bandwidths (i.e. Theta (3–7 Hz), Alpha (8–12 Hz), Beta (13–29 Hz), and Gamma (30–40 Hz)).

Prior to computing the 1-Hz PSD bins, the software automatically processes the raw signals to eliminate known artifacts including electromyographic signals from muscle activity (EMG), electrooculographic signals from eye blinks (EOG), spikes, excursions and amplifier saturations (See B-Alert Software Manual, 2009; Berka et al., 2007 for more details). Missing data during any epoch of data collection was screened for and removed prior to data analysis. Bandwidths were not recorded during any testing for two participants. Bandwidths were not recorded during the Connors CPT Part 2 for one participant, and the alpha, beta, and gamma bandwidths were not recorded during the Connors CPT Part 2 for one participant. These values can be found in Table 7. The cognitive state metric during the WCST was not recorded for one participant. Finally, the cognitive state metric during both Part 1 and Part 2 of the Connors CPT was not recorded for one participant. These values can be found in Table 2. All participants with missing data were excluded from the analysis that corresponds to said missing data.

The software also provides metrics of cognitive states in the form of probabilities of high and low engagement, high cognitive load and distractibility. These cognitive state metrics are based on individualized statistical models that utilize the absolute and relative PSD values from the midline Fz-POz and Cz-POz derivations during completion of three 5-minute benchmark tasks (a Visual Passive Vigilance Task (VPVT), an Auditory Passive Vigilance Task (APVT), and a 3-Choice Active Vigilance Task (3CVT)) to derive coefficients for a discriminant function that generates classification probabilities for each 1 s epoch. During the model training procedure, APVT, VPVT, and 3CVT represent distraction/relaxed wakefulness, low engagement, and high engagement, respectively. The quality of the individual models was assessed by auto-validation on these three tasks (APVT, VPVT, and 3CVT), and for all subjects the majority of the epochs were classified into the expected class (e.g. Johnson et al., 2011; Stikic et al., 2011). This model has been validated in several previous studies across a range of applications, such as sleep deprivation (Westbrook et al., 2004), team collaboration (Stevens et al., 2009), and emergent leadership (Waldman et al., 2013).

The EEG-based validated workload model (Berka et al., 2007) was utilized to extract the subject's cognitive workload levels on a second-by-second basis. This is a general model that was trained on the EEG data from a large population performing the Forward Digit Span (FDS) and Backward Digit Span (BDS) tasks. The model utilizes the absolute and relative PSDs from the differential EEG derivations (C3-C4, Cz-POz, F3-Cz, Fz-C3, and Fz-POz) into a 2-class linear Discriminant Function Analysis classifier (DFA) (i.e., low workload and high workload). For both FDS and BDS, the task difficulty was manipulated by increasing the number of digits at each level.

2.2.4. Cognitive tasks

2.2.4.1. WCST. The Wisconsin Card Sorting Task (WCST) is a classic measure of one's executive functioning. Namely, it is used as a measure of the selectivity feature of attention and can reflect a variety of cognitive impairments. A meta-analysis of studies using WCST showed a significantly poorer 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. Individuals who experienced child abuse regularly score significantly lower on the WCST as compared to the normal population, indicating less cognitive flexibility (Spann et al., 2012).

A computerized version of the test was used in this study. This task consists of four stimulus cards and 128 response cards. The test proceeds through a number of shifts in a set (sorting principles) that varies along three dimensions (color, form, and number). Successful performance on the WCST requires the participant first to determine the correct sorting principle based on computer feedback, and then to
maintain this sorting principle or set.

The dependent measures included the total number of correct answers, the total number of incorrect answers, the number of perseverative errors, the number of successfully completed categories, and the sum score of a participant's ability to maintain the set of rules in any given trial of the WCST.

2.2.4.2. Conners CPT. The Conners Continuous Performance Task (Conners CPT) is a psychological measure of sustained/selective attention and impulsivity. Performance on the Conners CPT was found to differ significantly between children with and without ADHD (Bart et al., 2014). Ruckert and Grafman (1996) also showed that individuals with frontal lobe lesions had slower reaction times when completing the Conners CPT compared to normal controls. Attentional and inhibitory deficits on Conners CPT were also reported by Miller et al. (2015) in participants with a history of childhood abuse.

During the first part of this task (CPT 1), participants are shown a series of letters in the center of a computer screen that appear briefly and are presented at variable intervals. Participants were instructed to press the spacebar whenever they saw the letter “X”. If any other letter appeared, they were told not to respond. After CPT 1 had been completed, a brief 2-minute break began to give the participant time to rest before the second part of this task (CPT 2). During CPT 2, participants again had to press the spacebar whenever they see the letter “X”, but only if it appears immediately after the letter “A”. Any other individual letters or grouping of letters should not have elicited any response.

The dependent variables of interest included the error omission rate, the error omission count, the commission error rate, and the commission error count. Data of these four dependent variables were collected both for parts 1 and 2 of the Conners CPT.

2.2.4.3. OSPAN. Developed by Turner and Engle (1989), the Operation Span Task (OSPAN) can assess an individual's general working memory capacity. In this task, participants read and verify a simple math problem (e.g., “Is (4/2) – 1 = 1?” – operation), and then read a word after the operation (e.g., SNOW). After a series of operation-word pairs have been presented, participants are asked to recall the words that followed each operation. The number of operation-word strings in a sequence is increased and decreased during the task to measure the participant's operation span. Operation span measures predicted verbal abilities and reading comprehension even though the subjects are solving mathematical problems. A computerized version of OSPAN was used in the present study. This version of OSPAN correlates well with other measures of WM capacity and has both good internal consistency and test-retest reliability (Unsworth et al., 2005). 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 et al., 2001).

The dependent variables under observation for the OSPAN task are total score, total number of correct letters recalled, total number of math errors, math errors attributed to a participant’s speed, and math errors attributed to a participant’s accuracy.

2.3. Procedure

Initial screening measures that included a demographic questionnaire, LPAA, PALA and SALA scales and TCUDS-V were completed online using the University Experiment Management System by SONA. If the participant met criteria for the specific group assignment, she/he was invited to participate in the in-lab portion of the study. Upon arrival to the lab written informed consent was obtained from each participant prior to any testing. Next an electrode strip connected to a B-Alert X-10 wireless EEG system was applied over the participant's head. Each participant then completed three 5-minute neuropsychological tasks to establish baseline indices of cognitive load, engagement and distractibility. The baseline session comprised a Visual Passive Vigilance Task (VPVT), an Auditory Passive Vigilance Task (APVT), and a 3-Choice Active Vigilance Task (3CVT). During the 5 min of VPVT and APVT, subjects were required to press the space bar on the keyboard every 2 s. Subjects were prompted to maintain the 2 s time intervals by a 10 cm diameter red circle that appeared in the center of the monitor during the VPVT, or by an audio tone during the APVT. The 3CVT is a sustained attention task that requires subjects to discriminate one primary target (presented 70% of the time) from two secondary non-target geometric shapes that were presented for 0.2 s and randomly interspersed over the test period. It challenges the ability to sustain attention by increasing the inter-stimulus interval (ISI) from 1.5 s up to 10 s at the end of the task. Participants were instructed to respond as quickly and as accurately as possible to each stimulus presented by pressing the left arrow to indicate target stimuli, and the right arrow to indicate non-target stimuli. A brief training period was provided prior to the start of the testing period to minimize practice effects for the 3CVT. The training period lasted until a certain number of correct responses to both targets and non-targets was reached (2 targets and 2 non-targets).

The participant then began experimental tasks with simultaneous recording of physiological parameters (EEG). Participants completed the Wisconsin Card Sorting Task, the Conners Continuous Performance Task, and the Operation Span Task. These tasks were counterbalanced among participants using a Latin Square. Start and end markers were inputted by the researcher in the EEG data to denote the start and stop time of each of the three tasks. Upon completion of the tasks, EEG data acquisition was terminated, the headset removed, and the participant was dismissed. The entire experimental session took approximately 60 min to complete.

2.4. Statistical analyses

The design of this study included one between subject factor of group with 3 levels (no history of child abuse, mild child abuse and moderate-to-severe child abuse), and one covariate (drug use total score on TCUDS-V). Specific dependent variable measures for each of the tasks are described above. A series of one-way Analyses of covariance (ANCOVA) were performed on groups, with drug use (as measured by the TCUDS-V) serving as a covariate. Electrophysiological dependent measures of bandwidth and cognitive state were also analyzed with a series of ANCOVA’s within a specific cognitive task (e.g. Conners CPT) as a function of group while co-varying for drug use.

3. Results

Demographic characteristics of the sample are provided in Table 1. All non-significant tests are described in Table 3 through Table 11.

3.1. EEG

Analyses of EEG-derived cognitive state metrics showed that there was a statistically significant main effect of group (F(2,38) = 3.712, p = .034) for the probability of cognitive workload averaged during completion of the Operation Span Task (OSPAN). Post hoc pairwise comparisons (Bonferroni) between groups showed that those in the moderate-to-high child abuse groups had a significantly (p = .011) higher workload during completion of OSPAN (M = 0.56, SD = 0.11) than those in the no child abuse group (M = 0.36, SD = 0.31) (see Fig. 1). None of the other indices of cognitive state were significant (see Table 2 for descriptive statistics). Furthermore, no significant effects were found for the covariate on the OSPAN (Table 4).

ANCOVA results also showed a statistically significant effect for the covariate of drug abuse group (F(2,38) = 6.33, p = .016) for the total beta bandwidth power (13–29 Hz) on the Conners CPT Part 1 (Table 5). To better understand the relationship between drug abuse and the
power of beta waveform, the continuous variable of total score on the TCUDS-V was further divided into three drug abuse groups based on quartile distributions of scores. The no drug abuse group contained participants all with a score of 0 (< 50th percentile). The mild drug abuse group contained participants with a score ranging from 1 to 3 (50th–75th percentiles). The moderate-to-high drug abuse group contained participants with scores of 4 or greater (> 75th percentile). Post hoc pairwise comparisons (Bonferroni) between groups showed that those in the moderate-to-high drug abuse group had a significantly higher total beta bandwidth power ($M = 1.953, SD = 0.282$) than those in the no drug abuse group ($M = 1.868, SD = 0.271$). These results are presented in Fig. 2.

The analyses also showed a statistically significant main effect for the covariate of drug abuse group ($F(2,38) = 5.459, p = .025$) for the total beta bandwidth power on the Conners CPT Part 2. Post hoc pairwise comparisons (LSD) between the three drug abuse groups were not significant. Scores were then divided into two groups at the 50th percentile, where scores of 0 indicated no drug abuse, and scores of 1 or greater indicated drug abuse. The between subjects ANOVA showed a significant main effect ($F = 6.664, p = .014$) for total beta power during the Conners CPT Part 2 (Table 6). Those in the no drug abuse group ($M = 1.629, SD = 0.270$) had significantly higher beta power than those in the drug abuse group ($M = 1.343, SD = 0.259$).

3.2. Cognitive tests

3.2.1. Conners CPT

There was a statistically significant main effect of group ($F(2,38) = 3.259, p = .049$) for the error omission rate (i.e., the rate of errors when an "X" or an "A" was presented, but no response was given) on the Conners CPT Part 2. Post hoc pairwise comparisons (Bonferroni) between groups showed that those in the moderate-to-high child abuse groups had a significantly higher error omission rate ($M = 0.05, SD = 0.053$) than those in the no child abuse group ($M = 0.02, SD = 0.02$). There were no statistically significant differences among the groups on other dependent measures of Conners CPT. No significant effects of either childhood abuse or drug abuse were observed on any of the dependent measures of WCST or OSPAN. These results are presented in Fig. 2.

4. Discussion

Consistent with our original hypothesis, a significant difference was

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Table 1

Demographics of age, child abuse, and drug abuse for total sample.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Sample size (n)</th>
<th>Valid percent of sample size (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age ($M = 19.60, SD = 1.545$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>8</td>
<td>18.6</td>
</tr>
<tr>
<td>19</td>
<td>19</td>
<td>44.2</td>
</tr>
<tr>
<td>20</td>
<td>6</td>
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</tr>
<tr>
<td>21</td>
<td>7</td>
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</tr>
<tr>
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<td>1</td>
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<tr>
<td>26</td>
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<td>2.3</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>33</td>
<td>76.7</td>
</tr>
<tr>
<td>Male</td>
<td>10</td>
<td>23.3</td>
</tr>
<tr>
<td>Child abuse group ($M = 1.884, SD = 0.879$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No abuse</td>
<td>19</td>
<td>44.2</td>
</tr>
<tr>
<td>Mild abuse</td>
<td>10</td>
<td>23.3</td>
</tr>
<tr>
<td>Moderate-to-high abuse</td>
<td>14</td>
<td>32.6</td>
</tr>
<tr>
<td>TCUDS-V score ($M = 0.767, SD = 2.103$)</td>
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<tr>
<td>0</td>
<td>35</td>
<td>81.4</td>
</tr>
<tr>
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<td>2.3</td>
</tr>
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<td>11</td>
<td>1</td>
<td>2.3</td>
</tr>
</tbody>
</table>

The demographics of the total sample size of participants who completed both Part 1 and Part 2 of the current study are listed above (n = 43). Participants were placed in one of the Child Abuse Groups based on total scores of the LPAA, the PALA, and the SALA (e.g., 0 = no abuse, 1–3 = mild abuse, and ≥ 4 = moderate-to-high abuse group).

Fig. 1. Mean workload across no child abuse, mild child abuse, moderate-to-high child abuse on the operation span.

* - significant at alpha = 0.05.
processes linked to inhibition, which suggests this metric is a sensitive

to changes associated with the attentional demands and cognitive

and valid measure of a participant’s workload. Heathcote et al. (2015)
also collected measures of cognitive workload during OSPAN testing
from University of Utah undergraduate students. While direct EEG
measurements were not utilized in their study, dual task performance
(as is required during the OSPAN task) significantly increases an
individual’s overall cognitive workload, thus increasing mental effort.
Similarly, Cowell et al. (2015) showed that individuals who had been
subjected to moderate-to-high levels of child abuse from ages 3–9 may
exert more mental effort to complete a working memory task as com-
pared to their non-abuse counterparts. The researchers further sug-
gested that maltreatment during infancy and toddlerhood, a period of
major brain organization and development, disrupts the normative
neurological structure formation and functioning, which is further ex-
cerated by prolonged stress during the early years of life (Table 8).
Our neurophysiological finding was further supported by the results of attentional testing. Specifically, individuals who had experienced a moderate-to-high level of abuse as a child showed a significantly higher omission error rate on Part 2 of Conners CPT compared to individuals who did not experience any child abuse. The error omission rate refers to the failure to produce a response to a target letter when a target is present. This suggests failure to sustain attentional focus perhaps due to more limited cognitive resources during completion of a dual task. Given that dual task performance leads to an overall increase in workload due to sharing of this limited processing capacity between

Table 5
Non-significant main and interaction effect F-ratios and corresponding p-values for the three primary cognitive state metrics under observation during Part 1 of Conners Continuous Performance Test.

<table>
<thead>
<tr>
<th>CPT Part 1</th>
<th>Main effect of child abuse</th>
<th>Main effect of drug abuse</th>
<th>Interaction effect (child abuse + drug abuse)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>p</td>
<td>F</td>
</tr>
<tr>
<td>Probability of low engagement</td>
<td>0.264</td>
<td>.769</td>
<td>0.622</td>
</tr>
<tr>
<td>Probability of high engagement</td>
<td>0.346</td>
<td>.710</td>
<td>0.386</td>
</tr>
<tr>
<td>Probability of average workload</td>
<td>0.328</td>
<td>.723</td>
<td>0.570</td>
</tr>
</tbody>
</table>

Table 6
Non-significant main and interaction effect F-ratios and corresponding p-values for the three primary cognitive state metrics under observation during Part 2 of Conners Continuous Performance Test.

<table>
<thead>
<tr>
<th>CPT Part 2</th>
<th>Main effect of child abuse</th>
<th>Main effect of drug abuse</th>
<th>Interaction effect (child abuse + drug abuse)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>p</td>
<td>F</td>
</tr>
<tr>
<td>Probability of low engagement</td>
<td>0.160</td>
<td>.853</td>
<td>1.434</td>
</tr>
<tr>
<td>Probability of high engagement</td>
<td>0.305</td>
<td>.739</td>
<td>0.956</td>
</tr>
<tr>
<td>Probability of average workload</td>
<td>1.339</td>
<td>.274</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 7
Non-significant main and interaction effect F-ratios and corresponding p-values for theta, alpha, beta, and gamma bandwidths during all executive functioning tasks.

<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>Theta</th>
<th>Alpha</th>
<th>Beta</th>
<th>Gamma</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>p</td>
<td>N</td>
<td>F</td>
</tr>
<tr>
<td>Main effect of child abuse</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WCST</td>
<td>0.885</td>
<td>.421</td>
<td>41</td>
<td>0.597</td>
</tr>
<tr>
<td>OSPAN</td>
<td>0.727</td>
<td>.490</td>
<td>41</td>
<td>0.563</td>
</tr>
<tr>
<td>CPT 1</td>
<td>1.128</td>
<td>.335</td>
<td>41</td>
<td>0.842</td>
</tr>
<tr>
<td>CPT 2</td>
<td>1.003</td>
<td>.377</td>
<td>40</td>
<td>0.584</td>
</tr>
<tr>
<td>Main effect of drug abuse</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WCST</td>
<td>0.044</td>
<td>.836</td>
<td>41</td>
<td>0.187</td>
</tr>
<tr>
<td>OSPAN</td>
<td>0.035</td>
<td>.852</td>
<td>41</td>
<td>0.639</td>
</tr>
<tr>
<td>CPT 1</td>
<td>0.187</td>
<td>.668</td>
<td>41</td>
<td>2.488</td>
</tr>
<tr>
<td>CPT 2</td>
<td>0.003</td>
<td>.958</td>
<td>40</td>
<td>1.677</td>
</tr>
<tr>
<td>Interaction effect (child abuse + drug abuse)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WCST</td>
<td>0.023</td>
<td>.879</td>
<td>41</td>
<td>0.038</td>
</tr>
<tr>
<td>OSPAN</td>
<td>0.025</td>
<td>.876</td>
<td>41</td>
<td>0.012</td>
</tr>
<tr>
<td>CPT 1</td>
<td>0.0779</td>
<td>.781</td>
<td>41</td>
<td>0.157</td>
</tr>
<tr>
<td>CPT 2</td>
<td>0.008</td>
<td>.931</td>
<td>40</td>
<td>0.051</td>
</tr>
</tbody>
</table>

The “N” values represent the total data included in the final analysis. Any values < 43 indicate missing data for the corresponding test.
The TCUDS-V utilizes to identify severity of SUD. However, pairwise comparisons between the three groups in one instance did not show statistical significance, necessitating creation of only two drug abuse groups. This may have been due to a fairly small number of participants in the moderate-to-high drug abuse group (n = 7) and, consequently, low statistical power to detect an effect of group.

### 4.1. Study limitations

There are several limitations to the current study. While the study was exploratory in nature trying to understand executive functioning of individuals with histories of childhood abuse and drug abuse in the context of brainwave activity and cognitive workload, the number of statistical tests conducted on each dependent measure naturally increased Type I error. Furthermore, the post hoc pairwise comparison method utilized for the main effect for the covariate of drug abuse group for the total beta bandwidth power on the Conners CPT Part 2 was Fischer’s Least Significant Difference (LSD) correction. The LSD correction is a liberal test that does not correct for multiple comparisons, which increases the likelihood of a Type I error.

The study was considerably underpowered due to a fairly small number of participants and was thus able to detect only large effect sizes thus increasing the possibility of Type II error. This may be one of the reasons for the lack of significant differences between the abuse groups on the Wisconsin Card Sorting Test. Additionally, Spann et al. (2012) found that physical abuse and neglect are associated with diminished cognitive flexibility and judgment making skills, which was evident from preservative errors on the WCST. These differences were not identified in the current study, possibly because most participants did not score highly on the physical abuse measure. Scores that were identified as being in the moderate-to-high abuse range were primarily found in the psychological abuse measure, while the physical abuse measure consisted primarily of scores that fell within either the no abuse or mild abuse range. A related issue concerns the method of identification of the target population. Since the topic of child abuse is of a sensitive nature and qualitative techniques, such as unstructured interviews, may produce better results in identifying abused individuals, only self-report online instruments were utilized in the present study, which may have potentially compromised recruitment.

### Table 10

Nonsignificant main and interaction effect F-ratios and corresponding p-values for the specific dependent variable measures within Part 1 of the Connors Continuous Performance Task.

<table>
<thead>
<tr>
<th>CPT Part 1</th>
<th>Main effect of child abuse</th>
<th>Main effect of drug abuse</th>
<th>Interaction effect (child abuse + drug abuse)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>p</td>
<td>F</td>
</tr>
<tr>
<td>Omission error count</td>
<td>0.046</td>
<td>.955</td>
<td>0.006</td>
</tr>
<tr>
<td>Omission error rate</td>
<td>0.116</td>
<td>.890</td>
<td>0.055</td>
</tr>
<tr>
<td>Commission error count</td>
<td>0.250</td>
<td>.780</td>
<td>0.181</td>
</tr>
<tr>
<td>Commission error rate</td>
<td>0.307</td>
<td>.737</td>
<td>0.011</td>
</tr>
</tbody>
</table>

### Table 11

Nonsignificant main and interaction effect F-ratios and corresponding p-values for the specific dependent variable measures within Part 2 of the Connors Continuous Performance Task.

<table>
<thead>
<tr>
<th>CPT Part 2</th>
<th>Main effect of child abuse</th>
<th>Main effect of drug abuse</th>
<th>Interaction effect (child abuse + drug abuse)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>p</td>
<td>F</td>
</tr>
<tr>
<td>Omission error count</td>
<td>2.782</td>
<td>.075</td>
<td>1.307</td>
</tr>
<tr>
<td>Omission error rate</td>
<td>-</td>
<td>-</td>
<td>0.778</td>
</tr>
<tr>
<td>Commission error count</td>
<td>0.181</td>
<td>.835</td>
<td>1.103</td>
</tr>
<tr>
<td>Commission error rate</td>
<td>0.141</td>
<td>.869</td>
<td>1.085</td>
</tr>
</tbody>
</table>
procedures and resulted in a relatively small sample size.

Finally, there was a significant skew of the sample between male and female participants, with most of the sample consisting of females. It is unlikely that this non-proportional ratio of the sexes had an impact on the findings of the present study. In an examination of sex differences on the neurocognitive functioning of maltreated youth, Nooner et al. (2018) found that both maltreated boys and girls showed poorer executive function than their non-maltreated sex-matched controls. Furthermore, no gender-wise comparisons were performed, as previous literature does not provide sufficient evidence for gender/sex impacting outcomes of child abuse on cognitive functioning (Crozier et al., 2014; Nooner et al., 2018). When treated as a secondary covariate, sex did not have any significant impact on the findings of the present study, which is consistent with previous research.

5. Conclusion

Overall, the results of the study support the notion of compromised executive functions in individuals with a history of childhood abuse and drug abuse. Furthermore, this study also suggests limited cognitive resources available to these individuals for the completion of cognitive tasks, which, in our study, was indexed by increased cognitive workload and increased overall beta power. More research is needed in exploring the interaction between childhood abuse, drug abuse, executive function and cognitive workload as a function of abuse severity. These findings, along with previous research, may lead to the development of treatment monitoring protocols that, if implemented appropriately, could contribute to reduction of negative neurological effects of experienced child abuse. Thus, this would allow for increased executive functioning, which could significantly benefit victims in their personal and professional lives.

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Disclosure statement

None.

References


B-Alert Software Manual, v. 1.1 ed. ABM. Goleta, CA. USA.


Fig. 2. Mean power spectral densities (PSDs) for theta, alpha, beta and gamma across Drug abuse categories on the Conners CPT Part 1. * - significant at alpha = 0.05.


