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Neurobiological Metric of Cortical-Delay Discounting Differentiates Risk for Self- and Other-Directed Violence Among Trauma-Exposed Individuals

Ana E. Sheehan, M.A., Nadia Bounoua, M.A., Anna Stumps, B.A., Rickie Miglin, M.A., Wendy Huerta, B.A., & Naomi Sadeh, PhD.

Department of Psychological and Brain Sciences, University of Delaware

Author Note

Corresponding author: Ana E. Sheehan [University of Delaware, Department of Psychological and Brain Sciences, 108 Wolf Hall, Newark, DE 19176. Email: ansheeha@udel.edu. The study procedures were approved by the Institutional Review Board of Human Studies Research at the University of Delaware (Protocol nos.: 1073423-17, 1361164-1). The present data was disseminated in poster format that Annual Society for Research in Psychopathology conference September, 2022. No further dissemination of the data have been previously presented. The data that support the findings of this study are available from the author (N.S), upon reasonable request. This study was not preregistered. **Word Count:** 8,809/9,000

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Abstract

Self- and other-directed violence (SDV/ODV) contribute to elevated rates of mortality. Early trauma exposure shows robust positive associations with these forms of violence but alone does not distinguish those at heightened risk for later engagement in SDV/ODV. Novel assessment metrics could aid early identification efforts for individuals with vulnerabilities for violence perpetration. This study examined a novel neurobiological measure of impulsive choice for reward as a potential moderator of associations between childhood trauma exposure and lifetime SDV/ODV. A high-risk community sample of 177 adults (89 men; 50.3%) were assessed for childhood trauma exposure, engagement in SDV (e.g., suicide attempts), and ODV (e.g., assault). A cortical delay discounting (C-DD) measure was created using a multivariate additive model of gray matter thickness across both hemispheres, previously found to be positively associated with susceptibility to impulsivity and externalizing disorders. Childhood trauma exposure was positively associated with ODV and SDV; however, these relationships differed as a function of C-DD. Engagement in ODV increased as scores on C-DD *increased,* and SDV increased as scores on C-DD *decreased*. Further, moderation revealed biological sex differences, as the association between childhood trauma and SDV depended on C-DD for women but not for men. Findings from the present work demonstrate that risk conferred by childhood trauma exposure for violence varied as a function of a C-DD. Together, these findings point to the utility of neurobiological markers of impulsive decision-making for differentiating risk for violence among individuals with a history of trauma exposure.

Keywords: *Violence, Suicide, Aggression, Cortical Delay Discounting, Trauma, Risky Behaviors, Impulsivity*

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General Scientific Summary: Childhood trauma exposure is associated with increased negative health outcomes including greater likelihood of engagement in violence perpetration onto oneself and others. However, trauma exposure on its own does not determine who might be at greatest risk for later violence later in life. Our findings suggest that a neurobiological measure representing an individual's vulnerability towards impulsive decision making was able to differentiate individuals at elevated risk for violence among those with a history of trauma exposure.

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Introduction

Violence defined as behaviors exerted through physical force with intent to hurt, damage or kill oneself (Self-Directed Violence; SDV) or others (Other-Directed Violence; ODV) are among the top ten leading causes of morbidity and mortality among adults ages 15 to 44, incurring substantial costs to individuals and society more broadly (Spencer et al., 2019). Recent data suggest that periods of national lockdown due to the COVID-19 pandemic were associated with elevated levels of violent crime among U.S. adults, including aggravated assault (Killgore et al., 2021). In addition, suicide remains the 12th leading cause of death for individuals in the U.S., impacting the recent observed decrease in life expectancy (Spencer et al., 2019; Woolf & Schoomaker, 2019). Previous work has established that ODV and SDV are highly comorbid (Harford et al., 2012, 2016) and share many common risk factors including substance abuse, history of psychiatric hospitalization, and poor impulse control (Arseneault et al., 2000; Harford et al., 2018; Pulay et al., 2008). However, exploration of factors that differentiate risk for engagement in violent behaviors remains an important research priority, as early identification efforts could mitigate the onset of negative health outcomes and associated public health consequences.

Childhood exposure to trauma is a well-established risk factor for engagement in SDV and ODV later in life (Angelakis et al., 2019; Augsburger et al., 2019; Dodge et al., 1990; Zatti et al., 2017). Only a minority of individuals who experience these stressful events in childhood go on to perpetrate violence, however, underscoring the need to incorporate additional risk indices into models of trauma-related violence perpetration to improve their predictive validity. Further, identifying biomarkers that interact with early trauma exposure to explain risk for violence perpetration has the potential to improve prevention and intervention efforts. The goal

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of this study was to examine the synergistic utility of childhood trauma exposure and a neurobiological indicator of impulsive choice for reward, Cortical-Delay Discounting (C-DD), for explaining SDV and ODV.

Violence as a Long-term Sequela of Early Trauma Exposure

Extant research points to links between childhood experiences of trauma and later perpetration of violence against oneself (Angelakis et al., 2019; Zatti et al., 2017) and others (Augsburger et al., 2019; Dodge et al., 1990; Heleniak & McLaughlin, 2020; Maxfield & Widom, 1996; Wright et al., 2019). For instance, a meta-analysis by Zatti and colleagues (2017) indicates that physical, emotional, and sexual abuse increase risk for lifetime suicide attempts. Similarly, a recent review by Fitton and colleagues (2020) indicates that childhood maltreatment is prospectively associated with violence later in life. Given these robust associations, research has sought to identify individual difference factors that influence who ultimately manifests these behaviors among individuals exposed to childhood trauma.

One potential moderator of the association between childhood trauma exposure and violence perpetration in adulthood is individual differences in impulsive choice. The tendency to discount delayed rewards over smaller more immediate rewards has been linked to ODV. For example, it has been found that monetary delay discounting is a positive predictor of aggressive behavior across different populations (Koepfler et al., 2012; Lee et al., 2017). Similarly, recent work has linked the preference for immediate versus delayed rewards to certain forms of SDV, especially suicide attempts (Dombrovski et al., 2011; Dougherty et al., 2009; Liu et al., 2012). However, findings in the literature on SDV remain inconsistent, with some prior work finding no evidence of preference for immediate rewards among suicide attempters and others reporting such a link (Bridge et al., 2015; Millner et al., 2020). Given the complexity of suicide-related

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behaviors as multidetermined phenomena, it would be important to model contextual factors, such as environmental stressors, which might increase an individual's vulnerability towards impulsive choice and subsequent SDV (Howarth et al., 2020; Zatti et al., 2017). This possibility is supported by stress-diathesis frameworks (Mann et al., 1999), which maintain that individuals possess trait vulnerabilities towards impulsivity that are amplified following exposure to stressful life events, which in turn increases likelihood of engagement in SDV. Discrepancies across these studies point to the need for further investigation into the relationship between delay discounting and SDV, including novel assessment methods as a means of clarifying this ambiguity.

Neurobiological Markers of Impulsive Choice for Reward

New research demonstrates the utility of creating neurobiological markers of impulsive decision-making for explaining maladaptive behavior (Noda et al., 2020; Sadeh et al., 2023). One such neurobiological assay is Cortical-Delay Discounting (C-DD; Sadeh et al., 2023), which assays a propensity to discount future rewards specifically conferred by variation in cortical thickness. Although novel, initial validation of this measure provides preliminary evidence for the validity and reliability of this tool as a neurobiological marker of impulsive choice. Across three adult samples, C–DD was associated with delayed discounting, substance use, and psychiatric disorders that share impulsivity as a core feature (Sadeh et al., 2023). A relative advantage of this measure, compared to behavioral measures of impulsive choice, is that C-DD values encompass cortical thickness associations with impulsive choice across multiple brain regions. However, to date, there has been no work evaluating the utility of this novel assessment tool for identifying individuals who engage in violence.

Despite a plethora of research on links between childhood trauma, delay discounting, and violence perpetration, few studies have examined the interplay of these factors for explaining

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who manifests violent behavior. For instance, many studies investigating the role of childhood maltreatment and impulsivity have postulated that these represent distinct mechanisms of risk for SDV and ODV (Van Orden et al., 2010; Wenzel & Beck, 2008). However, a paucity of information explains how these factors work in concert to increase risk for SDV and ODV. One study by Stewart and colleagues (2015) did examine the interactive effects of trauma exposure, impulsivity, and suicide attempts and found that, among adolescents with a history of sexual abuse, greater disinhibition was associated with suicide attempts (Stewart et al. 2015). In addition, results from another empirical study suggest that the gray matter ratio between subcortical and cortical regions associated with greater temporal delay discounting mediated the relationship between early adverse events and antisocial behaviors in adulthood (Mackey et al., 2017). Altogether, this body of literature remains limited, pointing to a need for more research elaborating on these relationships and incorporating neurobiological metrics and potential biomarkers of impulsivity to better understand the links between these factors.

Current Study

Given the shortcomings of existing models of links between childhood trauma and later engagement in SDV and ODV, the present study examined the moderating role of a novel neurobiological assay of impulsive choice for understanding when trauma relates to the perpetration of violence. We used the terms self- and other-directed violence, which have been employed in previous research (Harford et al., 2018; Sadeh et al., 2011) to refer to behaviors exerted through physical force, intended to hurt, damage, or kill oneself or others (DeWall et al., 2011; Hamby, 2017). Specifically, we tested whether the association between exposure to adversity in childhood and violence in adulthood differs as a function of C-DD. In other words, we examined whether C-DD moderates the association between childhood adversity and

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adulthood violence. Implementation of novel neural metrics of impulsivity into our models of risk could help expand the accuracy of identification efforts above and beyond traditional risk indicators.

We hypothesized that childhood trauma would be positively associated with both SDV and ODV. However, we expected C-DD scores (indicative of a tendency to discount future rewards) to moderate this association, such that those scoring relatively higher on C-DD would be at greater risk for engagement in SDV and ODV. As an exploratory analysis, we also examined potential sex differences in our models of violence perpetration. A substantial body of evidence points to differences in rates of SDV and ODV across biological sex, with women being more likely than men to engage in self-harm behaviors, such as non-suicidal self-injury and suicide attempts (Bresin & Schoenleber, 2015; Verona et al., 2004; Zatti et al., 2017) and men showing higher rates of aggressive and assaultive behaviors amongst men compared to women (Bettencourt & Kernahan, 1997; Björkqvist, 2018). However, sex is still an important yet understudied potential moderator of risk factors associated with violence. To address this knowledge gap, we explored whether the risk conferred by trauma exposure and cortical delay discounting for SDV and ODV vary as a function of biological sex.

Methods

Participants

Participants included 177 community adults (89 men; 50.3%) aged 18 –55 (M/SD = 32.15/ 10.53 years old) who were recruited through flyers and online advertisements for a study on risky and impulsive behaviors (see Table 1 for sample characteristics). Eligibility criteria included adults aged 18 to 55, English language fluency, and individuals with no serious medical or neurological conditions, history of psychosis, or MRI contraindications. Participants

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completed an initial clinical interview, including the *Structured Clinical Interview for DSM-5*, and a battery of self-report questionnaires. To be eligible for the neuroimaging protocol, individuals had to either i) meet criteria for an externalizing disorder (n = 122/ 68.9%) defined as Substance Use, Alcohol Use, Antisocial Personality, Borderline Personality, Gambling, or Attention Deficit Hyperactivity Disorder or ii) be classified as a healthy control, defined as not meeting criteria for a mental disorder and not taking psychotropic medication. Individuals with externalizing disorders were not excluded if they also met criteria for internalizing disorders. Moreover, individuals designated as healthy controls were not excluded if they reported psychopathology symptoms as long as they did not meet full criteria for a psychiatric disorder. Consequently, the degree and type of psychopathology present in the sample was varied. More than two-thirds of the sample (68.9%) met criteria for at least one externalizing disorder and almost half (48%) met criteria for at least one internalizing disorder.

A majority of participants came from socioeconomically disadvantaged neighborhoods in Wilmington, Delaware (https://www.neighborhoodscout.com/de/wilmington/crime; Wilmington, DE Crime Rates, 2021), which resulted in elevated rates of trauma and adversity in the sample. The sample was diverse with respect to racial/ethnic identity, the median household income of the sample was $50,000, and the highest grade level attained by the majority of participants was a high school diploma/General Educational Development (GED) (see Table 1).

Procedures

The study procedures were approved by the Institutional Review Board of Human Studies Research at the University of Delaware (Protocol nos.: 1073423-17, 1361164-1). Prior to data collection, informed consent was obtained after reviewing the study description and procedures, and participants were compensated financially for their participation. Study data

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were collected, managed, and stored at the University of Delaware using REDCap electronic data capture tools (Research Electronic Data Capture; Harris et al., 2009, 2019).

Measures

MRI Acquisition. Data were collected using a Siemens 3T Magnetom Prisma scanner with a 64-channel head coil. A T1-weighted multi-echo MPRAGE anatomical scan (resolution = $1mm^3$, TR = 2530ms, TEs = 1.69, 3.55, 5.41,7.27ms) was collected, which has the advantage of less distortion and higher contrast than standard MPRAGE sequences, resulting in more reliable cortical models. A T2-weighted variable flip-angle turbo spin-echo scan (resolution = 1mm, TR = 3200ms, TE = 564ms) was also collected (Van der Kouwe et al., 2008).

Cortical Thickness. Thickness of the cortical mantle was estimated using FreeSurfer's (v6) standard morphometric pipeline. T1 and T2 images were visually inspected and at least two trained raters examined the data for errors, including the inclusion of dura or skull after brain extraction or errors in the pial or white matter surfaces. Cortical thickness was calculated for each parcellation derived from the FreeSurfer Destrieux Atlas which parcellates the cortex into 74 neuroanatomically-distinct structures for each hemisphere (Destrieux et al., 2010; Van der Kouwe et al., 2008).

Cortical-Delay Discounting. As described in Sadeh and colleagues (2023), cortical delay discounting (C-DD) was calculated by regressing average gray matter thickness in each cortical parcellation on ln(k) values, age, and sex, and extracting the standardized beta coefficient for each regression analysis. We then computed total C-DD by weighting each z-scored cortical thickness parcellation by its corresponding standardized beta coefficient and summing the resulting values. Higher scores indicate thinner cortex and greater propensity to engage in impulsive decision making. The construct, incremental, and predictive validity of this measure

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were previously evaluated in the initial validation of the C-DD (Sadeh et al., 2023). Results of this investigation provide evidence that C-DD is concurrently and prospectively associated with delay discounting performance in addition to psychiatric disorders that share impulsivity as a core feature (i.e., externalizing disorders) across three independent adult samples. Furthermore, C-DD was found to be uniquely associated with impulsive choice for reward and evidenced discriminant validity with other measures of cognitive performance (i.e., Flanker Inhibitory Control and Attention test) and internalizing forms of psychopathology. For further elaboration on the properties of this measure please see Sadeh and colleagues (2023).

Childhood Trauma. Early experiences of trauma were assessed using the Childhood Trauma Questionnaire (CTQ; Bernstein et al., 2003) where participants rated experiences of abuse and neglect that took place before the age of 18 from 1 "*Never True"* to 5 "*Always True"*. Items included when I was growing up "*I got hit so hard by someone in my family that I had to see a doctor or go to the hospital.*" and "*People in my family hit me so hard that it left me with bruises or marks.*" This measure is widely used and demonstrates convergent validity with independent ratings of maltreatment provided by primary therapists in psychiatric samples (Bernstein et al., 2003). A total score was created by summing all items on the CTQ (Skewness/Kurtosis = 1.06/0.48).

Self-Directed and Other-Directed Violence. The Life History of Aggression (LHA; (Coccaro et al., 1997) interview was used to assess experiences of violence directed towards the self and others. This interview has demonstrated excellent test-retest reliability and internal consistency and has been associated with future engagement in SDV and ODV (Coccaro, 1998; Coccaro et al., 1997; Hoptman et al., 2002; O'Reilly et al., 2020). Furthermore, we chose to use the terms SDV and ODV to refer to behaviors in which physical damage or pain was inflicted on oneself

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or others, respectively, and used in prior work (Harford et al., 2018; Sadeh et al., 2011). Participants were asked about any events occurring across their lifetime, including adolescence, which rated from 0 *"No events" to* 5 *"So many events that they can't be counted."* To measure SDV, we examined the average score for the self-injurious behaviors and suicide attempt items (*"Have you ever hurt yourself on purpose, like by cutting, burning, or scratching yourself, without trying to kill yourself?"* and *"Have you ever tried to kill yourself?"*. To reduce the skewness and kurtosis, SDV was Blom transformed, resulting in acceptable skewness (1.36) and kurtosis (-0.32). For ODV, we also examined the average score for the other-directed aggressive behaviors items (*"Have you ever assaulted another person, whether during a physical fight or not? What about injuring an animal out of anger?"* and *"How many physical fights have you had since you turned 15?";* Skewness/Kurtosis = 0.68/-0.37).

Data Analysis

Separate hierarchical linear regression analyses were performed with (1) self-directed violence and (2) other-directed violence. These dependent variables were regressed on covariates (Block 1), childhood trauma (Block 2), C-DD (Block 3), and the interaction of childhood trauma and C-DD (Block 4). Biological sex, age, and education were entered as covariates of no interest in analyses. In addition, we controlled for SDV or ODV when the opposite was entered as the outcome of interest. The PROCESS macro v.4 for SPSS (model 1; Hayes, 2018) was used for these analyses in SPSS v28 (IBM Corp 2021). We also tested an exploratory model with biological sex moderating C-DD values using Model 3 in PROCESS macro v.4 (Hayes 2018).

A Bonferroni correction was applied to account for multiple corrections across the four hierarchical linear regression models we conducted, resulting in a critical *p*-value of 0.0125. We only interpret findings with *p*-values below the corrected value of 0.0125 as significant. R-square

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values were calculated to provide measures of effect size. All variables were z-scored prior to multivariate analysis to obtain standardized betas. Assumptions of statistical testing were evaluated suggesting assumptions of homoscedasticity, multicollinearity, and normality for linear regressions were met.

Data Availability

The data that support the findings of this study are available from the corresponding author (N.S.), upon reasonable request.

Results

Descriptive Statistics

Participants reported a range of violence across the lifespan, with 23.1% reporting some form of SDV and 83.6% reporting some form of ODV. When broken down by sex, 30.7% of women and 15.7% of men reported SDV. Further, 79.6% of women and 87.6% of men reported some ODV. Overall, the sample reported a range of childhood trauma exposure, which included any exposure to the following items: emotional neglect (54.8%), emotional abuse (50.8), physical abuse (41.8%), physical neglect (30.5%), and sexual abuse (33.9%). Further, at least low to moderate levels of trauma were reported by 47.8% of women and 50.6% of men.

Bivariate correlations among the study variables are reported in Table 2. As expected, significant positive correlations emerged between childhood trauma exposure and SDV/ODV. ODV also demonstrated a significant positive correlation with C-DD values. SDV was reported at higher levels in women (30.7% reported SDV) than men (15.7% reported SDV). Lifetime ODV was positively associated with age and inversely related to educational attainment.

Moderation Analyses

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Other-Directed Violence. We conducted a hierarchical linear regression analysis to test the main and interactive effects of childhood trauma and C-DD on other-directed violence. Childhood trauma was positively associated with the perpetration of other-directed violence after adjusting for the covariates (β = 0.35, *SE* = 0.07, $p < 0.001$, $R^2 = 0.44$, 95% CI [0.32-0.52]), whereas C-DD values were not (β = 0.13, *SE* = 0.08, $p = 0.07$, $R^2 = 0.45$, 95% CI [0.32-0.52]). As expected, C-DD values moderated the relationship between childhood trauma and other-directed violence (β = 0.19, *SE* = 0.06, $p = 0.003$, $R^2 = 0.48$, 95% CI [0.35-0.55]). This relationship is depicted in Figure 1. The well-established positive association of childhood trauma and other-directed violence was significant at medium (β = 0.32, *SE* = 0.06, $p < 0.001$) and high (β = 0.50, *SE* = 0.08, $p < 0.001$), but not low (β = 0.12, *SE* = 0.10, $p = 0.24$) levels of C-DD.

Self-Directed Violence. We tested a parallel regression analysis to examine the main and interactive effects of childhood trauma and C-DD on self-directed violence. Experiences of childhood trauma were positively associated with engaging in self-directed violence (β = 0.27, *SE* = 0.08, $p < 0.001$, $R^2 = 0.25$, 95% CI [0.13-0.34]), but not C-DD scores (β = -0.18, *SE* = 0.09, $p = 0.03$, $R^2 = 0.27$, 95% CI [0.14-0.35]). As hypothesized, C-DD values moderated the relationship between childhood trauma and self-directed violence (β =-0.27, *SE* = 0.07, $p < 0.001$, $R^2 = 0.33$, 95% CI [0.20-0.41]). Figure 2. displays the association between childhood trauma and self-directed violence at different levels of C-DD. In contrast to other-directed violence, childhood trauma was positively related to self-directed violence at low (β = 0.56, *SE* = 0.11, $p < 0.001$) and medium (β = 0.27, *SE* = 0.08, $p < 0.001$), but not high (β = 0.02, *SE* = 0.10, $p = 0.88$) levels of C-DD.

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Exploratory Model of Sex Differences. Finally, we conducted two exploratory three-way interaction models examining the interactive effects of childhood trauma, C-DD, and sex on other-directed violence and self-directed violence, separately. A significant three-way interaction emerged for self-directed violence (β = 0.27, *SE* = 0.07, *p* = 0.002, R^2 = 0.40, CI [0.25–0.47], ΔR^2 = 0.06), but not other-directed violence (β = 0.08, *SE* = 0.07, *p* = 0.25, R^2 = 0.42, CI [0.28–0.49], ΔR^2 = 0.005). Tests of the conditional interaction of childhood trauma and C-DD on self-directed violence were significant for women ($p < 0.001$), but not for men ($p = 0.34$). For women, the positive association between childhood trauma and self-directed violence was significant at low (β = 1.03, *SE* = 0.13, $p < 0.001$) and medium (β = 0.57, *SE* = 0.09, $p < 0.001$), but not high levels of C-DD (β = 0.15, *SE* = 0.13, *p* = 0.24). These results indicate that childhood trauma is positively associated with self-directed violence only at low to medium levels of C-DD in women. Conversely, the positive association between childhood trauma and self-directed violence was significant regardless of C-DD scores for men.

In order to estimate the reproducibility of our findings, a post-hoc power analysis was conducted using G*Power version 3.1.9.6 (Faul et al., 2007) for sample size estimation. Our results suggest that the minimum detectable effect size was estimated to range from ΔR^2 = 0.04 at 77.04% power to ΔR^2 = 08 at 97.38% power. Thus, our findings suggest that our sample was within a reasonable range of power to detect effects.

Discussion

We examined the utility of a novel neurobiological measure of impulsive choice, named cortical delay discounting (C-DD), for explaining engagement in self-directed (SDV) and other-directed (ODV) violence following childhood trauma exposure. We found that the relationship between childhood trauma and violence perpetration in a sample of community adults was

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moderated by individual differences in C-DD. As expected, childhood trauma exposure was positively associated with the perpetration of both ODV and SDV; however, these relationships differed as a function of C-DD. Specifically, engagement in ODV increased as scores on C-DD *increased,* and SDV increased as scores on C-DD *decreased*. Further, moderation of the relationship between childhood trauma and SDV showed biological sex differences, as the association between childhood trauma and SDV depended on C-DD for women but not for men. Taken together, these findings provide initial evidence that a novel neurobiological indicator of impulsive choice may be useful for determining risk for SDV and ODV following childhood trauma exposure.

Other-Directed Violence

First, we observed a positive relationship between childhood trauma and ODV, replicating past work showing the degree of exposure to childhood trauma is relevant for explaining the perpetuation of violence against others later in life (Dodge et al., 1990; Heleniak & McLaughlin, 2020; Maxfield & Widom, 1996). Notably, our findings extend upon this literature, coined the "cycle of violence", by identifying a novel neural metric that moderates this well-established process of risk transmission. Specifically, our work suggests that the positive link between childhood trauma exposure and ODV became stronger as scores on the C-DD increased (indicative of greater impulsive tendency). Of note, this finding provides further evidence for the utility of C-DD as a neurobiologic metric of impulsive choice that differentiates risk for violence in our sample. Evidence from structural and functional neuroimaging studies suggest that impulsive decision making is associated with multiple brain regions across the cortex (Barry et al., 2020; Cho et al., 2013; Dombrovski et al., 2012; Owens et al., 2017). C-DD values capture the global influence of cortical thickness associations across the cortex, a unique

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advantage over traditional self-report or behavioral measures. Furthermore, given the relative stability of cortical thickness (Han et al., 2006; Noble et al., 2017), C-DD scores represent a relatively stable and objective biological index of impulsivity. These characteristics are a considerable advantage of C-DD compared to self-report or behavioral measures, which may be more sensitive to bias or fluctuations in attention. Therefore, our findings suggest that this global neurobiological risk factor may be a useful tool for differentiating individuals with a susceptibility towards engagement in violent behaviors. Although outside the scope of the present study, future research should consider investigating whether current findings replicate using self-reported impulsive choice and determine whether C-DD provides any incremental validity for differentiating risk compared to other well-established assessment tools.

Self-Directed Violence

In addition to other-directed violence, exposure to trauma in childhood was positively associated with the number of suicidal behaviors across the lifespan. However, two notable moderating effects were also observed. First, we found that the positive association between childhood trauma and SDV became stronger as scores on C-DD decreased. Unlike other-directed violence, scoring low on the C-DD metric was related to greater engagement in SDV, suggesting that suicide attempts and non-suicidal self-injury were greater among individuals who reported more exposure to childhood maltreatment and scored relatively lower on a neurobiological metric of impulsive choice for reward. Second, we examined the potential moderating effect of biological sex and found C-DD influenced the relationship between childhood trauma and SDV for women but not men. Our findings are consistent with prior work identifying biological sex differences in trauma responses (Maguen et al., 2012; Wamser-Nanney & Cherry, 2018) and

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may inform inconsistent relationships between measures of delay-discounting and SDV reported in the literature.

These novel findings point to new directions for future research. First, the findings suggest that biological sex differences influence the relevance of C-DD for explaining the relationship between childhood trauma and SDV. More specifically, the pattern of findings indicate the risk conferred by childhood trauma for SDV may reflect more careful planning than impulsive decision-making as scores on C-DD decrease selectively in women. Second, assuming less C-DD corresponds to a tendency to prioritize *delayed* gratification over impulsive decision-making, these findings suggest women with higher levels of childhood trauma who tend to devalue immediate rewards may be at greater risk for engaging in self-directed violence. Although this finding may seem contradictory to research suggesting the tendency to delay gratification contributes to positive outcomes, like academic success and fewer psychiatric symptoms (Acuff et al., 2018; Amlung et al., 2019), the extent to which these findings generalize to populations with elevated rates of childhood adversity requires further investigation. Based on the present findings, we speculate that the tendency to delay immediate gratification may not serve the same protective role for women with a history of childhood adversity, but rather could lead to or exacerbate anhedonia, a known risk factor for suicidal behavior (Ducasse et al., 2018). Consistent with this interpretation, a study by Lempert and Pizzagalli (2010) found that individuals who showed a preference for larger, delayed rewards over smaller more immediate rewards reported relatively greater anhedonia, possibly reflecting less responsivity to immediate rewards. Another potentially relevant study found that, among individuals who attempted suicide, individuals with high-lethality compared to low-lethality attempts were better able to delay gratification for future rewards, which could contribute to movement along the suicidal

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continuum from ideation to attempts (Dombrovski et al., 2011). Given that our findings are novel and interpretations speculative, further examination and replication of the findings and proposed mechanisms are needed before strong conclusions can be drawn.

Implications

Findings from the present work have important implications for early intervention and identification efforts. First, in light of chronic mental health care shortages and barriers to care (Demyttenaere et al., 2004; Ku et al., 2021), effective distribution of resources to those in greatest need is imperative. Thus, development of innovative methods which move beyond traditional metrics of risk assessment to identify individuals at greatest risk for engagement in violence is essential. Given the limitations of frequently used assessment tools (i.e., self-report measures) which may be more susceptible to reporter bias, C-DD has potential as an objective indicator of neurobiologically-instantiated impulsive choice. Insofar as structural MRI is widely used in clinical practice, these methods may provide a unique opportunity to develop novel biomarkers of risk for engagement in violence to be used in conjunction with well-established indicators of risk (e.g. trauma exposure, presence of psychopathology, substance use;Arseneault et al., 2000; Harford et al., 2018; Jokinen et al., 2010; Pulay et al., 2008) and improve models of risk identification. C-DD offers a significant advantage compared to self-report measures in that it may be less prone to reporter bias and an objective indicator of the neurobiological predisposition towards impulsive choice. This is particularly relevant, in light of the current mental health crisis where resources are scarce. Specifically, given research showing that not all trauma-exposed individuals go on to engage in violent behaviors, the use of an objective neurobiological assay, like the C-DD, could provide practitioners with additional insight into those individuals who may have difficulty with impulsive choice, a known risk factor for an

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array of negative outcomes. Future work should continue to test this potential biomarker using larger samples to determine the replicability of our findings. Second, while theoretical models examining the transmissions of risk, such as the "cycle of violence", have received considerable attention, factors that modulate these risk processes remain poorly understood. Given the highly heritable nature of both impulsive decision-making (Anokhin et al., 2011, 2015) and cortical thickness (Panizzon et al., 2009), there is reason to believe C-DD scores may be heritable. A wealth of prior research on the "cycle of violence" has shed light on the influence of both genetic and environmental factors relevant in the perpetuation of violence intergenerationally (Bounoua et al., 2020; Byrd & Manuck, 2014). Although the heritability of C-DD was not determined by the present study, the extent to which C-DD may have the potential to capture processes relevant in the heritable transmission of risk for violence intergenerationally and differentiate individuals with greater vulnerability for violence perpetration would be important areas of study for future research. Although cortical thickness and impulsivity tend to be relatively stable across trait-like components across the lifespan (Han et al., 2006; Noble et al., 2017; Odum, 2011), an important next step would be to evaluate C-DD in childhood with more temporal proximity to the occurrence of abuse and identify individuals at risk of manifesting later violence. Finally, although outside of the scope of the present work, extending these findings to youth remains a priority to inform early identification efforts. To this end, integrating C-DD into early assessment efforts among youth with trauma exposure could help differentiate children with the highest level of need and inform diversion of mental health services. Assessment of novel targets of risk transmission, such as C-DD, has the potential to interrupt the cycle of violence during this critical developmental period.

Strengths, Limitations, and Future Directions

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There are several notable strengths of the present study that call for mention. First, the current study integrates multiple methods of analysis including self-report and biological measures to differentiate individuals at risk for engagement in diverse forms of violence. Furthermore, our findings supply preliminary support for the utility of C-DD as a novel risk target and a potential biomarker of impulsive choice. In light of the current limitations of well-established targets in identifying individuals at risk for engagement in violence, C-DD may provide novel information not captured by traditional risk assessment tools. Additionally, the prevalence rates of psychiatric disorders in our sample suggest the present findings likely generalize to high-risk community samples characterized by high rates of adversity and clinical samples. Finally, our study contributes to the literature by examining gender differences in differentiating risk for engagement in violence, an area that has received scant attention. As such, this work could be used to inform gender-responsive care practices for individuals exposed to trauma to mitigate the onset of future violence, particularly for SDV.

Our findings should also be interpreted within the context of several limitations. First, study variables were assessed cross-sectionally, which inherently limits our ability to determine causality regarding the directionality of these relationships or rule out other potentially relevant variables. Second, with respect to our examination of sex differences combined with the relatively low prevalence of SDV in our sample, this finding should be replicated in independent samples. However, given the dearth of literature exploring biological sex differences, particularly within the violence literature, these findings shed light on an important consideration and highlight how sex may be influencing the relationships between trauma, C-DD and SDV. Relatedly, due to the relatively low prevalence of SDV and our interest in violent behaviors broadly speaking, we combined nonsuicidal self-injury and suicide attempts, limiting our ability

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to uncover specific risks associated with each of these behaviors. Future research should replicate our findings in independent samples with sufficient representation of distinct types of self-injurious behaviors. Another limitation of our study was that we did not include details about the type (e.g. physical emotional, or sexual abuse) or developmental timing (e.g. early, middle, late childhood) of trauma exposure. Given that the developmental timing and type of abuse has shown distinct associations with violence (Dunn et al., 2018) it would be important to include these factors in future models investigating the moderating role of C-DD. Future work should implement longitudinal models to clarify the impact of type and timing of trauma exposure on the development of biological vulnerabilities for future engagement in violence. In addition, the present study did not consider other potential moderators in the relationship between trauma and SDV/ODV. Given the multi-determined nature of these behaviors, it would be useful to examine how other known risk factors such as avoidance motivations (Li et al., 2014) might interact with C-DD to give rise to violence perpetration. Finally, our findings did not consider the influence of other established risk factors associated with violence perpetration, such as lifetime history of psychopathology or other forms of impulsivity, such as cognitive control (Carcone et al., 2022; McGirr et al., 2012). Although our findings were focused on understanding the moderating effect of C-DD on the relationship between childhood trauma and violence, future work should consider exploring the models that consider the influence of previously mentioned risk factors as well.

Overall, the present study provides new insight into the utility of a novel neurobiological measure of risk for differentiating risk for SDV and ODV following trauma exposure. Importantly, these results have the potential to inform etiological models of violence and may be used in the future to aid in early identification and prevention efforts aimed at reducing violence.

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Future work should continue to investigate the role of C-DD as a potential mechanism underlying violence.

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Ethical Standards: The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional guides on the care and use of laboratory animals.

Declaration of Interest: None

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Version of Record at: https://doi.org/10.1037/abn0000857

References

Acuff, S. F., Soltis, K. E., Dennhardt, A. A., Berlin, K. S., & Murphy, J. G. (2018). Evaluating behavioral economic models of heavy drinking among college students. *Alcoholism: Clinical and Experimental Research*, *42*(7), 1304–1314.

Amlung, M., Marsden, E., Holshausen, K., Morris, V., Patel, H., Vedelago, L., Naish, K. R., Reed, D. D., & McCabe, R. E. (2019). Delay discounting as a transdiagnostic process in psychiatric disorders: A meta-analysis. *JAMA Psychiatry*, *76*(11), 1176–1186.

Angelakis, I., Gillespie, E. L., & Panagioti, M. (2019). Childhood maltreatment and adult suicidality: A comprehensive systematic review with meta-analysis. *Psychological Medicine*, *49*(7), 1057–1078.

Anokhin, A. P., Golosheykin, S., Grant, J. D., & Heath, A. C. (2011). Heritability of delay discounting in adolescence: A longitudinal twin study. *Behavior Genetics*, *41*(2), 175–183.

Anokhin, A. P., Grant, J. D., Mulligan, R. C., & Heath, A. C. (2015). The genetics of impulsivity: Evidence for the heritability of delay discounting. *Biological Psychiatry*, *77*(10), 887–894.

Arseneault, L., Moffitt, T. E., Caspi, A., Taylor, P. J., & Silva, P. A. (2000). Mental disorders and violence in a total birth cohort: Results from the Dunedin Study. *Archives of General Psychiatry*, *57*(10), 979–986.

Augsburger, M., Basler, K., & Maercker, A. (2019). Is there a female cycle of violence after exposure to childhood maltreatment? A meta-analysis. *Psychological Medicine*, *49*(11), 1776–1786.

Barry, A. B., Koeppel, J. A., & Ho, B.-C. (2020). Impulsive decision making, brain cortical

Accepted Manuscript
Version of Record at: https://doi.org/10.1037/abn0000857

thickness and familial schizophrenia risk. *Schizophrenia Research*, *220*, 54–60.

Bernstein, D. P., Stein, J. A., Newcomb, M. D., Walker, E., Pogge, D., Ahluvalia, T., Stokes, J., Handelsman, L., Medrano, M., & Desmond, D. (2003). Development and validation of a brief screening version of the Childhood Trauma Questionnaire. *Child Abuse & Neglect*, *27*(2), 169–190.

Bettencourt, B. A., & Kernahan, C. (1997). A meta-analysis of aggression in the presence of violent cues: Effects of gender differences and aversive provocation. *Aggressive Behavior: Official Journal of the International Society for Research on Aggression*, *23*(6), 447–456.

Björkqvist, K. (2018). Gender differences in aggression. *Current Opinion in Psychology*, *19*, 39–42.

Bounoua, N., Miglin, R., Spielberg, J. M., & Sadeh, N. (2020). Childhood assaultive trauma and physical aggression: Links with cortical thickness in prefrontal and occipital cortices. *Neuroimage: Clinical*, *27*, 102321.

Bresin, K., & Schoenleber, M. (2015). Gender differences in the prevalence of nonsuicidal self-injury: A meta-analysis. *Clinical Psychology Review*, *38*, 55–64.

Bridge, J. A., Reynolds, B., McBee-Strayer, S. M., Sheftall, A. H., Ackerman, J., Stevens, J., Mendoza, K., Campo, J. V., & Brent, D. A. (2015). Impulsive aggression, delay discounting, and adolescent suicide attempts: Effects of current psychotropic medication use and family history of suicidal behavior. *Journal of Child and Adolescent Psychopharmacology*, *25*(2), 114–123.

Byrd, A. L., & Manuck, S. B. (2014). MAOA, childhood maltreatment, and antisocial behavior: Meta-analysis of a gene-environment interaction. *Biological Psychiatry*, *75*(1), 9–17.

Accepted Manuscript
Version of Record at: https://doi.org/10.1037/abn0000857

Carcone, D., Gardhouse, K., Goghari, V. M., Lee, A. C., & Ruocco, A. C. (2022). The transdiagnostic relationship of cumulative lifetime stress with memory, the hippocampus, and personality psychopathology. *Journal of Psychiatric Research*, *155*, 483–492.

Cho, S. S., Pellecchia, G., Aminian, K., Ray, N., Segura, B., Obeso, I., & Strafella, A. P. (2013). Morphometric correlation of impulsivity in medial prefrontal cortex. *Brain Topography*, *26*, 479–487.

Coccaro, E. F. (1998). Impulsive aggression: A behavior in search of clinical definition. *Harvard Review of Psychiatry*, *5*(6), 336–339.

Coccaro, E. F., Berman, M. E., & Kavoussi, R. J. (1997). Assessment of life history of aggression: Development and psychometric characteristics. *Psychiatry Research*, *73*(3), 147–157.

Demyttenaere, K., Bruffaerts, R., Posada-Villa, J., Lepine, J. P., Angermeyer, M. C., Bernert, S., De Girolamo, G., Morosini, P., Polidori, G., & Kikkawa, T. (2004). Prevalence, severity, and unmet need for treatment of mental disorders in the World Health Organization World Mental Health Surveys. *Journal of the American Medical Association*, *291*(21), 2581–2590.

Destrieux, C., Fischl, B., Dale, A., & Halgren, E. (2010). Automatic parcellation of human cortical gyri and sulci using standard anatomical nomenclature. *Neuroimage*, *53*(1), 1–15.

DeWall, C. N., Anderson, C. A., & Bushman, B. J. (2011). The general aggression model: Theoretical extensions to violence. *Psychology of Violence*, *1*(3), 245.

Dodge, K. A., Bates, J. E., & Pettit, G. S. (1990). Mechanisms in the cycle of violence. *Science*, *250*(4988), 1678–1683.

Dombrovski, A. Y., Siegle, G. J., Szanto, K., Clark, L., Reynolds, C. F., & Aizenstein, H.

Accepted Manuscript
Version of Record at: https://doi.org/10.1037/abn0000857

(2012). The temptation of suicide: Striatal gray matter, discounting of delayed rewards, and suicide attempts in late-life depression. *Psychological Medicine*, *42*(6), 1203–1215.

Dombrovski, A. Y., Szanto, K., Siegle, G. J., Wallace, M. L., Forman, S. D., Sahakian, B., Reynolds III, C. F., & Clark, L. (2011). Lethal forethought: Delayed reward discounting differentiates high-and low-lethality suicide attempts in old age. *Biological Psychiatry*, *70*(2), 138–144.

Dougherty, D. M., Mathias, C. W., Marsh-Richard, D. M., Prevette, K. N., Dawes, M. A., Hatzis, E. S., Palmes, G., & Nouvion, S. O. (2009). Impulsivity and clinical symptoms among adolescents with non-suicidal self-injury with or without attempted suicide. *Psychiatry Research*, *169*(1), 22–27.

Ducasse, D., Loas, G., Dassa, D., Gramaglia, C., Zeppegno, P., Guillaume, S., Olié, E., & Courtet, P. (2018). Anhedonia is associated with suicidal ideation independently of depression: A meta-analysis. *Depression and Anxiety*, *35*(5), 382–392.

Dunn, E. C., Nishimi, K., Gomez, S. H., Powers, A., & Bradley, B. (2018). Developmental timing of trauma exposure and emotion dysregulation in adulthood: Are there sensitive periods when trauma is most harmful? *Journal of Affective Disorders*, *227*, 869–877.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191.

Fitton, L., Yu, R., & Fazel, S. (2020). Childhood Maltreatment and Violent Outcomes: A Systematic Review and Meta-Analysis of Prospective Studies. *Trauma, Violence, & Abuse*, *21*(4), 754–768. https://doi.org/10.1177/1524838018795269

Hamby, S. (2017). *On defining violence, and why it matters.*

Accepted Manuscript
Version of Record at: https://doi.org/10.1037/abn0000857

Han, X., Jovicich, J., Salat, D., van der Kouwe, A., Quinn, B., Czanner, S., Busa, E., Pacheco, J., Albert, M., & Killiany, R. (2006). Reliability of MRI-derived measurements of human cerebral cortical thickness: The effects of field strength, scanner upgrade and manufacturer. *Neuroimage*, *32*(1), 180–194.

Harford, T. C., Chen, C. M., & Grant, B. F. (2016). Other-and self-directed forms of violence and their relationship with number of substance use disorder criteria among youth ages 12–17: Results from the National Survey on Drug Use and Health. *Journal of Studies on Alcohol and Drugs*, *77*(2), 277–286.

Harford, T. C., Chen, C. M., Kerridge, B. T., & Grant, B. F. (2018). Self-and other-directed forms of violence and their relationship with lifetime DSM-5 psychiatric disorders: Results from the National Epidemiologic Survey on alcohol related conditions- III (NESARC- III). *Psychiatry Research*, *262*, 384–392.

Harford, T. C., Yi, H., & Freeman, R. C. (2012). A typology of violence against self and others and its associations with drinking and other drug use among high school students in a US general population survey. *Journal of Child & Adolescent Substance Abuse*, *21*(4), 349–366.

Harris, P. A., Taylor, R., Minor, B. L., Elliott, V., Fernandez, M., O'Neal, L., McLeod, L., Delacqua, G., Delacqua, F., & Kirby, J. (2019). The REDCap consortium: Building an international community of software platform partners. *Journal of Biomedical Informatics*, *95*, 103208.

Harris, P. A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., & Conde, J. G. (2009). Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. *Journal of Biomedical*

Accepted Manuscript
Version of Record at: https://doi.org/10.1037/abn0000857

Informatics, *42*(2), 377–381.

Hayes, A. F. (2018). Partial, conditional, and moderated moderated mediation: Quantification, inference, and interpretation. *Communication Monographs*, *85*(1), 4–40.

Heleniak, C., & McLaughlin, K. A. (2020). Social-cognitive mechanisms in the cycle of violence: Cognitive and affective theory of mind, and externalizing psychopathology in children and adolescents. *Development and Psychopathology*, *32*(2), 735–750.

Hoptman, M. J., Volavka, J., Johnson, G., Weiss, E., Bilder, R. M., & Lim, K. O. (2002). Frontal white matter microstructure, aggression, and impulsivity in men with schizophrenia: A preliminary study. *Biological Psychiatry*, *52*(1), 9–14.

Howarth, E. J., O'Connor, D. B., Panagioti, M., Hodkinson, A., Wilding, S., & Johnson, J. (2020). Are stressful life events prospectively associated with increased suicidal ideation and behaviour? A systematic review and meta-analysis. *Journal of Affective Disorders*, *266*, 731–742.

Jokinen, J., Forslund, K., Ahnemark, E., Gustavsson, J. P., Nordström, P., & Šsberg, M. (2010). Karolinska Interpersonal Violence Scale predicts suicide in suicide attempters. *The Journal of Clinical Psychiatry*, *71*(8), 10089.

Killgore, W. D., Cloonan, S. A., Taylor, E. C., Anlap, I., & Dailey, N. S. (2021). Increasing aggression during the COVID-19 lockdowns. *Journal of Affective Disorders Reports*, *5*, 100163.

Koepfler, J., Brewster, J., Stoloff, M., & Saville, B. (2012). Predicting police aggression: Comparing traditional and non-traditional prediction models. *Journal of Police and Criminal Psychology*, *27*(2), 141–149.

Ku, B. S., Li, J., Lally, C., Compton, M. T., & Druss, B. G. (2021). Associations between mental

Accepted Manuscript
Version of Record at: https://doi.org/10.1037/abn0000857

health shortage areas and county-level suicide rates among adults aged 25 and older in the USA, 2010 to 2018. *General Hospital Psychiatry*, *70*, 44–50.

Lee, C. A., Derefinko, K. J., Milich, R., Lynam, D. R., & DeWall, C. N. (2017). Longitudinal and reciprocal relations between delay discounting and crime. *Personality and Individual Differences*, *111*, 193–198.

Lempert, K. M., & Pizzagalli, D. A. (2010). Delay discounting and future-directed thinking in anhedonic individuals. *Journal of Behavior Therapy and Experimental Psychiatry*, *41*(3), 258–264.

Li, H., Xie, W., Luo, X., Fu, R., Shi, C., Ying, X., Wang, N., Yin, Q., & Wang, X. (2014). Clarifying the role of psychological pain in the risks of suicidal ideation and suicidal acts among patients with major depressive episodes. *Suicide and Life-Threatening Behavior*, *44*(1), 78–88.

Liu, R. T., Vassileva, J., Gonzalez, R., & Martin, E. M. (2012). A comparison of delay discounting among substance users with and without suicide attempt history. *Psychology of Addictive Behaviors*, *26*(4), 980.

Mackey, S., Chaarani, B., Kan, K.-J., Spechler, P. A., Orr, C., Banaschewski, T., Barker, G., Bokde, A. L., Bromberg, U., & Büchel, C. (2017). Brain regions related to impulsivity mediate the effects of early adversity on antisocial behavior. *Biological Psychiatry*, *82*(4), 275–282.

Maguen, S., Cohen, B., Ren, L., Bosch, J., Kimerling, R., & Seal, K. (2012). Gender differences in military sexual trauma and mental health diagnoses among Iraq and Afghanistan veterans with posttraumatic stress disorder. *Women's Health Issues*, *22*(1), e61–e66.

Mann, J. J., Waternaux, C., Haas, G. L., & Malone, K. M. (1999). Toward a clinical model of

Accepted Manuscript
Version of Record at: https://doi.org/10.1037/abn0000857

suicidal behavior in psychiatric patients. *American Journal of Psychiatry*, *156*(2), 181–189.

Maxfield, M. G., & Widom, C. S. (1996). The cycle of violence: Revisited 6 years later. *Archives of Pediatrics & Adolescent Medicine*, *150*(4), 390–395.

McGirr, A., Dombrovski, A. Y., Butters, M. A., Clark, L., & Szanto, K. (2012). Deterministic learning and attempted suicide among older depressed individuals: Cognitive assessment using the Wisconsin Card Sorting Task. *Journal of Psychiatric Research*, *46*(2), 226–232.

Millner, A. J., Lee, M. D., Hoyt, K., Buckholtz, J. W., Auerbach, R. P., & Nock, M. K. (2020). Are suicide attempters more impulsive than suicide ideators? *General Hospital Psychiatry*, *63*, 103–110.

Noble, S., Spann, M. N., Tokoglu, F., Shen, X., Constable, R. T., & Scheinost, D. (2017). Influences on the test–retest reliability of functional connectivity MRI and its relationship with behavioral utility. *Cerebral Cortex*, *27*(11), 5415–5429.

Noda, Y., Barr, M. S., ElSalhy, M., Masuda, F., Tarumi, R., Ogyu, K., Wada, M., Tsugawa, S., Miyazaki, T., & Nakajima, S. (2020). Neural correlates of delay discount alterations in addiction and psychiatric disorders: A systematic review of magnetic resonance imaging studies. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *99*, 109822.

Odum, A. L. (2011). Delay discounting: Trait variable? *Behavioural Processes*, *87*(1), 1–9.

O'Reilly, L. M., Pettersson, E., Quinn, P. D., Klonsky, E. D., Lundström, S., Larsson, H., Lichtenstein, P., & D'Onofrio, B. M. (2020). The association between general childhood psychopathology and adolescent suicide attempt and self-harm: A prospective, population-based twin study. *Journal of Abnormal Psychology*, *129*(4), 364.

Accepted Manuscript
Version of Record at: https://doi.org/10.1037/abn0000857

Owens, M. M., Gray, J. C., Amlung, M. T., Oshri, A., Sweet, L. H., & MacKillop, J. (2017). Neuroanatomical foundations of delayed reward discounting decision making. *NeuroImage*, *161*, 261–270.

Panizzon, M. S., Fennema-Notestine, C., Eyler, L. T., Jernigan, T. L., Prom-Wormley, E., Neale, M., Jacobson, K., Lyons, M. J., Grant, M. D., & Franz, C. E. (2009). Distinct genetic influences on cortical surface area and cortical thickness. *Cerebral Cortex*, *19*(11), 2728–2735.

Pulay, A. J., Dawson, D. A., Hasin, D. S., Goldstein, R. B., Ruan, W. J., Pickering, R. P., Huang, B., Chou, S. P., & Grant, B. F. (2008). Violent behavior and DSM-IV psychiatric disorders: Results from the national epidemiologic survey on alcohol and related conditions. *Journal of Clinical Psychiatry*, *69*(1), 12.

Sadeh, N., Javdani, S., Finy, M. S., & Verona, E. (2011). Gender differences in emotional risk for self-and other-directed violence among externalizing adults. *Journal of Consulting and Clinical Psychology*, *79*(1), 106.

Sadeh, N., Miglin, R., Bounoua, N., Sheehan, A., & Spielberg, J. M. (2023). Development of a cortical delay discounting assay: A potential biomarker of externalizing disorders. *Psychological Medicine*, *53*(4), 1143–1150.

Spencer, M. R., Warner, M., & Bastian, B. A. (2019). National vital statistics reports. *National Vital Statistics Reports*, *68*(3).

Stewart, J. G., Kim, J. C., Esposito, E. C., Gold, J., Nock, M. K., & Auerbach, R. P. (2015). Predicting suicide attempts in depressed adolescents: Clarifying the role of disinhibition and childhood sexual abuse. *Journal of Affective Disorders*, *187*, 27–34.

Van der Kouwe, A. J., Benner, T., Salat, D. H., & Fischl, B. (2008). Brain morphometry with

Accepted Manuscript
Version of Record at: https://doi.org/10.1037/abn0000857

multiecho MPRAGE. *Neuroimage*, *40*(2), 559–569.

Van Orden, K. A., Witte, T. K., Cukrowicz, K. C., Braithwaite, S. R., Selby, E. A., & Joiner Jr, T. E. (2010). The interpersonal theory of suicide. *Psychological Review*, *117*(2), 575.

Verona, E., Sachs-Ericsson, N., & Joiner Jr, T. E. (2004). Suicide attempts associated with externalizing psychopathology in an epidemiological sample. *American Journal of Psychiatry*, *161*(3), 444–451. https://doi.org/10.1176/appi.ajp.161.3.444

Wamser-Nanney, R., & Cherry, K. E. (2018). Children's trauma-related symptoms following complex trauma exposure: Evidence of gender differences. *Child Abuse & Neglect*, *77*, 188–197.

Wenzel, A., & Beck, A. T. (2008). A cognitive model of suicidal behavior: Theory and treatment. *Applied and Preventive Psychology*, *12*(4), 189–201.

Woolf, S. H., & Schoomaker, H. (2019). Life expectancy and mortality rates in the United States, 1959-2017. *Jama*, *322*(20), 1996–2016.

Wright, E. N., Hanlon, A., Lozano, A., & Teitelman, A. M. (2019). The impact of intimate partner violence, depressive symptoms, alcohol dependence, and perceived stress on 30-year cardiovascular disease risk among young adult women: A multiple mediation analysis. *Preventive Medicine*, *121*, 47–54.

Zatti, C., Rosa, V., Barros, A., Valdivia, L., Calegaro, V. C., Freitas, L. H., Ceresér, K. M. M., da Rocha, N. S., Bastos, A. G., & Schuch, F. B. (2017). Childhood trauma and suicide attempt: A meta-analysis of longitudinal studies from the last decade. *Psychiatry Research*, *256*, 353–358. https://doi.org/10.1016/j.psychres.2017.06.082

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Version of Record at: https://doi.org/10.1037/abn0000857

Table 1. Sample characteristics ($N = 177$)

Demographics	*M/SD or N/%*	*Range*
Age	32.6/10.7	18-55
Biological Sex		
Female	88/ 49.7 %	
Male	89/ 50.3%	
Race/Ethnicity		
White	115/65.0%	
Black/African American	49/27.7%	
Hispanic/Latino	16/9.0%	
Asian	15/8.5%	
American Indian/Alaskan Native	3/1.7%	
Native Hawaiian	3/1.7%	
Household Income	$68,104/$55,953	$5,000-$300,000
Education		
Less than Grade 12	9/5.1%	
High School/GED	91/51.4%	
Associate's Degree	13/7.3%	
Bachelor's Degree	35/19.8%	

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Master's Degree	22/12.4%	
Doctoral/Professional Degree	7/4.0%	
Childhood Trauma Exposure	43.6/17.0	24.0-103.0
Other-Directed Violence	1.45/1.20	0-4.0
Self-Directed Violence	0.35/0.77	0-4.8

Note: GED = General Education Development Test.

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Table 2. *Bivariate Correlations of Study Variables*

	1	2	3	4	5	6
1. Self-Directed Violence[a]						
2. Other-Directed Violence[a]	0.36**					
3. Childhood Trauma[b]	0.40**	0.54**				
4. C-DD[c]	-0.08	0.28**	0.19*			
5. Age	0.03	0.32**	0.26**	0.63**		
6. Male Sex	-0.19*	0.14	0.01	0.13	0.06	
7. Education	-0.03	-0.26*	-0.10	0.09	0.10	-0.06

Note. * $p < 0.05$, ** $p < .0.01$. [a]Lifetime History of Aggression. [b] Childhood Trauma Questionnaire. [c] Cortical-Delay Discounting. Values represent Pearson correlation coefficients.

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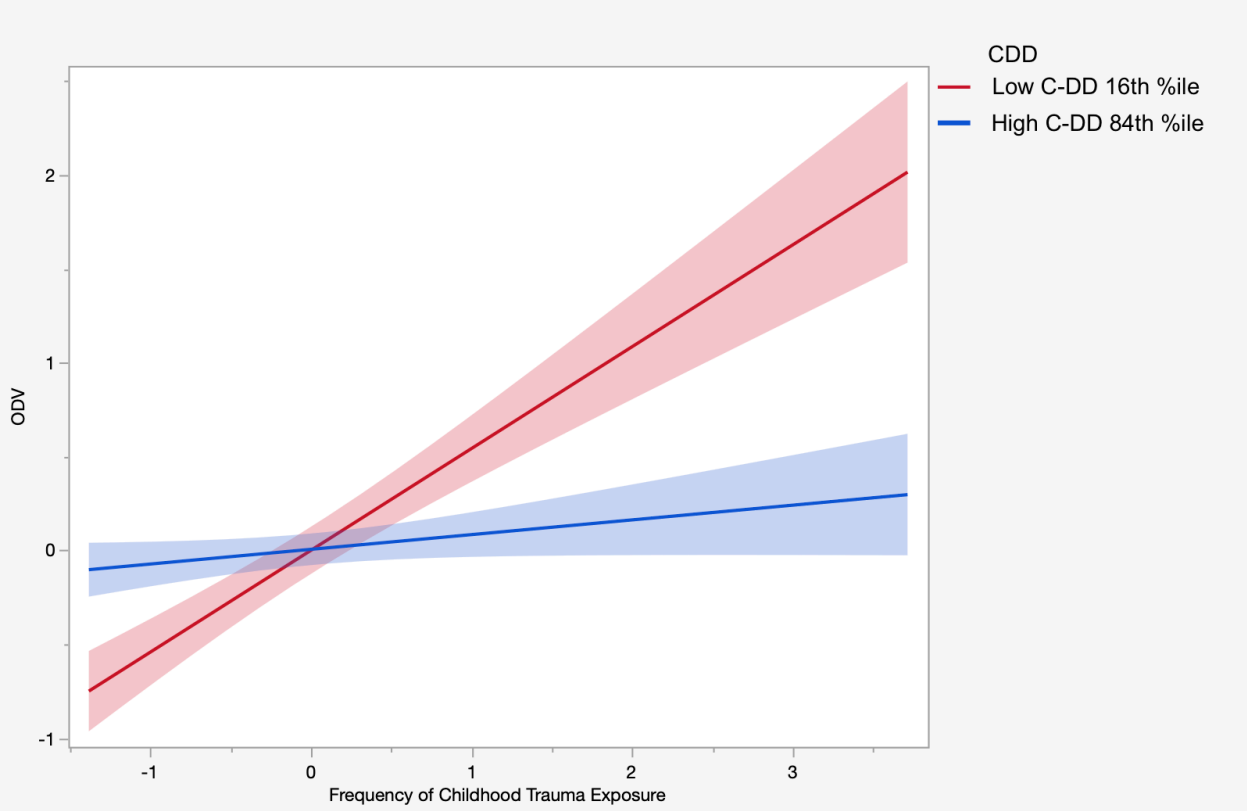
Figure 1. *Moderating Effect of C-DD on Relationship Between Frequency of Childhood Trauma Exposure and Other-Directed Violence*



Note. ODV = Other-Directed Violence. Data for visualizing the conditional effects of C-DD on the relationship between childhood trauma exposure and ODV. 95% confidence interval bands depicted.

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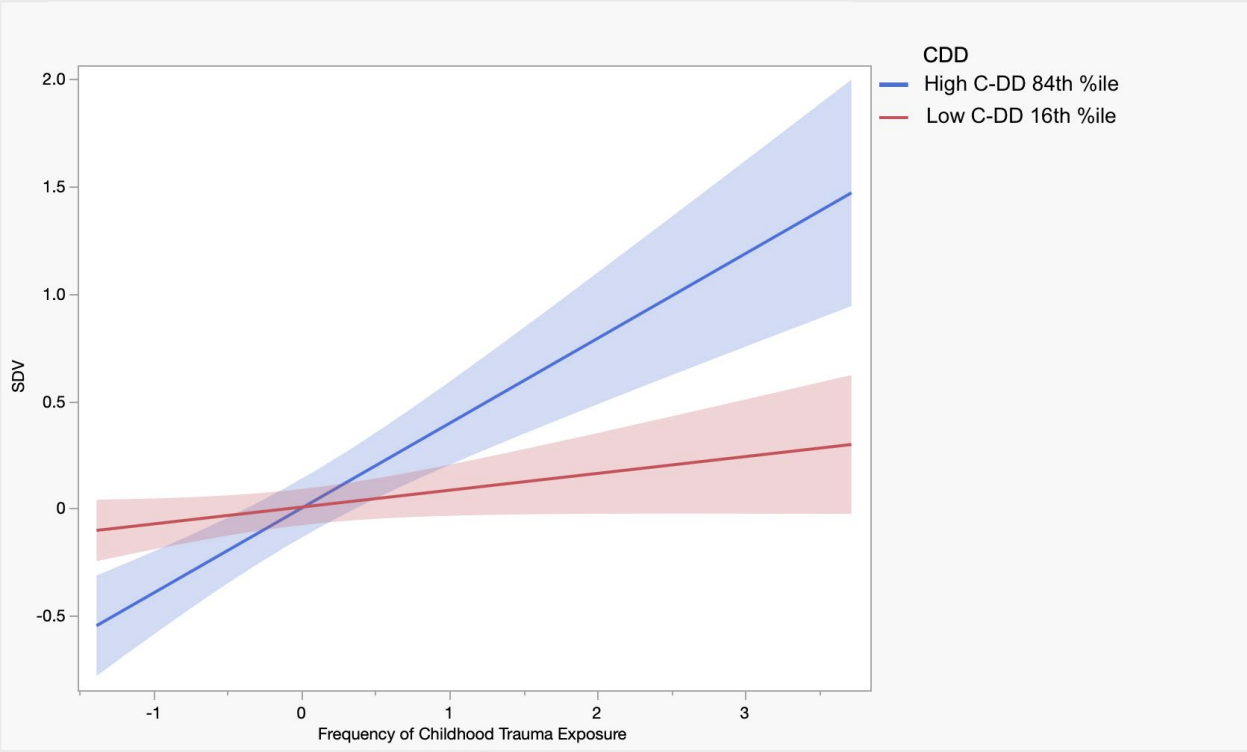
Figure 2. *Moderating Effect of C-DD on Relationship Between Frequency of Childhood Trauma Exposure and Self-Directed Violence*



Note. SDV = Self-Directed Violence. Data for visualizing the conditional effects of C-DD values on the relationship between childhood trauma exposure and SDV. 95% confidence interval bands depicted.