# Psychopathy and Cognitive Control – Examining Event Related Potentials of Psychopathy in a Go/No-Go Task

**by**

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**Abstract**

Previous studies have shown mixed results regarding the association between neural processes and psychopathic personality traits. Specifically, event related potentials (ERP) associated with cognitive processes reflecting conflict monitoring, impulsivity, and error processing are inconsistently associated with measurements of psychopathic constructs. These ERP may be related to activity in the anterior cingulate cortex of the brain, which is also associated with motivation and behavioral monitoring. Using a Go/No-Go task, this study investigated the relationship between psychopathic traits and cognitive processes at the neural level using a psychopathic trait self-report measure (i.e., the Short Dark Tetrad questionnaire) and ERP measures of conflict monitoring (N2), response inhibition (P3), and error monitoring (ERN/Pe). We hypothesized that N2, P3, ERN, and Pe amplitudes would be inversely associated with psychopathic traits, suggesting deficient neural activity related to monitoring task-relevant information or behavior, inhibiting impulsive responses, and processing errors to improve task-related performance are associated with increased psychopathic traits. However, we found no evidence of a relationship between psychopathic traits and Go/No-Go task performance or related neural activity. These findings indicate that traits of psychopathy may not be associated with these neurocognitive processes in a simple executive task such as the Go/No-Go task. Future research investigating the relationship between these processes and psychopathic traits utilizing more complex cognitive tasks may be more effective in capturing differences in neural activity by requiring engagement of multiple cognitive processes simultaneously.

*Keywords:* Psychopathy, Dark Tetrad, impulsivity, error processing, conflict monitoring, EEG, N2, P3, ERN, Pe, Anterior Cingulate Cortex

## Chapter I Introduction

Psychopathy has long been a focus of psychological study due to its large-scale impacts on individuals and society. It was first described by Hervey Cleckley as a person who is a hybrid of superficial charm, emotional impoverishment, and impulse control deficits (Lilienfeld, et al., 2018). Billions of dollars of harm and countless violent crimes are associated with those who act out psychopathic traits (Gatner et al. 2023, Reidy et al., 2011).

The neural basis of psychopathy has been extensively explored through imaging studies showing reduced grey matter volume across multiple cortical and subcortical regions (Johanson et al., 2020). One of these regions, the anterior cingulate cortex (ACC), is implicated in cognitive functions including error processing, reinforcement learning, affect, and motivation (Bush et al., 2000; Devinsky et al., 1995; Johanson et al., 2020; Koenigs, 2012).

Several models have emerged to describe the cognitive processes associated with psychopathy. For example, attentional deficit models describe an inability to process multiple information streams or change behavior as a response to peripheral information, similar to a predator so focused on its prey that it doesn't notice another animal in its peripheral vision (Baskin-Sommers & Brazil, 2022; Gorenstein & Newman, 1980; Smith & Lilienfeld, 2015). Models explaining deficits in reinforcement learning describe an inability to learn from punishment or negative reinforcement, while showing changes in cognitive processing modulated by reward (Blair et al., 2004; Newman et al., 1990). However, previous research shows mixed findings regarding the relationship between psychopathy, these cognitive processes,

and their neural markers when measured using electroencephalogram (EEG) (Clark et al., 2019; Schulreich, 2016; Vallet et al., 2021).

The current study aims to address this gap in the literature by measuring the relationship of neurophysiological markers of conflict monitoring, response inhibition, and error processing to subclinical levels of psychopathic traits in a sample of undergraduate students.

**Conceptual Models of Psychopathy: Theory and Measurement**

Psychopathy is a multidimensional construct encompassing frequently co-occurring traits of affective deficits including exploitation of others with no remorse, and antisocial traits such as emotional instability (Harpur et al., 1989). Current theoretical models of psychopathy describe these differences with the distinctions of "primary" and "secondary." Variations between these two groups are characterized by whether emotional deficiency (primary psychopathy) or emotional disturbance (secondary psychopathy) is a greater factor for externalizing behavior (Lee & Salekin, 2010; Yildirim & Derksen, 2015).

The most widely used models of psychopathy show between two and four factors, with the two-factor model described by the Psychopathy Checklist–Revised (PCL-R) being the most prominently used in clinical and forensic settings (Hare, 2021). The two factors in the PCL-R align with conceptions of "primary" and "secondary" psychopathy. Other validated assessment tools include the Levenson Self-Report Psychopathy Scale (LSRP) and the Psychopathic Personality Inventory-Revised (PPI-R) (Levenson et al., 1995; Lilienfeld & Widows, 2005). Recently, the Triarchic Psychopathy Measure (TriPM) has been utilized as a self-report tool based on the triarchic theory of psychopathy (Patrick, 2010). This model measures three factors separate from the two-factor model, which are meanness, boldness, and disinhibition.

However, while some research paradigms use this three-factor model, it does not see widespread clinical and diagnostic use like the PCL-R (Evans & Tully, 2016).

Although categorical measures have traditionally been used in assessment, there is robust debate surrounding the utility of categorical versus dimensional models of personality pathology (Trull & Durrett, 2005). The use of dimensional personality assessments in clinical settings has gained traction due to the clinical utility of such measures (Bach & Tracy, 2022; Bornstein & Natoli, 2019). One such tool, the Short Dark Tetrad (SD4), is a dimensional model of four interpersonally harmful personality traits that includes measures of psychopathy, Machiavellianism, narcissism, and sadism (Paulhus et al., 2020).

The SD4 was designed to capture subclinical levels of aversive personality characteristics that cause interpersonal distress, but at levels that may not be harmful (or may be of benefit) to those who demonstrate them (Neumann et al., 2020; Paulhus, 2014). Exploratory factor analysis (EFA) in our sample shows factor loadings of the psychopathy measure in this survey to fall between .325 and .724, indicating adequate correlation of survey items to a latent psychopathic factor (Neumann et al., 2021). Previous research shows differences in how the behavior of those with “dark” personality traits is perceived by lay persons, with more exploration needed to better understand the relationship between psychopathy and other “dark” traits (Rauthmann, 2011). One study investigating differences between “dark” traits found an inverse relationship of all dark tetrad traits to personality measures of honesty and humility, while individual dark traits showed different combinations of other personality traits (Book et al., 2016). Therefore, distinguishing between differing constellations of “dark” personality traits may help to accurately reflect individual differences, rather than grouping those who demonstrate psychopathic characteristics under a single psychopathic construct. One study by Blötner et al (2021) showed

correlations of psychopathic traits using the SD4 ranging from .55 to .67 on positive and negative urgency scales, which have been previously shown as key features of impulsivity constructs (Whiteside & Lynam, 2001). Additionally, this survey can control for shared variance against other "dark" traits with a dominance-oriented motivational component (Blötner et al., 2021).

Regardless of the measurement tool used, in all models of psychopathy, deficits of response inhibition have reliably emerged as a key feature (Gray et al., 2019; Hare & Neumann, 2008; Jones & Paulhus, 2011; Patrick et al., 2009; Poythress & Hall, 2011; Snowden & Gray, 2011). Specifically, impulsivity and a lack of self-control have demonstrated strong relationships across individual factors within the construct in measures related to lifestyle factors/facets, while showing zero or negative correlations to measures more closely aligned with affective elements (Gray et al., 2019; Morgan et al., 2011; Ray et al., 2009; Weidacker et al., 2017). Additionally, recent self-report and ecological momentary assessment studies of the single-psychopathy factor within the Dark Triad/Tetrad framework have also shown strong correlations to impulsivity (Jonason & Tost, 2010; Kiire et al., 2020).

**Neurocognitive Correlates of Psychopathy**

Theoretical models of psychopathy overlap with research exploring possible neurobiological correlates of these characteristics. Thus, modern conceptualizations of psychopathy are both informed by and inform how the construct has been studied from a neurocognitive perspective. Emerging from these theoretical constructs of psychopathy, many neural imaging studies have investigated cortical thickness in the frontal and temporal lobes of individuals with psychopathy (Johanson et al., 2020). One such study found reduced cortical thickness in the right and frontal temporal cortices of the brain, linking the emotional and

affective deficits partially characterizing the pathology to poor recognition of negative facial expression (Yang et al., 2009). Additionally, a review of structural magnetic resonance imaging (MRI) studies showed consistently reduced gray matter volume in the ACC of individuals exhibiting psychopathic traits (Johanson et al., 2020). The ACC is involved with the cognitive processes of response inhibition and environmental monitoring, which are processes that support the functions considered to operate at a deficit in those who demonstrate psychopathic traits (Carter et al., 1998; Golchert et al., 2017; Hester et al., 2005; Yeung, 2004). Additionally, the ACC plays a role in behavioral and social motivation that may mediate the relationship between cognitive control and reinforcement learning (Apps et al., 2016; Holroyd & Yeung, 2012; Shenhav et al., 2016).

The body of literature describing differences in behavioral outcomes and neural imaging implicating the ACC have created the foundation for several models of cognitive processing deficits to emerge in individuals demonstrating psychopathic traits. One model describes an exaggerated attentional bottleneck in which psychopathic individuals demonstrate deficits in an ability to process multiple streams of information simultaneously, with increased ability to focus on unitary goal-relevant stimuli (Baskin-Sommers & Brazil, 2022; Baskin-Sommers et al., 2011). Self-reported psychopathy was found to be associated with performance and neural marker deficits of attention and inhibition during a dual-task paradigm (Tillem et al., 2021).

Like the attention bottleneck hypothesis, the response modulation hypothesis describes psychopathic individuals' inability to change behavior as a response to cues that are peripheral or secondary to dominant response (Gorenstein & Newman, 1980; Smith & Lilienfeld, 2015). A recent study has shown a link between the antisocial facet of psychopathy and deficits in attentional control in a visual attention task (Goodhew & Edwards, 2025). Further deficits in top-

down attentional control were shown in a visual search task that included colored distractions, where psychopathic traits were linked to difficulty searching for target features, but not distractors (Hoppenbrouwers et al., 2015).

In addition to attention deficits, individuals expressing psychopathic traits have been characterized by an inability to learn from punishment or negative reinforcement (Newman et al., 1990). A study comparing ERP of individuals with and without psychopathic traits showed decreased learning and reduced neural markers of error related negativity (ERN) in those with psychopathic traits during a probabilistic learning task (Von Borries et al., 2010). In another study, difficulties with reinforcement learning were exacerbated by acute stress – but only when focused on obtaining rewards, with no significant effect between lower and higher psychopathic traits and reinforcement learning deficits while avoiding losses (Carvalheiro et al., 2022). Similar results of differences in learning based on reward or punishment in this population have been demonstrated in other studies, showing greater behavior modulations when seeking rewards rather than avoiding a punishment (Blair et al., 2004; Brazil et al., 2013).

These neurocognitive models describe individuals with psychopathic traits as showing a combination of deficits in their ability to monitor for errors and prioritize conflicts within their environment, inhibit dominant or habitual behavior, and to learn from punishment or negative results due to their behavior, which are related to functions of the ACC (Burghart et al., 2024; De Brito et al., 2021). In the literature, many studies have used EEG to measure event-related potentials (ERP) to investigate the neural underpinnings of these cognitive processes.

**Event-Related Potentials (ERP) as Measures of Monitoring and Inhibition**

A commonly used paradigm for measuring activity in the prefrontal cortex related to cognitive control is the Go/No-Go (GNG) task (Casey et al., 1997). In this task, participants are

instructed to press a button in response to a more frequently presented go stimulus (such as a letter or shape), and withhold their response when presented with a less frequently presented no-go stimulus. Participants are required to respond as quickly and accurately as possible. The GNG task demonstrates specificity in testing error monitoring by eliciting frequent errors, and impulsivity by measuring response inhibition (Garavan et al., 2002). Additionally, increased neural activity can be elicited during more cognitively complex (therefore, more demanding) GNG tasks, as measured by electroencephalogram (EEG) (Gajewski & Falkenstein, 2013). Another study analyzing differences in interstimulus intervals during a GNG task showed stronger effects on neural processes underlying conflict monitoring in faster conditions (Billeke et al., 2014). Therefore, utilizing EEG allows for more precise temporal measurement of neural activity during this task. Because of this, more pronounced differences in neural activity can be elicited compared to other measurement techniques by allowing for increased task complexity.

Studies utilize EEG to measure electrical activity in the brain by measuring the amplitude of event related potentials (ERP) (Bokura et al., 2001; Falkenstein et al., 1999). ERPs related to the cognitive processes of conflict monitoring (N2), response inhibition (P3), and error processing (ERN/Pe) in GNG tasks are likely supported by the ACC, and align with the cognitive processes described in cognitive models of psychopathy (van Veen & Carter, 2002). Because EEG provides greater temporal accuracy and accessibility than functional Magnetic Resonance Imaging (fMRI), there is an extensive body of literature associated with ERP measuring cognitive processing associated with psychopathy. Previous studies have explored differences in ERP related to impulsivity and response modulation while looking at conflict monitoring and error negativity using tasks such as the stop signal task, and found relationships between psychopathy and the associated ERP (Heritage & Benning, 2013). Many studies have also been

conducted using GNG tasks (Bresin et al., 2014; Fournier et al., 2021; Ribes-Guardiola et al., 2020), and have revealed mixed results that are summarized below.

**P3**

The no-go P3 ERP is measured as a peak positive deflection occurring between 300 and 600ms following a correct response inhibition during a no-go stimulus. Studies have shown links to response inhibition and impulsivity during GNG tasks (Kiefer et al., 1998, Ruchsow et al., 2008; Smith et al., 2008). In addition to measuring response inhibition, fMRI and EEG/ERP research has shown the ACC as a potential generator of components of early P3 due to its relationship to attention (Crottaz-Herbette & Menon, 2006; Gajewski et al., 2008). The literature shows mixed results regarding the relationship between psychopathy and P3. For example, Ribes-Guardiola et al (2020) utilized the TriPM, and found significantly reduced P3 amplitudes in those exhibiting higher scores in the Disinhibition factor/dimension of psychopathy measures. Guan et al (2015) found significantly lower P3 mean amplitudes in a juvenile delinquent sample when compared to age-matched healthy controls. These findings provide evidence for inhibition deficits at the neural level in those demonstrating elements of psychopathic traits.

However, some studies also showed no significant difference or even increased P3 amplitudes in those demonstrating psychopathic traits, or specific factors of them (Munro et al., 2007; Ribes-Guardiola et al., 2020; Verona et al., 2012; Verona & Bresin, 2015). For example, Verona and colleagues (2012) used an emotional-linguistic GNG task, in which participants demonstrating psychopathic traits, antisocial personality disorder, and a control group were instructed to press a button when presented with a word in normal font and withhold responding when a word was italicized while ignoring the emotional content of the word that was negative or neutral. The negative word group was further distinguished between offender relevance (with

words like jail), and general negative (with words like rabies).The study found no significant difference between the "psychopathic" group (which correlates to the interpersonal/affective factor, or "primary" psychopathy) and healthy controls, but saw increased P3 amplitudes in the "antisocial" group (which correlates to the lifestyle/antisocial factor, or "secondary" psychopathy) when the task stimulus was negatively emotionally-valenced. These results suggest that antisocial lifestyle traits are more closely associated with the inhibitory processes related to P3 than interpersonal/affective psychopathic traits. Munro and colleagues (2007) found smaller P3 amplitudes in an offender group compared to controls, but the difference was not correlated to levels of psychopathy within the offender group. To further demonstrate the distinction between individual factors of psychopathy, Ribes-Guardiola et al (2020) found meanness and boldness in a three-factor psychopathy model were not significantly related to no-go P3 amplitude. These findings describe a complex relationship between impulsivity and different theoretical factors of psychopathy, indicating a range of differences in neural activity based on where they fall within the psychopathic construct itself.

**N2**

N2 in a GNG task is an ERP component that reflects conflict-monitoring (Donkers & van Boxtel, 2004; Nieuwenhuis et al., 2003). N2 amplitudes are larger (i.e., more negative) following no-go than go stimulus in a GNG task, and likely originate in the ACC (Gajewski et al., 2008). A review of the literature shows an inconsistent relationship between psychopathic traits and N2 amplitudes in studies using a GNG task. For example, several previous studies have demonstrated decreased N2 amplitudes during this task when comparing individuals with and without psychopathic traits (Anderson & Stanford, 2012; Guan et al., 2015; Kiehl at al., 2000). The studies by Guan et al (2015) and Kiehl et al (2000) were conducted on male offender

populations with comparatively easier cognitive demands placed by the tasks due to the distribution of go to no-go stimuli presented. The task in Kiehl et al (2000) consisted of a 50% distribution of go stimulus, while the task in Guan et al (2015) had a distribution of 60% go trials and was conducted in a population with a mean age of 16.58 years old. These tasks were relatively easy, yet still describe a pattern of reduced N2 amplitude in those exhibiting higher levels of psychopathy.

However, several studies have found no significant difference in N2 amplitudes during a GNG task between individuals with and without psychopathic traits (Kim & Jung, 2014; Paiva et al., 2020; Ribes-Guardiola et al., 2020). For example, the study conducted by Kim and Jung (2014) compared individuals with and without psychopathic traits in an undergraduate sample as measured with the PPI-R, using a distribution of 66% go trials in their GNG task. The other two studies with nonsignificant results measured community and undergraduate samples using the TriPM. As significant differences were seen in P3 amplitudes when distinguishing between individual factors within the psychopathic construct uses, a need to differentiate psychopathy measures at the factor level may be warranted to observe a more robust relationship between N2 amplitude and psychopathic traits.

**ERN**

The error related negativity (ERN) ERP reflects the unconscious cognitive process of error detection, and is frequently measured using a GNG task paradigm (Scheffers et al., 1996). ERN is measured as a negative deflection peaking approximately 80ms after an error during a cognitive task, e.g., when participants pressed the key for no-go stimuli in the GNG task (Falkenstein et al., 2000). This process likely occurs in the ACC as a feature of cognitive control (Carter et al., 1998; Holroyd et al., 2004). While some research has indicated greatest reliability

in a flanker task paradigm, the GNG task has also been demonstrated to provide reliable measures of ERN (Meyer et al., 2013). Research has described a mixed relationship between ERN, psychopathy, and its individual factors.

Some studies have shown a non-significant relationship between ERN amplitude and psychopathy (Maurer et al., 2016; Maurer et al., 2016; Maurer et al., 2018; Ribes-Guardiola et al., 2020; Steele et al., 2016). For example, Maurer et al (2016a; 2016b; 2018) used a variety of measures (such as the PCL:SV, SCID for DSM, APSD), samples (female, male, children), and theoretical models of psychopathy (two and three factor), and found no significant differences in ERN amplitude regardless of measure used across all three studies. The authors made note that their findings may indicate that self-report and interview-based assessments of psychopathic traits do not measure the same cognitive processes, and warrant further study to determine the key differences in these assessment techniques (Maurer et al., 2018). Their interpretation highlights the value of exploring alternative assessment tools to include measurement of elements of psychopathy not captured by tools such as the PCL-R or TriPM.

However, some studies have found reduced ERN amplitudes during a GNG task in psychopathic samples (Varlamov et al., 2011; Paiva et al., 2020; Ribes-Guardiola et al., 2020). Multiple studies that measured psychopathy using the TriPM showed reduced ERN amplitudes only for individuals scoring higher in the Disinhibition factor (Paiva et al., 2020; Ribes-Guardiola et al., 2020). Varlamov et al (2011) found reduced ERP amplitudes in a sample demonstrating psychopathic traits at the N100 ERP following negative feedback, which is unconsciously elicited in response to unexpected stimulus (similar to ERN as an unconscious recognition of error). It is worth noting that this study provided positive feedback for correct trials, and negative feedback for incorrect trials during the GNG task, which is different from

many other studies. Additionally, no significant differences were shown at N300, which is reflective of conscious feedback-related negativity (Varlamov et al., 2011). Previous research has shown greater N2 and ERN amplitude on punishment motivated trials in non-psychopathic samples, which indicates that feedback received during this study may have influenced neural activity following either a correct or incorrect response at 100ms time point after the error occurs (Potts, 2011). These mixed results of cognitive deficits in reinforcement learning in those with psychopathic traits emphasize a need for further investigation into other factors that may be influencing this process.

**Pe**

In conjunction with ERN, error positivity (Pe) represents a later ERP component of conscious recognition of the commission of an error (Falkenstein et al., 2000; Ridderinkhof et al., 2009). However, there is evidence that Pe exists as a distinct unit of error processing from ERN (Di Gregorio, et al., 2018). This signal also likely originates in the ACC (O'Connell et al., 2007). It is measured as a positive deflection occurring approximately 300-600ms following the commission of an error during a cognitive task (Falkenstein et al., 2000; Ridderinkhof et al., 2009). Differences have been demonstrated between "early" and "late" Pe. Early Pe reflects automatic error processing, with one study showing no dissociation between aware and unaware errors (Endrass et al., 2007). Later Pe measurements have been demonstrated to reflect greater conscious awareness of response errors (Endrass et al., 2007; Falkenstein et al., 2000; Hewig et al., 2011; Overbeek et al., 2005; Ridderinkhof et al., 2009). For example, one study comparing error processing components using GNG compared more impulsive to less impulsive participants based on reaction times during the task, and found significantly lower "early" Pe amplitudes in the more impulsive group with faster reaction times (Ruchsow et al., 2005). The current literature

on post-error processing in psychopathy is mixed, showing increased Pe amplitudes, non-significant relationships between psychopathy and Pe, and reduced Pe amplitudes.

Several studies have shown reduced Pe amplitudes in samples of individuals demonstrating psychopathic traits (Maurer et al., 2016; Maurer et al., 2016; Ribes-Guardiola et al., 2020). Two of these studies describe reduced amplitudes for specific psychopathic factors, rather than total scores within the construct they used (Maurer et al., 2016; Ribes-Guardiola et al., 2020). A study by Ribes-Guardiola et al (2020) demonstrated reduced Pe amplitudes in the TriPM measure of Disinhibition specifically. A study performed by Maurer et al (2016) using a two-factor model of psychopathy found reduced late Pe amplitudes in a female sample, with the affective facet (factor one) being a significant predictor.

However, one study by Maurer et al (2016) found no significant relationship between total or factor psychopathy scores, and total Pe mean amplitude. Maurer et al (2018) later ran an additional study that found no significant relationships on any self-report psychopathy assessment to be correlated to Pe amplitude. A study Ribes-Guardiola et al (2020) showed no significant relationship between Pe amplitudes and the TriPM measure's Meanness and Boldness factors in their sample.

Multiple studies using the TriPM showed increased Pe amplitudes in samples showing elevated Meanness (Paiva et al., 2020; Ribes-Guardiola et al., 2020). One study by Steele et al (2016) showed increased Pe amplitudes in a sample of individuals scoring higher on factor one (interpersonal/affective) and facet three (impulsive lifestyle) of the PCL-R. These varied results describe distinctions in observable neural markers of error processing at the factor level within the psychopathic construct.

**Mixed Research Findings and Gaps in Prior Research**

Previous research has shown some mixed relationships between ERP measurements reflecting impulsivity and error processing in those who demonstrate psychopathic traits (Clark et al., 2019; Schulreich, 2016; Vallet et al., 2021). Although differences in measures used to assess psychopathy may contribute to the mixed findings, how GNG tasks in the studies were designed may also play a role. Two important aspects of task design varied across studies – whether participants were given feedback for their mistake, and the difficulty of the task.

Studies measuring ERP related to cognitive processing in samples demonstrating psychopathic traits involving feedback were scant, with a single study providing both positive and negative feedback based on responses (Varlamov et al., 2011). Studies investigating the influence of feedback on ERP response in the general population have shown increased ERN amplitude without differences in task performance when value-based feedback was manipulated to be worth "more" or "less" (Hajcak et al., 2005). Another study using a modified flanker task with a general population sample showed greater ERN and Pe amplitudes on mistakes when accuracy on the task was rated compared to the same task when it was not rated (Grützmann et al., 2014). These studies suggest that when individuals without psychopathy are motivated enough by salient feedback, they demonstrate greater neural activity consistent with cognitive control processes like error monitoring or inhibition. In previous studies where no feedback was given in GNG tasks, differences in the underlying neural response patterns may not emerge among individuals with and without psychopathic traits. Thus, the presence or absence of feedback could account for the mixed findings across studies. Therefore, if the GNG task provides feedback to errors, such as a message of "Incorrect!" when a mistake is made, we may

be able to better detect neural deficits (measured by these ERP) in those with greater levels of psychopathic traits by a lack of increased neural activity as a response to feedback.

Additionally, the GNG tasks in the studies reviewed were less cognitively demanding. Previous research has shown that GNG task difficulty can impact ERP amplitudes. For example, one study showed reduced P3 amplitude during no-go trials with greater numbers of go trials (Zhang et al., 2024). Another study found increased N2 amplitudes when response time allowed for no-go stimulus was reduced (Jodo & Kayama, 1992). The reviewed tasks in samples measuring psychopathy may not be demanding enough to measure the level of cognitive control that effectively differentiates individuals along differing levels of psychopathic traits within the general population.

**The Current Study**

Based on a review of the literature, the proposed study investigated whether the ERPs related to impulsivity, conflict monitoring, and error processing predicted individual psychopathy scores using a GNG task that established a strong prepotent response. The proposed task provided negative feedback for incorrect responses. We believed these changes to the task would be more sensitive, and result in ERP amplitudes that would differentiate among subclinical levels of psychopathy in our sample. Our prediction was similar to prior research with the general population (Grützmann et al., 2014; Hajcak et al., 2005). Additionally, increasing the challenge of the task was expected to tax the cognitive abilities of the participant in a way that would further distinguish how differences in ERP measurements within the sample would predict levels of psychopathy. The study employed the SD4, which has been demonstrated valid for assessing the psychopathy construct measurement in undergraduate samples (Chabrol et al., 2017; Neumann et al., 2021). The use of the SD4 also allowed us to explore the effects of other socially

aversive traits (i.e., narcissism, sadism, and Machiavellianism) that often co-occur with psychopathy.

**Hypotheses**

We predicted that psychopathy would be inversely related to error monitoring. Therefore, we anticipated that reduced ERN and Pe amplitudes obtained during the GNG task (i.e., smaller absolute value of ERN/Pe amplitudes) were associated with higher psychopathy scores (**Hypothesis One)**.

We predicted that psychopathy would be inversely related to conflict monitoring and response inhibition. Therefore, we anticipated that reduced N2 and P3 amplitudes obtained during the GNG task (i.e., smaller absolute value of N2/P3 amplitudes) were associated with higher psychopathy scores. (**Hypothesis Two).**

# Chapter II Methods

## Participants

A total of 70 undergraduate students were recruited through the University of Michigan-Dearborn as part of an introductory psychology course. The participants were screened for eligibility, and excluded for history of traumatic brain injury or surgery, or a current head wound, irritation or allergy. Of the 70, one participant voluntarily withdrew from the study. Additionally, three participants were excluded from analysis using ERN and Pe due to a lack of sufficient trials. Thus, the final sample on which we ran analysis to test our hypotheses consisted of 66 participants for the analyses that utilized ERN and Pe components, and 69 participants for analyses that utilized N2 and P3 components. All participants received course credit. Participants were 35% male and 65% female. Participant ages ranged from 18 to 38 years, with a mean age of 19.6. 12% of participants disclosed a previous psychiatric diagnosis, and 3% disclosed being under the influence of a non-routine substance (such as a psychoactive medication). This information was gathered in order to control for whether substance use or psychiatric diagnosis would impact performance on the GNG task, or influence ERP amplitudes during analysis. See Table 1 for a detailed breakdown of demographic information.

## EEG Recording

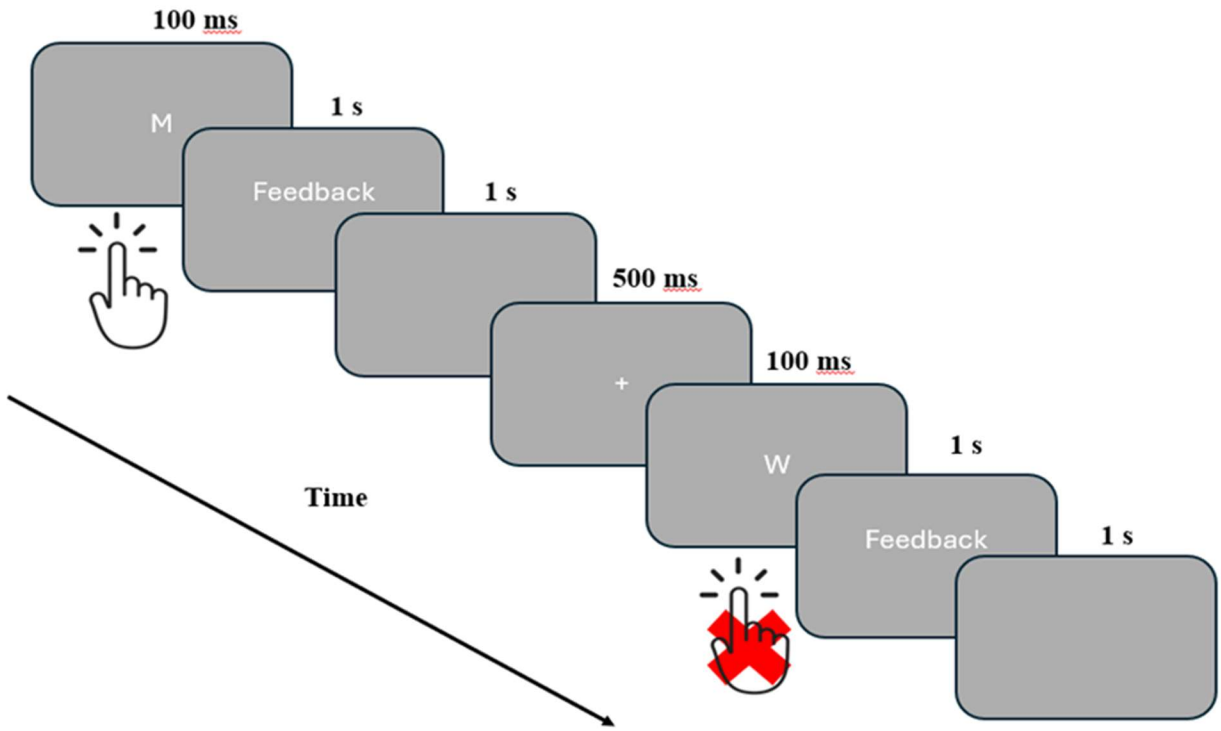
EEG data were collected using Ag/AgCl active electrodes connected to a BioSemi 64 active electrode EEG system (Biosemi Active Two; The Netherlands). EEG data were collected

from 64 scalp sites using the international 10-20 system. Four additional electrodes were used to capture vertical and horizontal electrooculogram recording through placement beneath and on the outer corner of each eye, for a total of 68 electrodes. Two reference electrodes (one on each earlobe as offline references) were used. Data was digitized at 512 Hz. Biosemi Common Mode Sense (CMS) and a Driven Right Leg (DRL) were used as online reference electrodes. EEG data were recorded using BioSemi ActiView software.

**Go/No-Go Task**

**Figure 1**

*Go/No-Go Task*




*Note.* Schematic diagram illustrating sample stimuli in the Go/No-Go task. Adapted from *Neurocognitive components of the behavioral inhibition and activation systems: Implications for theories of self-regulation* by Amodio et al., 2008 (https://doi.org/10.1111/j.1469-8986.2007.00609.x). In this example, the letter "M" is the go stimulus and "W" is the no-go stimulus. If participants' responses in the go trials are not fast enough (within 500ms), the

feedback message is “Too Slow!” in red. If participants make a response in a no-go trial, the feedback message “Incorrect!” is shown in red.

The GNG task was identical to that used by Amodio et al (2007; 2008), as this study was conducted alongside a replication of these studies (Amodio et al., 2007; Amodio et al., 2008). The task was presented using Psychopy version 2022.2.4 (Peirce et al., 2019). Participants were given instructions on the screen prior to starting the task that followed established procedure for this type of task (Nieuwenhuis et al., 2003). Participants pressed the right shift key on a keyboard with their right index finger as a response to either the letter “M” or “W,” and withheld from pressing the key in response to the opposing letter (i.e., press “W” and withhold for “M”, see Figure 1). For half of the participants, “W” was the go stimulus (“M” was the no-go stimulus) and for the other half of participants, “M” was the go stimulus (“W” was the no-go stimulus). Each trial began with a fixation point presented for 500ms in the center of the screen, followed by the presentation of the target stimulus for 100ms, followed by a blank screen. Participants were instructed to respond as quickly and accurately as possible following stimulus presentation, and were given a deadline of 500ms. Participants saw the feedback “Too Slow!” on the screen if they did not correctly respond to a go trial within 500ms, and “Incorrect” if they pressed the shift key in response to a no-go trial (see Figure 1).

The task included 20 practice trials that provided feedback, and 500 total trials split into two blocks with a 2-minute rest break between. Blocks consisted of 80% go trials and 20% no-go trials. The high frequency of go trials were designed to induce development of a prepotent go response to increase the cognitive resources required to inhibit a response for no-go trials.

### Short Dark Tetrad (SD4)

Psychopathy traits were assessed using the Short Dark Tetrad (SD4) scale (Paulhus et al., 2020). The SD4 measures subclinical levels of "dark" personality characteristics including Machiavellianism, narcissism, psychopathy and sadism. All 7 item responses on the Psychopathy subscale were summed to create a composite score for analysis, as no designated cutoff score exists. Therefore, all four traits were included in this study to control for the impact of other dark traits on dependent variable measures. Internal consistency of the Short Dark Tetrad (SD4) subscales were assessed in our sample using Cronbach's alpha (α). Reliability for individual subscales ranged from nearly acceptable to good: Machiavellianism (α = .649), Narcissism (α = .718), Psychopathy (α = .744), and Sadism (α = .806). While Machiavellianism fell below the generally accepted value .7 as a cutoff for reliability, a German sample was shown to have a similar value (α = .63) (Blötner et al., 2022). Additionally, Exploratory factor analysis (EFA) in our sample showed factor loadings of the psychopathy measure in this survey to fall between .325 and .724, indicating adequate correlation of survey items to a latent psychopathic factor (Neumann et al., 2021) (See Appendix C for detailed EFA results).

### Data Processing

#### EEG Processing

EEG data were processed using the EEGLab toolbox (Delorme & Makeig, 2004) within the MATLAB software package (The MathWorks Inc., 2024). Data were digitally processed using a 0.1 - 30 bandpass filter and 60 Hz notch filter. Recordings were referenced to the average of two offline earlobe electrodes. Datasets containing channels with excessive noise were manually identified by two researchers, and interpolated. EEG signals were decomposed using Independent Component Analysis (Delorme et al., 2007; Makeig et al., 2004). Independent

components with significant artifacts were labeled using the ICLabels tool and manually checked and removed with emphasis on eye blinking, eye muscle artifacts, significant electrode channel noise, and heartbeat (Pion-Tonachini et al., 2019). Independent components that did not contain these types of artifacts were kept.

After ICA artifact removal, continuous EEG data were segmented into epochs (see next section for different ERP segmentations). Epochs with extreme power spectrum (threshold = 90dB), Kurtosis (threshold = 3.9 SD), and probabilities (threshold = 3.9 SD) values were removed using EEGLab trial rejection function.

**ERP Processing**

N2 component was isolated using a 1200ms stimulus-locked epoch of EEG, and baseline corrected using the average signal from -200 - 0ms for each artifact-free trial. Epochs associated with correct responses on no-go trials were averaged. N2 was measured as the peak negative deflection occurring between 200 – 400ms relative to target onset in correct no-go trials at site FCz. Specifically, the time point corresponding to the peak N2 was first located, then data in 20ms preceding and following the peak time point were averaged to produce the final N2 amplitude value. A similar averaging procedure was used to obtain other ERPs described in this section, with the exception of ERN. Participants with fewer than 20 artifact-free correct no-go trials were to be excluded from the analyses, with no exclusions based on this criterion.

P3 was measured as the peak positive deflection occurring between 350 - 500ms relative to target onset in correct no-go trials at site Cz. P3 component was isolated using a 1200ms stimulus-locked epoch of EEG, and baseline corrected using the average signal from -200 - 0ms for each artifact-free trial. Epochs associated with correct responses on no-go trials were

averaged. Participants with fewer than 20 artifact-free correct no-go trials were to be excluded from the analyses, with no exclusions based on this criterion.

ERN was measured as the peak negative deflection occurring between -50 – 150ms, relative to response onset during incorrect no-go trials at site FCz. Specifically, the ERN component was isolated using a 1400ms response-locked epoch of EEG, with 400ms preceding and 1000ms following the incorrect response. The time point corresponding to the peak ERN was first located, then data in 20ms preceding and following the peak time point were averaged to produce the final ERN amplitude value. Epochs were baseline corrected by subtracting the average voltage occurring from -150 - -50ms relative to response onset time within usable epochs. Epochs associated with incorrect responses on no-go trials were averaged. Participants were excluded from analysis if they had 12 artifact-free ERN trials, shown to be an adequate trial count in previous research (Pontifex et al., 2010). Three participants were excluded from analysis for having less than 12 artifact-free trials.

Pe was measured as the peak positive deflection occurring between 100 – 400ms, relative to response onset during incorrect no-go trials at site Cz (Falkenstein et al., 1991; Overbeek et al., 2005). Pe component was isolated using a 1400ms response-locked epoch of EEG, and baseline corrected by subtracting the average voltage occurring from -150 - -50ms prior to response time within usable epochs (Olvet & Hajcak, 2009). Epochs associated with incorrect responses on no-go trials were averaged within trial type. Participants were excluded from analysis if they had fewer than 12 artifact-free Pe trials, shown to be an adequate trial count in previous research (Olvet & Hajcak, 2009; Pontifex et al., 2010). Three participants were excluded from analysis for having less than 12 artifact-free trials.

**Procedure**

Upon arrival, participants received a consent form and were provided an opportunity to review and ask questions regarding their participation in the study. Included in the consent process was a verbal affirmation from participants that they did not meet any of the exclusion criteria. Next, participants provided demographic, substance use, and psychiatric diagnosis information using an online tool. Participants then completed a battery of self-report assessments that were part of a broader study being conducted alongside this one. Next, each participant was fitted with the EEG cap, and their vision was calibrated for a pupillometry tracker that was not relevant to this study. Participants were then given a resting EEG task which will not be analyzed in the current study. They then performed a GNG task while their brain activity was measured using the Biosemi EEG system. Following task completion, participants completed two additional questionnaires, including the SD4 to measure psychopathic traits. Each session lasted approximately 2 hours from start to finish, and participants were debriefed on the experiment following an opportunity to wash their hair after EEG electrode removal.

**Data Analysis**

Linear regression analyses were conducted to examine the relationship between psychopathic traits and ERP, with ERP measures as the predictor and psychopathic trait as the outcome variable. Demographic variables were used as covariates to control for potential confounding effects. All analyses were conducted using Jamovi (Version 2.6.26.0) and IBM SPSS Statistics (Version 29.0.1.1) (The jamovi project, 2025). A potential outlier was found, however, results remained the same when this participant was excluded from analysis. Therefore, the results reported here excluded only those who did not meet the minimum threshold of trials required for individual ERPs.

# Chapter III Results

## Behavioral Results

Demographic data are presented in Table 1:

**Table 1**

*Descriptive Statistics of Sample Demographic Data*

| Variable | Mean | Range |
|---|---|---|
| Age | 19.6 (3.03) | 18-38 |
| Handedness | 62.3 (68.6) | -100 - 100 |
| | No | Yes |
| Psychiatric Diagnosis | 61 (88%) | 8 (12%) |
| Substance Use | 67 (97%) | 2 (3%) |
| | **Males** | **Females** |
| Gender | 24 (35%) | 45 (65%) |

*Note.* Gender consisted of 1 = male, 2 = female. For handedness, a lower value denotes more frequent use of the left hand in daily activities. Substance use represents a participant who participated under the influence of a prescription psychiatric medication or psychoactive substance not routinely used. Values in parenthesis for mean age and handedness indicate standard deviation values. Percentage values listed in parentheses indicate total percentage of participants in category within the sample.

Descriptive statistics for the ERP predictor variables, behavioral data, and outcome measures are presented in Table 2:

**Table 2**

*Descriptive Statistics of Variable Data*

| Variable | N | *M* | *SD* | Minimum | Maximum |
|---|---|---|---|---|---|
| go_RT | 69 | .300 | .037 | .188 | .35 |
| nogo_Accuracy | 69 | .599 | .192 | .210 | .930 |
| N2_AMP | 69 | -5.01 | 5.56 | -19 | 11 |
| P3_AMP | 69 | 19.1 | 5.68 | 6.19 | 32.4 |
| ERN_AMP | 66 | -6.78 | 6.19 | -24.5 | 3.73 |
| Pe_AMP | 66 | 20.5 | 6.02 | 7.59 | 34 |
| Mach_Composite | 69 | 24 | 3.87 | 13 | 35 |
| Narc_Composite | 69 | 21 | 4.11 | 10 | 31 |
| Psycho_Composite | 69 | 14.4 | 4.24 | 7 | 30 |
| Sadism_Composite | 69 | 17.8 | 5.78 | 7 | 35 |

*Note.* Go_RT (response times) measured in seconds. Nogo_Accuracy reflects percentage of trials correctly withheld. Ending _AMP (amplitude) reflects corresponding prefix ERP measured in microvolts (μV). Ending _Composite represents composite score of prefix SD4 subscale items.

Zero order correlations among GNG task performance, ERP components, and Dark Tetrad traits are presented in Table 3:

**Table 3**

*Correlations Among Performance, ERP Amplitudes, and SD4 Subscale Scores*

| Variable | no-go Acc. | go RT | ERN amp. | Pe amp. | N2 amp. | P3 amp. | Psycho. comp. | Mach. comp. | Narc. comp. |
|---|---|---|---|---|---|---|---|---|---|
| no-go acc. | | | | | | | | | |
| go RT | .804** | | | | | | | | |
| ERN amp. | -.424** | -.299* | | | | | | | |
| Pe amp. | .013 | .065 | .065 | | | | | | |
| N2 amp. | -.068 | -.108 | .605** | -.058 | | | | | |
| P3 amp. | .142 | .130 | .015 | .691** | .093 | | | | |
| Psycho. comp. | -.151 | -.050 | .157 | .139 | -.004 | .120 | | | |
| Mach comp. | -.124 | -.041 | .264* | .096 | .171 | .086 | .338** | | |
| Narc. comp. | .073 | .077 | .047 | .017 | .034 | .016 | .406** | .228 | |
| Sadism comp. | .171 | -.087 | .216 | .059 | .091 | -.033 | .524** | .488** | .328** |

*Note.* ERP amplitudes designated by "amp." suffix. SD4 subscale scores indicated by "comp." suffix following personality trait. Assessment: Composite scores were calculated by summing individual item scores for each subscale. "Mach." indicates Machiavellianism, "Narc." indicates narcissism. Performance data: no-go acc. percentage accurate no-go responses withheld. "go RT" indicates mean value of response time to go stimulus in milliseconds. *$p < 0.05$, ** $p < 0.01$. Correlations not subjected to multiple testing corrections.

Behaviorally, increased no-go accuracy was significantly correlated with increased go response time ($r = .80$, $p < .001$, two-tailed). For ERP components, ERN amplitude showed

significant correlations with both no-go accuracy ($r$ = -.42, $p$ < .001, two-tailed) and go response time ($r$ = -.3, $p$ = .02, two-tailed). ERN has previously been shown to predict individual differences in error monitoring during a GNG task in as little as 8 trials (Franken et al., 2014; Holbrook et al., 2025). Consistent with the literature, ERN amplitudes in our sample show a relationship between GNG task performance, such that those with stronger (more negative) ERN amplitudes show greater accuracy withholding responses, and longer response times. ERN amplitude was also significantly positively correlated to N2 amplitude ($r$ = .61, $p$ < .001, two-tailed). Both are negative ERPs, although N2 was not correlated with behavioral performance. Prior research has shown that while these ERPs are dissociable, they exhibit overlapping activity in the caudal ACC during a GNG task (Mathalon et al., 2003). Additional studies have suggested that while these ERP are elicited as neural responses to different processes, they share a neural mechanism (Van Veen & Carter, 2002; Van Veen & Carter, 2002), indicating validity of these ERP measures in our study. Pe amplitude was significantly positively correlated with P3 ($r$ = .69, $p$ < .001, two-tailed), another positive ERP. Pe and P3 have shown similar prefrontal cortex activation in fMRI data (Hester et al., 2005), suggestive of a shared origin and function. However, neither ERP was significantly correlated with the behavioral performance of the GNG task. Overall, the observed correlation pattern among these ERP measures were expected.

Correlations were also found amongst SD4 items. Psychopathy was found to have a significant positive correlation to Machiavellianism ($r$ = .34, $p$ = .004, two-tailed), narcissism ($r$ = .41, $p$ = .001, two-tailed), and sadism ($r$ = .52, $p$ < .001, two-tailed). Machiavellianism was observed to have a significant positive correlation to sadism ($r$ = .49, $p$ < .001, two-tailed). Additionally, narcissism was found to have a significant positive correlation to sadism ($r$ = .33, $p$ = .006, two-tailed).

The results also showed that ERN amplitude was significantly positively correlated with Machiavellianism ($r$ = .26, $p$ = .03), with higher Machiavellianism associated with less negative ERN amplitudes. Although these correlations revealed no significant results with psychopathy, it was unknown if a significant relationship between psychopathy and ERP amplitudes was masked by demographic variables, which were interrogated using hierarchical linear regression analyses in the next step.

A hierarchical linear regression analysis was conducted to examine whether the combined behavioral variables no-go accuracy ($M$ = .6, $SD$ = .19) and go response time ($M$ = .3, $SD$ = .04) predicted psychopathy scores, controlling for age, gender, psychiatric diagnosis, non-routine substance use at time of participant, and degree of handedness (See Table 4). The inclusion of behavioral data was not statistically significant ($\Delta F(2, 61) = 1.17$, $p$ = .32) and numerically accounted for an additional 3.5% of the variance in psychopathy scores ($\Delta R^2$ = .04) beyond demographic variables. Research on the relationship between psychopathy and executive function performance has been mixed, with some literature describing small but significant performance impairment during the GNG task and others indicating no significant differences between those with psychopathic traits and those without (Gillespie et al., 2022).

**Table 4**

*Hierarchical Regression Analyses of Performance Predictors of Psychopathy*

| Independent Variables | Model 1 | Model 2 |
|---|---|---|
| Step 1: Demographics | | |
| Age | -.190 | -.196 |
| Gender | -.095 | -.106 |
| Diagnosis | .008 | .033 |
| Subs. Use | -.058 | -.048 |
| Handedness | .098 | .065 |
| $R^2$ | .039 | .074 (step 1+2) |
| $F$ | .508 | .699 (step 1+2) |
| Step 2: Performance | | |
| no-go acc. | | -.321 |
| Go RT | | .229 |
| $\Delta R^2$ | | .035 |

| | |
|---|---|
| $\Delta F$ | 1.168 |

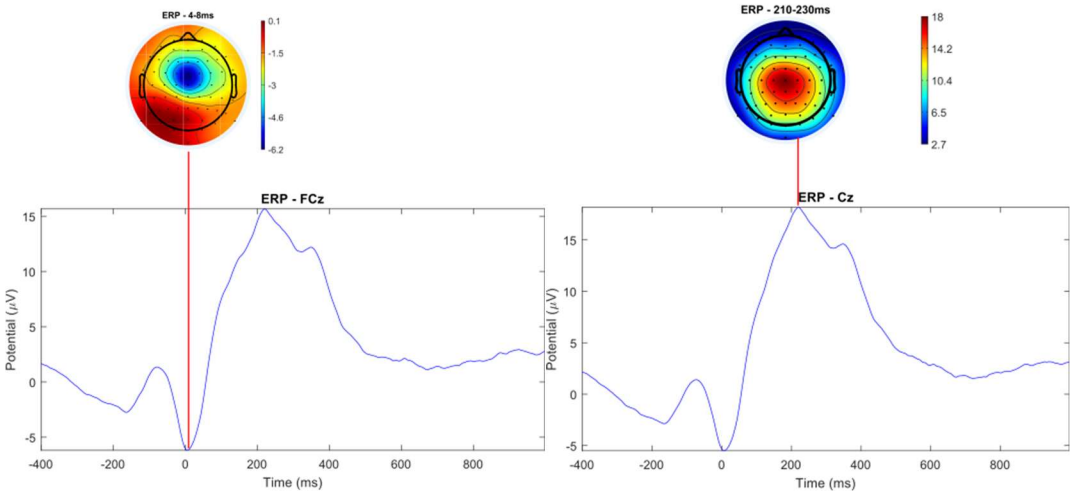
*Note.* Values reported are standardized regression coefficients unless otherwise specified. No values reached significance. Gender consisted of 1 = male, 2 = female. For handedness, a lower value denotes more frequent use of the left hand in daily activities. Substance use represents a participant who participated under the influence of a prescription psychiatric medication or psychoactive substance not routinely used. Go_RT (response times) measured in seconds. Nogo_Accuracy reflects percentage of trials correctly withheld.

## ERP Results

The time course and scalp distributions of the four ERP components are presented in Figures 2 and 3:

**Figure 2**

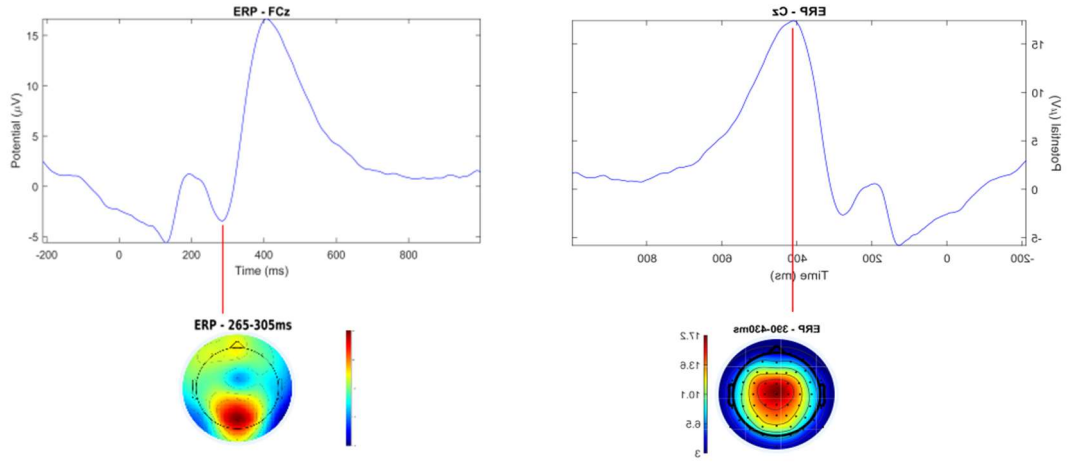
*The Time Course and Topographic Scalp Distribution of ERN and Pe*




*Note.* Figure demonstrates ERN as negative deflection measured at site FCz from 4-8ms, and Pe as positive deflection measured at site Cz from 210-230ms. The scalp distribution of ERPs around the peak time of ERN and Pe, indicated by the red line, are presented above the ERP time course. Red color indicates positive and blue color indicates negative voltage (unit: microvolts).

**Figure 3**

*The Time Course and Topographic Scalp Distribution of N2 and P3*




*Note.* Figure demonstrates N2 as negative deflection measured at site FCz from 265-305ms, and P3 as positive deflection measured at site Cz from 390-430ms. The scalp distribution of ERPs around the peak time of ERN and Pe, indicated by the red line, are presented below the ERP time course. Red color indicates positive and blue color indicates negative voltage (unit: microvolts).

While zero order correlation analysis did not indicate a significant relationship between psychopathy and event-related potential (ERP) measures, to confirm whether demographic factors masked potential relationships between ERP measures and psychopathy, a series of additional multiple linear regression analyses were performed in SPSS. First, separate models were constructed with each ERP component ERN, Pe, N2, and P3 serving as primary predictor. Then, in the last analysis, all ERPs were entered together as primary predictors to examine whether these ERPs together predicted Psychopathy. All models included the same covariates: age, gender, psychological diagnosis status, substance use at time of participation, and handedness score. When each ERP was individually entered as a predictor variable, none of the analyses yielded statistically significant results ($p$ = .70 ~ .86). These findings suggest that individual ERP amplitude, when controlling for relevant demographic variables, does not have an inverse relationship to psychopathy scores in this sample. Detailed statistics for each linear regression can be found in Tables 5:

**Table 5**

*Linear Regression Analyses for Psychopathy Scores and ERP Amplitudes*

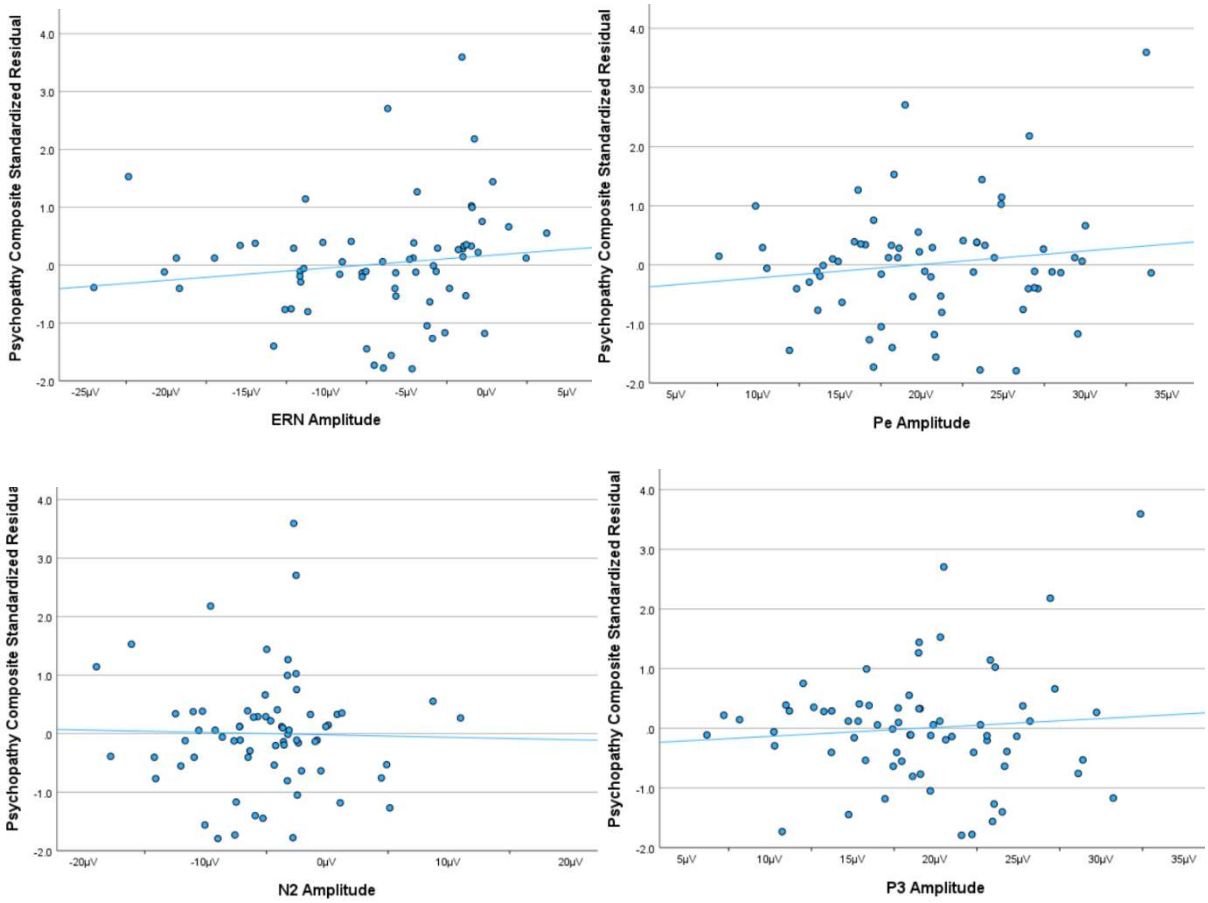
| | | | Psycho. Scores | |
|---|---|---|---|---|
| **Independent Variables** | | | | |
| Age | -.173 | -.169 | -.196 | -.173 |
| Gender | -.054 | -.101 | -.097 | -.094 |
| Diagnosis | .016 | .007 | .011 | -.011 |
| Subs. Use | .005 | .027 | -.056 | -.051 |
| Handedness | .108 | .074 | .094 | .090 |
| | **ERN** .130 | **Pe** .149 | **N2** -.026 | **P3** .093 |
| $R^2$ | .057 | .061 | .039 | .047 |
| Adjusted $R^2$ | -.039 | -.035 | -.054 | -.045 |
| *F* | .595 | .634 | .424 | .508 |

*Note.* Values listed as standardized regression coefficients unless otherwise specified. No values reached significance. Gender consisted of 1=male, 2=female. For handedness, a lower value denotes more frequent use of the left hand in daily activities. Substance use represents a participant who participated under the influence of a prescription psychiatric medication or psychoactive substance not routinely used.

To illustrate the null relationship between these ERPs and psychopathy scores, bi-variate scatter plots are presented in Figure 4. To control for the influence of demographic covariates on psychopathy scores, standardized residual values were calculated by regressing the psychopathy composite score on age, gender, psychiatric diagnosis, substance use at time of participation, and handedness, and used in subsequent visualization analyses. When residual values for psychopathy scores including individual ERP amplitudes were analyzed, the same single participant was an outlier for each of the individual ERP measures. However, removal of this participant did not impact the results of this study, so they were included in analysis.

**Figure 4**

*Correlation Between Psychopathy Composite Score and ERP Amplitude*




*Note.* Scatter plots depicting the correlation between levels of psychopathy as measured by the SD4 psychopathy subscale and average ERP amplitudes for ERN, Pe, N2, and P3 respectively. Standardized residual values for psychopathy were calculated by removal of demographic variable effects.

Finally, a hierarchical linear regression analysis was conducted to examine whether all four ERP (ERN, Pe, N2, P3) variables together predicted psychopathy scores, controlling for age, gender, psychiatric diagnosis, non-routine substance use at time of participant, and degree of handedness. In the first step, demographic covariates were entered into the model and accounted for 4.2% of the variance in psychopathy scores ($F(5,60) = .52$, $p = .76$, $R^2 = .04$). In the second step, the four ERP amplitudes were added to the model. This resulted in a small increase in explained variance ($\Delta R^2 = .05$), but the change was not statistically significant ($\Delta F(4, 56) = 0.83$, $p = .51$). Therefore, all ERPs together did not significantly enhance prediction beyond

demographic factors. Detailed statistics for the analysis of the four ERPs together are located in Table 6:

**Table 6**

*Hierarchical Regression Analyses for Psychopathy Scores and ERP Amplitudes*

| Independent Variables | Model 1 | Model 2 |
|---|---|---|
| Step 1: Demographics | | |
| Age | -.196 | -.172 |
| Gender | -.073 | -.058 |
| Diagnosis | .030 | .023 |
| Subs. Use | .030 | .047 |
| Handedness | .104 | .056 |
| $R^2$ | .042 | .095 (step 1+2) |
| $F$ | .522 | .656 (step 1+2) |
| Step 2: ERP Amplitude | | |
| ERN | | .235 |
| Pe | | .086 |
| N2 | | -.203 |
| P3 | | .050 |
| $\Delta R^2$ | | .054 |
| $\Delta F$ | | .831 |

*Note.* Values listed as standardized regression coefficients unless otherwise specified. No values reached significance. Gender consisted of 1 = male, 2 = female. For handedness, a lower value denotes more frequent use of the left hand in daily activities. Substance use represents a participant who participated under the influence of a prescription psychiatric medication or psychoactive substance not routinely used.

**Supplementary Analysis: Exploring ERPs and other Dark Tetrad traits**

Although psychopathy was the primary focus of this study, the SD4 also measures 3 additional "dark" personality traits (Machiavellianism, Narcissism, and Sadism) that collectively comprise the Short Dark Tetrad. Given the conceptual overlap between these traits and their shared associations with impulsivity, cognitive control, and error processing, exploratory analyses were conducted to assess whether behavioral results or ERP amplitudes predicted scores on these subscales.

GNG performance did not significantly predict any of the additional SD4 subscales after controlling for demographics ($p$ = .10 to .94; See Supplementary Table 2 in Appendix B for detailed results). Additionally, ERP amplitudes did not show a significant association with any of

the subscales after controlling for demographics ($p$ = .06 to .94). However, Pe amplitudes did show a trend towards a significant association with sadism scores (β = .35, $p$ = .06).

Notable findings emerged among the covariates during supplementary analysis (found in Supplementary Table 3 in Appendix B). Machiavellianism was significantly associated with age while controlling for other demographic and ERP variables (β = -.33, $p$ = .01), with younger individuals scoring higher. Sadism was significantly associated with gender (β = -.41, $p$ = .002) with higher scores among males. All demographic variables together explained a significant portion of variance in both Machiavellianism ($R^2$ = .21, $p$ = .014) and Sadism ($R^2$ =.18, $p$ = .03).

Finally, being under the influence of a prescription psychiatric medication or non-routine psychoactive substance significantly predicted Machiavellianism (β = -.286, p = .022) when including ERP amplitudes into the second step of the model, with those not under the influence of a substance scoring higher in the trait. These findings suggest that while dark traits may be linked to some demographic factors, the ERP measures examined here do not appear to predict variance in Machiavellianism, narcissism, or sadism in this sample (detailed analysis can be found in Supplementary Table 3 in Appendix B).

**Supplementary Analysis: Exploring the Factor Structure of Short Dark Tetrad (SD4)**

Because we did not find significant evidence that the ERPs predicted psychopathy, we also explored the factor structure of the Short Dark Tetrad (SD4) to determine if a lack of significant relationship between psychopathy and ERP amplitude was due to low validity of the psychopathy measure. Items from the SD4 scale were subjected to exploratory factor analysis (EFA) using principal axis factoring with oblimin rotation to allow for correlation among factors. Factorability was assessed using the Kaiser-Meyer-Olkin (KMO) measure (.630) and Bartlett's test of sphericity was significant ($\chi^2(378) = 751$, $p < .001$). The number of retained factors was

determined through parallel analysis. Standardized loadings were interpreted using a threshold of .30, and cross-loadings were reviewed for conceptual clarity (see Appendix C).

Consistent with theoretical expectations, four factors were extracted using EFA, corresponding to the SD4's conceptual structure: Machiavellianism, Narcissism, Psychopathy, and Sadism. Although some items showed low factor loadings in this sample (item 5 "Manipulating the situation takes planning," and item 18 "I tend to dive in, then ask questions later"), results are consistent with the literature. In order to determine if items with lower factor loading impacted the linear regression analysis exploring the relationship between ERP amplitude and psychopathy scores, two items with high face validity (item 16 "I tend to fight against authorities and their rules," and item 21 "People who mess with me always regret it") were analyzed in a hierarchical regression including the four ERP amplitude measures and did not significantly enhance predictive value of the model beyond demographic variables ($p$ = .41 and .86, respectively

## Chapter IV Discussion

The goal of the current study was to examine whether event related potentials (ERPs) associated with conflict monitoring (N2 and P3) and error processing (ERN and Pe) were inversely associated with psychopathic traits. The cognitive processes represented by these ERPs have been linked to activity in the anterior cingulate cortex (ACC) (Bush et al., 2000; Devinsky et al., 1995; Johanson et al., 2020; Koenigs, 2012), which has been shown through imaging studies to have thinner cortical volume and worse functional connectivity in those with psychopathy (Johanson et al., 2020; Ly et al., 2012). Multiple measures and models of psychopathy exist, with the Psychopathy Checklist Revised (PCL-R) (Hare, 1991) and Triarchic Psychopathy Measure (TriPM) (Patrick, 2010) being frequently used in forensic and research paradigms. Our study measured ERPs using a Go/No-Go (GNG) task, and investigated the association between ERP amplitude and psychopathy scores using the Short Dark Tetrad (SD4) (Paulhus et al., 2020) due to its accessibility and assessment of additional aversive personality traits.

We found no evidence of a relationship between the neural activity underlying error processing (represented by ERN and Pe ERPs) during a GNG task and psychopathy traits in the current study. Additionally, we found no evidence of a relationship between neural activity underlying conflict monitoring and response inhibition (represented by N2 and P3 ERPs) and psychopathic traits. These null findings were unexpected based on prior literature linking psychopathy to anterior cingulate cortex activity (ACC) and its associated cognitive processes

(Deming & Koenigs, 2020). Previous studies investigating the relationship between psychopathy and ERP amplitudes have been mixed (Clark et al., 2019; Gao & Raine, 2009; Pasion et al., 2019). However, only one of the dozens of studies reviewed provided task feedback for response errors (Varlamov et al., 2011). In addition, many of these studies utilized GNG tasks that did not emphasize the development of a strong prepotent response through the go to no-go ratio used (Guan et al., 2015; Kiehl et al., 2000; Kim & Jung, 2014; Munro et al., 2007). Because our task gave negative feedback on no-go errors, we believed greater error monitoring activity represented by higher ERN and Pe ERP amplitudes would be predictive of lower psychopathic traits due to the link between psychopathy and deficits in learning from errors (Hypothesis one) (Blair et al., 2004; von Borries et al., 2010). Additionally, Because our study design included an 80% go to no-go ratio, we believed the task difficulty would tax cognitive resources enough to show deficits in conflict monitoring represented by N2 and P3 ERP amplitudes as predictors of psychopathic traits due to links between psychopathy and disinhibited behavior (Hypothesis two) (Paiva et al., 2020; Patrick et al., 2009.; Ribes-Guardiola et al., 2020). However, these modifications to the GNG task did not allow us to detect associations between psychopathy and these ERPs.

**Psychopathy and Error Processing**

Because previous research has shown reduced error-related neural activity in those with psychopathic traits (Varlamov et al. 2011; von Borries et al., 2010), we hypothesized an inverse relationship between error processing ERPs (ERN, Pe) and psychopathy scores would exist. This hypothesis was based on studies suggesting impairments in both unconscious (ERN) and conscious (Pe) error monitoring among those with psychopathic traits (Brazil et al., 2009; von Borries et al., 2010). Increased psychopathic traits have shown reduced amplitude in these ERP

components, suggesting an impaired ability to integrate feedback and learn from errors in order to modulate their responses (Paiva et al., 2020; Ribes-Guardiola et al., 2020). Additionally, externalizing behavior such as impulsivity shows clear associations to reduced ERN amplitudes and increased measures of psychopathy (Morgan et al., 2011; Pasion & Barbosa, 2019).

Despite these findings, this study found no evidence that ERN or Pe amplitudes are associated with psychopathy scores. Studies have demonstrated increased ERN and Pe amplitudes in response to punishment when compared to tasks without punishment in samples of college students in both flanker and GNG tasks, suggesting motivational significance of performance can influence error processing (Maruo et al., 2017; Potts, 2011). While our task gave negative feedback in response to inhibition errors, these studies subjected participants to monetary punishment. Even without money, one study showed increases in ERN amplitudes in a sample of female college students when feedback was manipulated to show correct answers in a flanker task being worth 100 or 5 points that would be converted to money at the end of the experiment. While there were no significant differences in behavior, there were significant increases in ERN amplitude when mistakes were made during 100 point trials (Hajcak et al. 2005). This suggests in the current study the negative feedback provided when participants made no-go errors may not have been aversive enough to heighten neural activity associated with unconscious (ERN) or conscious (Pe) error processing enough to demonstrate an association between levels of psychopathy in our sample. While these studies were not conducted as a study of psychopathy, a task used by Varlamov et al. (2011) showed psychopathic offenders demonstrated significantly reduced ERN amplitude compared to non-psychopathic offenders and a healthy control group. Varlamov and colleagues' study (2011) provided positive feedback represented by green £ symbols indicating monetary reward when they performed correctly, and

negative feedback consisting of red "x" symbols, where only negative feedback was presented in ours. Given that the ACC integrates both motivational and cognitive input (Bush et al., 2000), and previous studies suggest individuals high in psychopathy fail to integrate punishment cues into behavioral control with even greater emotional salience, our feedback design in the task may have lacked the emotional weight to sufficiently activate this region to a degree that is optimal to reveal psychopathy level differences (Baskin-Sommers et al., 2011). Even rats demonstrate greater neuronal activity in the ACC in response to more motivationally salient choices during decision making, especially during a high-cost high-reward scenario (Hillman & Bilkey, 2010).

In addition to motivational elements of ERN, previous research has shown differences in Pe amplitudes in children as young as four years old, where beliefs about greater competence were related to increased Pe amplitudes in a GNG task, and stronger intrinsic value of the task (they enjoyed it regardless of whether they performed well or not) was negatively related to Pe amplitudes (Kim et al., 2017). This, combined with evidence suggesting psychopathy may be more responsive to seeking reward than avoiding punishment (Wallace et al., 2009), indicates that future research paradigms where a relevant reward is used for motivation may be more effective in demonstrating a relationship between neural activity and psychopathic traits. Another factor impacting our results may be that the umbrella term "psychopathy" has different conceptualizations, as evidenced by the PCL-R 2 Factor/4 Facet model (Interpersonal/Affective deficits, and Lifestyle/Antisocial conduct) and the TriPM 3 Factor model (Boldness, Meanness, Disinhibition). Greater dimensionality within the psychopathy measure used is likely to provide greater sensitivity to differences within samples, regardless of the model used. For example, higher levels of the disinhibition factor of the Triarchic Model of psychopathy were shown to uniquely predict reduced ERN and Pe amplitudes, with no significant relationship between the

boldness and meanness factors (Paiva et al., 2020; Ribes-Guardiola et al., 2020). Additionally, One study using the PCL-R found that ERN amplitude was increased in those with elevated Factor 1 scores, but decreased ERN amplitudes in those with greater Factor 2 scores during a flanker task (Bresin et al., 2014). While analyzing the relationship between individual factors/facets of these constructs and neural activity has provided more consistent associations between decreased ERP amplitude and factor-level psychopathy measurements, dimensional models of personality have been recognized as providing clinical utility by looking at trait domains (such as disinhibition and antagonism) rather than categorical models like the PCL-R or TriPM (Bach & Tracy, 2022). While we were unable to find prior studies investigating the direct relationship between the SD4 and PCL-R or TriPM, we believed the SD4 psychopathy measure would align with Factor 2 of the PCL-R (Lifestyle/Antisocial conduct) and Disinhibition factor of the TriPM due to their associations with impulsivity (Jonason & Tost, 2010; Kiire et al., 2020; Ray et al., 2009; Weidacker et al., 2017). These results indicate a need for future research on the relationship between clinical/forensic definitions of psychopathy, the subclinical measure of the same name used by the SD4, and how they may be differentially associated with some neurocognitive substrates.

In addition to dimensional versus categorical differences at the construct measurement level, the SD4 was validated on nonclinical populations, where the PCL-R sees use in clinical and forensic settings. Our sample consisted of a general population of college students. Maurer and colleagues' study (2016) found decreased Pe amplitude for Factor 1 (interpersonal/affective) in a female incarcerated sample, while Steele et al.'s (2016) study found increases in Pe for an incarcerated male sample, indicating potential gender differences in significance of associations between ERP amplitude and psychopathy. Adding to the complexity of individual differences in

traits in our sample, fMRI studies have shown associations with psychopathic "deficits" in the OFC, ACC, dorsolateral PFC and superior temporal gyrus (Yang & Raine, 2008). However, it appears that differences between "successful" (Factor 1) and incarcerated "unsuccessful" (Factor 2) psychopath groups stems from brain deficiency in the PFC and hippocampus (Yang & Raine, 2008). What impacted differences between the hypothesized outcome based on previous studies is likely a hodgepodge of mismatched psychopathy construct measurements, a lack of motivational salience in the experimental task, and a lack of the spatial resolution of ERP methods likely required to capture such complex neural activity across multiple regions of the brain.

**Psychopathy and Cognitive Control**

N2 and P3 components, associated with conflict monitoring and inhibition respectively, were also hypothesized to have an inverse relationship with psychopathy scores. The N2 and P3 have been explored together previously as a "complex" representing the relationship between conflict monitoring and subsequent inhibition of a prepotent response as a neural marker of cognitive control (Kopp et al., 2020). Neural activity associated with these cognitive abilities align with both the response modulation and attention bottleneck hypotheses of psychopathy, the former of which proposes psychopathy is associated with reduced processing of information that is peripheral to the focus of attention, and the latter of which proposes psychopathy is associated with an inability to monitor information from multiple streams simultaneously (Baskin-Sommers & Brazil, 2022; Baskin-Sommers et al., 2011; Sadeh & Verona, 2008). Prior studies have reported that psychopathy is associated with both increased and reduced N2 amplitudes based on whether the core feature of the psychopathic presentation is more affective or impulsive, with clinical and forensic populations demonstrating more significant reductions (Pasion et al., 2019).

These deficits may stem from reduced structure and function of the prefrontal cortex, including the anterior cingulate cortex, as evidenced by the body of structural and functional neuroimaging studies of antisocial individuals (Yang & Raine, 2009; Yang et al., 2009). As indicated previously, SD4 psychopathy measures show associations to impulsivity, suggesting a relationship between this measure and N2/P3 (Jonason & Tost 2010; Kiire et al., 2020).

We hypothesized that establishing a stronger prepotent go response with a more demanding GNG task paradigm would be more taxing on cognitive resources related to conflict monitoring in such a way that ERP amplitudes would reflect an inverse relationship to psychopathy scores by way of an inability to recruit the level of neural activity necessary to complete the more difficult task. Newman and Lorenz (2003) argued that these deficits exist on a continuum, including within non-clinical populations. However, we found no significant relationship. Newman & Baskin-Sommers (2016) made the claim that more context, such as an affective component or set-shifting task, must be provided to a task to demonstrate the specific cognitive control deficits that are central to a conceptualization of psychopathy. For example, a dual task paradigm requiring participants to respond to both visual and audio cues demonstrated significantly reduced P3 amplitudes in a psychopathic group (Tillem et al., 2021). Regarding affective context, prior work by Verona et al. (2012) demonstrated blunted processing of negatively valenced emotional words compared to non-psychopathic offenders, while an antisocial personality disorder group demonstrated enhanced P3 amplitudes in response to negative emotional words. A task such as the parametric GNG task (Langenecker et al., 2007) may demonstrate more robust individual differences in the relationship between the ERP related to cognitive control and psychopathic traits due to having multiple difficulty levels, and its inclusion of set-shifting. Studies investigating the behavioral performance of both clinical and

subclinical levels of psychopathy in this task have shown significant results. For example, when looking at psychopathic offenders, one study found improved response inhibition performance in those with greater interpersonal facet scores (Facet 1), and worse response inhibition in those with higher lifestyle facet scores (Facet 3) (Weidacker et al., 2017). Even in subclinical samples, the blame externalization subscale of the Psychopathy Personality Inventory-Revised (PPI-R) predicted response inhibition deficits (Weidacker et al., 2017). These results differ from other studies using a standard GNG task such as the current study, and Kim & Jung's study (2014), where no evidence of behavioral differences was observed in subclinical populations demonstrating psychopathic traits. Therefore, although the GNG task engages conflict monitoring and inhibitory control processes at a general level, greater sensitivity to affective elements of psychopathy, or dual task conditions may probe conflict monitoring impairments hypothesized in the attention bottleneck hypothesis of psychopathy more effectively than simply increasing prepotent response generation (Dux, et al., 2006), as was the case in our study.

**Exploratory Findings**

Exploratory analysis incidentally found associations between demographic variables and other SD4 items. Age negatively predicted Machiavellianism, while being male positively predicted sadism. These Machiavellianism associations with age are consistent with results from a longitudinal study of over 1,000,000 with mean level changes from ages 10 to 67 showing a strong upward trend in trait Machiavellianism, which peaked during adolescence and exhibited a steady downward trend throughout adulthood until age 65 (Götz et al., 2020). As we collected data from a sample of college students, it may be the case that the manipulative interpersonal strategies associated with Machiavellianism are replaced over time as patterns of antisocial manipulation associated with the trait are replaced with more positive views of colleagues and

advisers in an academic setting who demonstrate their reliability and helpfulness (Wolff & Wetzel, 2023). Regarding sadism, the associations to being male are consistent with previous gender differences in dark tetrad traits (Paulhus et al., 2013). A bevy of prior research indicates men are more likely to utilize more physically aggressive and disagreeable strategies, which are characteristics that align with a sadistic construct that is inclusive of deriving pleasure from inflicting harm and discomfort onto others (Eagly & Steffen, 1986).

Beyond demographic variable associations, exploratory analysis also revealed a marginally significant positive relationship between Sadism and Pe amplitudes trending towards significance. While previous literature conceptualizes reduced conscious error processing amplitudes as indicating a deficit in conscious error awareness, sadistic traits are characterized by a heightened engagement in contexts involving harming others, dominance, or what are traditionally considered socially aversive outcomes (Buckels et al., 2013; Chester et al., 2019). It is plausible that individuals higher in sadism show increased post-error evaluation because they actively derive pleasure from harming others, a behavior which is widely considered a social error.

**Limitations**

While our study aimed to map ERP markers representative of cognitive abilities that have well established relationships to psychopathy, we relied on single electrode sites per ERP component, rather than more comprehensive topographic analysis. This approach limited our ability to detect nuanced spatial differences in neural activity, especially given the nature of distributed activity in the brain across networks. Recent work in neuroscience emphasizes the value of multivariate analytic approaches alongside cross validation to enhance detection of

effects in brain-behavior studies (DeYoung et al., 2025). Analyzing broader electrode topography could improve sensitivity in future work.

Additionally, our choice of ERP measurement may have limited significant findings. Several studies have divided the positive error processing component (Pe) into early, middle and late segments that reflect a positive post-error inflection following an error with neural activity beginning in the frontocentral scalp and moving towards the temporal scalp over time (Maurer et al., 2016; Maurer et al., 2016; Steele et al., 2016). And although our study investigated the no-go P3 as a marker of cognitive inhibition used in GNG paradigms (Smith et al., 2008), some studies have divided P3 into subcomponents such as P3a and P3b, which may reflect distinct neural pathways for attentional reorienting and context updating (Brazil et al., 2013; Polich, 2007). Beyond these ERP measures, Lakkso and colleagues (2001) found a negative correlation between psychopathy and volume of the posterior hippocampus, an anatomical structure previously demonstrated to assist in formulation of stimulus reward and punishment paradigms alongside the amygdala and ACC (Kosson et al., 2006). Our study did not divide Pe or P3 into subcomponents, nor did we analyze additional electrode locations or neuroanatomical structures. Our analysis was based on conceptualizations of Pe and P3 originating from the ACC. In light of this, further investigation of the association between psychopathy and neural activity should be investigated simultaneously with multiple measures and their interactions, rather than isolated to individual ones.

Another important limitation was our sample size. Small samples in neuroscience have been shown to contribute to both false positives and false negatives (Button et al., 2013). Of note is the trend of the relationship between the psychopathy measure, and ERN amplitude (positive) and Pe (positive). While neither of these results were significant, visual inspection of the

regression line suggests a larger sample size or more sensitive analysis may uncover a relationship between the variables.

Lastly, while the SD4 has been validated for subclinical populations, it differs from instruments more commonly used within the reviewed neuroimaging and ERP studies, such as the PCL-R. Many studies were designed to highlight key differences between groups of individuals with and without categorical psychopathic traits, rather than looking within a group to predict the level of individual differences. A mismatch in construct operationalization may have contributed to the discrepancies between the current findings and prior results. This limitation is not limited to our study, as others have called for dimensional changes to the psychopathic construct that include additional psychological constructs such as motivation (Schulreich, 2016; Steinert et al., 2021). A more direct comparison across measurement tools may provide greater predictability to specific ERPs.

**Conclusion**

The present study contributes to a growing body of literature that recognizes the importance of studying psychopathy dimensionally, rather than categorically, on its potential neural correlates. While the limitations in task sensitivity and sample size prevent definitive conclusions, these findings failed to support the notion that variability in psychopathic traits is reflected in neural differences within individuals. The relationship between psychopathy and ERP amplitudes is not obvious. Inconsistency of psychological assessment tools utilized across the body of literature may have contributed to the lack of solid evidence of a relationship between these ERPs and psychopathy scores. However, our lack of findings also suggests that the simplicity of the standard GNG task may not be an effective approach to investigating the underlying neural substrate of psychopathy. Instead, using tasks/paradigms that leverage multiple

aspects of cognitive control may elicit neural activity more reflective of that seen in real-world scenarios, and may show more promise capturing differences in neural activity by increasing difficulty across multiple cognitive domains simultaneously.

# Appendices

## Appendix A: Short Dark Tetrad (SD4)

*Responses given on 1-5 point scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)*

1. It's not wise to let people know your secrets.
2. Whatever it takes, you must get the important people on your side.
3. Avoid direct conflict with others because they may be useful in the future.
4. Keep a low profile if you want to get your way.
5. Manipulating the situation takes planning.
6. Flattery is a good way to get people on your side.
7. I love it when a tricky plan succeeds.
8. People see me as a natural leader.
9. I have a unique talent for persuading people.
10. Group activities tend to be dull without me.
11. I know that I am special because people keep telling me so.
12. I have some exceptional qualities.
13. I'm likely to become a future star in some area.
14. I like to show off every now and then.
15. People often say I'm out of control.
16. I tend to fight against authorities and their rules.
17. I've been in more fights than most people of my age and gender.
18. I tend to dive in, then ask questions later.
19. I've been in trouble with the law.
20. I sometimes get into dangerous situations.
21. People who mess with me always regret it.
22. Watching a fist-fight excites me.
23. I really enjoy violent films and video games.
24. It's funny when idiots fall flat on their face.

25. I enjoy watching violent sports.
26. Some people deserve to suffer.
27. Just for kicks, I've said mean things on social media.
28. I know how to hurt someone with words alone.

## Appendix B: Supplementary Tables

### Supplementary Table 1

*Linear Regression of ERN as Predictor of GNG Performance*

| Independent Variables | no-go Acc. | go RT |
|---|---|---|
| Age | .025 | .094 |
| Gender | -.028 | .105 |
| Diagnosis | .230 | .186 |
| Subs. Use | -.019$^{t}$ | -.023 |
| Handedness | -.098 | .055 |
| ERN Amp. | -.441** | -.279* |
| $R^2$ | .236 | .154 |
| $F$ | 3.042 | 1.796 |

*Note.* Values listed as standardized regression coefficients unless otherwise specified. *$p \leq .05$. **$p \leq .005$. $^{t}p \leq .06$. Gender consisted of 1 = male, 2 = female. For handedness, a lower value denotes more frequent use of the left hand in daily activities. Substance use represents a participant who participated under the influence of a prescription psychiatric medication or psychoactive substance not routinely used.

### Supplementary Table 2

*Hierarchical Regression Predicting SD4 Subscale Scores From Performance*

| | Machiavellianism | | Narcissism | | Sadism | |
|---|---|---|---|---|---|---|
| **Independent Variables** | **Model 1** | **Model 2** | **Model 1** | **Model 2** | **Model 1** | **Model 2** |
| Step 1: Demographics | | | | | | |
| Age | -.371** | -.374** | .117 | .184 | -.075 | -.078 |
| Gender | -.161 | -.168 | .099 | 1.164 | -.407** | -.416** |
| Diagnosis | .133 | .152 | .012 | -.001 | .087 | .116 |
| Subs. Use | -.383** | -.376** | -.093 | -.094 | -.027 | -.017 |
| Handedness | .197 | .173 | -.041 | -.040 | .100 | .066 |
| $R^2$ | .253 | .272 | .028 | .032 | .158* | .197 |
| $F$ | 4.273** | 3.248 | .360 | .287 | 2.373* | 2.138 |
| Step 2: Performance | | | | | | |
| no-go acc. | | -.228 | | .051 | | -.330 |
| Go RT | | .156 | | .017 | | .222 |
| $\Delta R^2$ | | .018 | | .004 | | .039 |

| | | | |
|---|---|---|---|
| $\Delta F$ | .765 | .128 | 1.465 |

*Note.* Values listed as standardized regression coefficients unless otherwise specified. *$p \leq .05$. **$p \leq .005$. Gender consisted of 1 = male, 2 = female. For handedness, a lower value denotes more frequent use of the left hand in daily activities. Substance use represents a participant who participated under the influence of a prescription psychiatric medication or psychoactive substance not routinely used.

**Supplementary Table 3**

*Hierarchical Regression Predicting SD4 Subscale Scores From ERP Amplitudes*

| | Machiavellianism | | Narcissism | | Sadism | |
|---|---|---|---|---|---|---|
| **Independent Variables** | **Model 1** | **Model 2** | **Model 1** | **Model 2** | **Model 1** | **Model 2** |
| Step 1: Demographics | | | | | | |
| Age | -.382** | -.327* | .109 | .123 | -.089 | -.057 |
| Gender | -.154 | -.148 | .147 | .145 | -.363** | -.414** |
| Diagnosis | .150 | .118 | .061 | .054 | .134 | .128 |
| Subs. Use | -.228$^{t}$ | -.286* | .086 | .083 | .139 | .113 |
| Handedness | .201 | 1.576 | -.030 | -.048 | .117 | .068 |
| $R^2$ | .207 | .281 | .032 | .040 | .179 | .252 |
| $F$ | 3.141* | 2.431 | .399 | .261 | 2.607* | 2.091 |
| Step 2: ERP Amplitude | | | | | | |
| ERN | | .236 | | .082 | | .117 |
| Pe | | .148 | | .067 | | .346$^{t}$ |
| N2 | | .032 | | -.046 | | -.015 |
| P3 | | -.112 | | -.014 | | -.268 |
| $\Delta R^2$ | | .073 | | .040 | | .252 |
| $\Delta F$ | | 1.431 | | .117 | | 1.366 |

*Note.* Values listed as standardized regression coefficients unless otherwise specified. *$p \leq .05$. **$p \leq .005$. $^{t}p \leq .06$. Gender consisted of 1 = male, 2 = female. For handedness, a lower value denotes more frequent use of the left hand in daily activities. Substance use represents a participant who participated under the influence of a prescription psychiatric medication or psychoactive substance not routinely used.

# Appendix C

## Results of Exploratory Factor Analysis on SD4 Items

*Factor Loadings*

| | Factor | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **Uniqueness** |
| **ShortDarkTetrad_1_MA** | | | | 0.485 | 0.658 |
| **ShortDarkTetrad_2_MA** | | | | 0.554 | 0.648 |
| **ShortDarkTetrad_3_MA** | | | | 0.572 | 0.644 |
| **ShortDarkTetrad_4_MA** | | | | 0.649 | 0.529 |
| **ShortDarkTetrad_5_MA** | | -0.331 | | | 0.812 |
| **ShortDarkTetrad_6_MA** | | | | 0.341 | 0.840 |
| **ShortDarkTetrad_7_MA** | | | | | 0.862 |
| **ShortDarkTetrad_8_NA** | -0.327 | | 0.585 | | 0.543 |
| **ShortDarkTetrad_9_NA** | | | 0.442 | 0.415 | 0.491 |
| **ShortDarkTetrad_10_NA** | | | 0.374 | | 0.760 |
| **ShortDarkTetrad_11_NA** | | | 0.493 | | 0.724 |
| **ShortDarkTetrad_12_NA** | | | 0.733 | | 0.489 |
| **ShortDarkTetrad_13_NA** | | | 0.396 | | 0.769 |
| **ShortDarkTetrad_14_NA** | | | 0.374 | | 0.714 |
| **ShortDarkTetrad_15_PSY** | | 0.399 | | 0.481 | 0.563 |
| **ShortDarkTetrad_16_PSY** | | 0.704 | | | 0.434 |
| **ShortDarkTetrad_17_PSY** | | 0.714 | | | 0.449 |
| **ShortDarkTetrad_18_PSY** | | | | | 0.892 |
| **ShortDarkTetrad_19_PSY** | | 0.534 | | | 0.538 |
| **ShortDarkTetrad_20_PSY** | | 0.628 | | | 0.549 |
| **ShortDarkTetrad_21_PSY** | | | 0.325 | | 0.673 |
| **ShortDarkTetrad_22_SAD** | 0.694 | | | | 0.377 |
| **ShortDarkTetrad_23_SAD** | 0.672 | | | | 0.526 |

| | | | | |
|---|---|---|---|---|
| **ShortDarkTetrad_24_SAD** | 0.447 | | | 0.686 |
| **ShortDarkTetrad_25_SAD** | 0.724 | | | 0.384 |
| **ShortDarkTetrad_26_SAD** | 0.454 | | | 0.596 |
| **ShortDarkTetrad_27_SAD** | | | 0.344 | 0.575 |
| **ShortDarkTetrad_28_SAD** | | 0.624 | 0.368 | 0.316 |

*Note.* 'Principal axis factoring' extraction method was used in combination with an 'oblimin' rotation. $KMO = .630$, $\chi^2(378) = 751$, $p < .001$

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