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Quantifying the Relations among Neurophysiological Responses, Dimensional Psychopathology, and Personality Traits.

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QUANTIFYING THE RELATIONS AMONG NEUROPHYSIOLOGICAL RESPONSES, DIMENSIONAL PSYCHOPATHOLOGY, AND PERSONALITY TRAITS

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ABSTRACT

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The Research Domain Criteria (RDoC) model, one of the transdiagnostic dimensional models of psychopathology proposed by the National Institute of Mental Health, emphasizes the integration of basic biological science into clinical research. The event-related negativity (ERN), a deflection in electroencephalogram after making an error, is a promising neurophysiological indicator for such endeavor. However, RDoC model posits that ERN is related to three of the five broad dimensions without any indication of how ERN relates differently across the dimensions. Recent research indicate that ERNs elicited from different tasks do not elicit the exact same ERNs. Therefore, constructing theoretically guided tasks and contextualizing them with other indicators may provide a promising avenue for the better integration of ERN into the RDoC framework. Four flanker tasks using different types of stimuli were constructed. The three RDoC domains posited to be indicated by ERNs also have only a few or no hypothesized self-report indicators. In this study, the five-factor model (FFM) of personality and three dimensional psychopathological models that matched the description of the RDoC domain were used as self-report indicator of the domains. The results indicated that the ERNs elicited from the tasks could be explained by one underlying general ERN. However, the tasks also seem to have task-specific variances and are important. Although general and task-specific ERNs may have different patterns in relationships with self-reported traits, these were generally small and did not have the expected pattern.

Interpretation of these relationships, limitations, and future directions are also discussed.

INTRODUCTION

Mental disorders are highly prevalent and costly to our society. The lifetime prevalence is estimated to be 46% of the population and the total direct and indirect cost is conservatively estimated to be $317.6 billion per year (Kessler, Chiu, Demler, & Walters, 2005; National Institute of Mental Health, 2015). Identifying the underlying causes and structures of psychopathology is essential for effective diagnosis and improving treatments. However, such efforts may have been hampered by the reliance on the categorical diagnostic system currently used for research and practice (American Psychiatric Association, 2013; Widiger & Clark, 2000). Empirical evidence suggests that psychopathology is better articulated by transdiagnostic dimensions that cut across traditional categories (Krueger, Markon, Patrick, Benning, & Kramer, 2007; Widiger & Trull, 2007). The Research Domain Criteria (RDoC) model proposed by the National Institute of Mental Health employs one such dimensional approach and employs multiple units of analyses to integrate biological sciences with clinical research in order to better understand the nature of psychopathology (Cuthbert & Insel, 2013; Insel et al., 2010).

A promising neurophysiological indicator for such an endeavor is the error-related negativity (ERN; Olvet & Hajcak, 2008). The ERN is a negative deflection of the event-related potential that occurs approximately 50 to 100 ms after the commission of an error and is thought to reflect automatic preconscious error detection that originates from the anterior cingulate cortex. Abnormal ERN amplitudes have been related to several mental disorders and their relevance to RDoC is evident in its designation as an indicator at the physiological unit of analysis for three of the five domains: Negative Valence (NVS; Sustained Threat construct), Positive Valence (PVS; Reward Learning construct), and

Cognitive Systems (CS; Performance Monitoring construct). However, the specific relationships among ERN and these three RDoC domains are unclear.

Past research suggests that ERNs represent trait-like individual differences in threat sensitivity (Weinberg, Riesel, & Hajcak, 2011). However, the majority of these studies have used a single task within each study to elicit an ERN under the assumption of ERNs as invariable across tasks. To the contrary, among the three common tasks that have been used to elicit ERNs (i.e., arrow flanker, Stroop, and Go/No-Go tasks), only a few studies have utilized more than one task, but, when compared, the elicited ERNs only share about 9 to 44% of variance (Riesel, Weinberg, Endrass, Meyer, & Hajcak, 2013). This implies the existence of general and task-specific ERNs. However, the properties of task-specific ERNs are not known. Contextualizing these ERNs by identifying such properties could clarify the representation of the ERN in three RDoC constructs. Specifically, task-specific variances of the ERN may differentially relate to RDoC constructs. Of particular interest are the ERNs elicited by interpersonal and emotional stimuli because contexts invoked by such stimuli are relevant to many mental disorders. Selecting stimuli by using known properties of personality traits and psychopathology dimensions also allow for generating theoretically-informed hypotheses on the relationships between ERNs and cross-cutting dimensions. For example, the ERN variances of a flanker task using letters of the alphabet did not relate to psychopathic trait while the same task using facial expressions as stimuli did (Munro et al., 2007). The results of the present project were expected to 1) demonstrate that the tasks modulated the ERNs elicited and 2) contextualize the properties of the general and task-specific ERNs.

The five-factor model (FFM) provides a compelling framework for contextualizing ERNs. The FFM is a well-validated, comprehensive dimensional personality model that emerged from basic personality research (Digman, 1990; McCrae & Costa, 2010). It consists of five broad domains that have well-documented relationships to mental disorders and human behaviors, including interpersonal and emotional behaviors (Ozer & Benet-Martínez, 2006). Specifically, FFM Conscientiousness (C) relates to occupational and academic performance, FFM Extraversion (E) and Agreeableness (A) relate to social processes and outcomes, FFM Neuroticism (N) relates to vulnerability to negative affect, FFM E relates to tendency to experience positive affect (Ozer & Benet-Martínez, 2006; Watson & Clark, 1992). The FFM also has emerged as a viable foundation for psychopathology classification and research (e.g., Widiger & Trull, 2007). In addition, using the FFM has the advantage of integrating its rich research literature (e.g., relatively well-understood developmental patterns) into psychopathology research (Watson & Clark, 1992; Widiger & Trull, 2007). It is noteworthy that some of the FFM domains are conceptually similar to the RDoC domains. For example, both RDoC NVS and FFM N emphasize negative emotions, such as fear, distress, and aggression (McCrae & Costa, 2010; Sanislow et al., 2010). Both RDoC PVS and FFM E emphasize positive emotions and the RDoC proposal group explicitly state their similarities (Sanislow et al., 2010). The present project aimed to identify the properties of the general and task-specific ERNs by using the known relationships between FFM and behaviors, especially interpersonal and emotional behaviors, and other relevant psychopathology measures.

Only a handful of studies have examined the relationships of personality traits to ERNs. In general, traits that fall under the umbrella of FFM N relate to larger ERNs (Luu, Collins, & Tucker, 2000). Personality traits also seem to moderate motivation or salience of tasks, which in turn appears to affect ERN amplitudes (Pailing & Segalowitz, 2004). Since ERNs are thought to reflect threat sensitivity, engagement may be key to larger ERN amplitude (Luu et al., 2000; Tops, Boksem, Wester, Lorist, & Meijman, 2006). In other words, ERN amplitude could be stronger as tasks are more relevant to the individual as indicated by one’s personality traits. However, most past studies have used only a single task to elicit an ERN. The two studies that examined the unique properties of ERNs elicited by two different tasks suggest that task-specific ERNs are related to traits (Foti, Kotov, & Hajcak, 2013; Munro et al., 2007). However, no research has simultaneously used a comprehensive FFM measure, a sample size larger than 50, and more than two tasks to elicit ERNs.

The FFM domains are also known to have unique relationships to many psychopathology constructs (Kotov, Gamez, Schmidt, & Watson, 2010; Miller, Lynam, & Jones, 2008) that have been related to ERNs. Specifically, the ERN has been related to the higher-order externalizing (Hall, Bernat, & Patrick, 2007) and internalizing (Weinberg, Kotov, & Proudfit, 2014) spectra of psychopathology, as well as several specific disorders, such as substance use (Franken, van Strien, Franzek, & van de Wetering, 2007), depression (Chiu & Deldin, 2007), anxiety (Proudfit, Inzlicht, & Mennin, 2013), and obsessive-compulsive disorder (Hajcak & Simons, 2002). Within the RDoC framework, a self-report measure was listed only for Performance Monitoring (i.e., Yale-Brown Obsessive Compulsive Scale) that has been related to an ERN (Riesel, Endrass, Kaufmann, & Kathmann, 2011). However, RDoC did not recommend any specific self-report measures for the Sustained Threat and Reward Learning constructs in 2016 when this project was proposed, and still does not for Reward Learning in their most recently updated version (National Institute of Mental Health, 2018). Past studies and RDoC construct descriptions suggest that RDoC Sustained Threat is likely related to global perceived stress, to FFM N, and inversely to well-being, RDoC Reward Learning is likely related to substance use (Hyman, Malenka, & Nestler, 2006), to FFM E, and inversely to depression (Vrieze et al., 2013).

In this project, I constructed three flanker tasks to elicit ERNs that were hypothesized to invoke interpersonal, negatively emotional, and positively emotional contexts. These were all picture-based tasks and each had two types of stimuli. First, the Interpersonal task was a modification of the task used by Munro and colleagues (2007). However, instead of using angry and fearful faces that could also convey negatively emotional context, I modified this task by only using pictures of neutral faces. The instructions for the participants were to identify, of the three pictures presented horizontally, whether the picture in the center was upright or inversed on each trial. Second, the Negative task was constructed using the pictures from the International Affective Pictures System (IAPS; Lang Bradly, Cuthbert, 2005) that have been rated as negative. The other type of stimuli was pictures from the IAPS that were rated as neutral. Participants were instructed to identify whether the center picture (of the three) was negative or neutral. The Positive task was essentially the same task as the Negative task, except that pictures used were rated as positive or neutral. Finally, I used the arrow flanker task as a reference to the previous studies as it has been found to have the best psychometric properties among tasks used to elicit ERNs (Riesel, et al., 2013). The stimuli themselves (i.e., arrows) in this task were not considered to add any personality-relevant context to the task.

Hypotheses

By identifying the properties of the general and task-specific ERNs, the designated indicator at the physiological units of analysis for three RDoC constructs, the present project examined whether the ERNs elicited by different tasks meaningfully varied. Linking ERNs to the FFM would also provided opportunities for the integration of the rich FFM research literature with ERN and RDoC literature. These findings were further expected to contribute to the refinement and better understanding of the RDoC model. I had two specific sets of hypotheses.

First, I hypothesized that all ERNs elicited within the same task would be unidimensional. This was conducted by dividing the 300 ERPs elicited within one task into five temporally defined units (e.g., first 60 trials, second 60 trials). This tested the assumption that ERNs elicited within a task covary by examining if a single latent ERN could explain the ERN covariances throughout the task. If the ERNs do not covary in such a way, it implies that other processes may be involved across different phases of the task (e.g., learning-related processes contribute stronger in early phases of the task or fatigue-related processes contribute stronger in later phases of the task than the error-monitoring process that ERN is hypothesized to reflect). If the unit ERNs are not unitary, this indicates the need for a closer examination of the common practice of calculating the grand average of the ERPs from all trails within a task (Luck, 2012). Such practice assumes that fluctuations within a task are due to error or processes not central to the

ERP of interest that would cancel out by averaging all trials. The examination of such psychometric properties of ERNs and testing of the structure of ERNs are essential for their use as indicators of individual differences. These hypotheses were conceptualized in a confirmatory factor analysis (CFA) framework.

I further hypothesized that these task-specific ERNs could in turn be explained by yet another general ERN underlying the tasks. In other words, I hypothesized that ERNs elicited by the different flanker tasks have something in common (e.g., the flanker task itself and the error-monitoring process that it assesses). If these tasks do not covary in a way that reflects a latent construct across tasks, it directly challenges the previously held assumption that ERNs are invariant across task and instead indicate that stimuli may have to do more to elicit ERNs than the task format (Riesel et al., 2013). This hypothesis was to be tested by combining all the CFA models and adding a higher-order latent construct. In other words, the model tested if a single general ERN could explain the intermediate task-specific ERNs that in turn explained the covariances across units within each task. A conceptual model that summarizes the final hypothesized model is provided in Figure 1. In sum, the first set of hypotheses were generated by the assumptions that ERNs are invariant within as well as across tasks.

The second set of hypotheses regarded the relationships of the task-specific and general ERNs with personality traits as well as pathological dimensions. Generally, I hypothesized that the task-specific ERNs and general ERNs will have different relationships with different personality traits as well as pathological dimensions. The specific hypothesized relationships were derived from the known properties of the traits and dimensions (e.g., Ozer & Benet-Martínez, 2006) and the context that the stimuli were designed to evoke. Specifically, I hypothesized that FFM N will correlate stronger with General and Negative ERNs because ERN have been often related to depression- and anxiety-related constructs (e.g., Weinberg, et al., 2012) and FFM N have been linked to vulnerability to negative affect. I also hypothesized that FFM E, that have been related to tendency to experience positive affect, and related traits (e.g., Detachment, Drug Use) would correlate stronger with Positive ERN. I further hypothesized that the FFM E and A (the two traits considered to be the interpersonal traits; McCrae and Costa, 1989) as well as the related traits (e.g., Antagonism, Callous Aggression, Detachment) would correlate stronger with Interpersonal ERN. Finally, I hypothesized that FFM C and related traits (e.g., Disinhibition) would correlate stronger with Arrow ERN than other tasks. This is because I hypothesized that the lack of personality-relevant stimuli will make this task most relevant to the pure motivation to do well on a menial non self-relevant task, which is thought to be captured by FFM C-related traits. Based on their conceptual descriptions and similarities to FFM domains, I hypothesized that RDoC Sustained Threat measures would relate to General and Negative ERNs, RDoC Reward Learning measures would relate to Positive and Interpersonal ERNs, and RDoC Performance monitoring measures would relate to Arrow ERN. All of these relationships were hypothesized within a structural equation modeling (SEM) framework. A conceptual model that summarizes these relationships is provided in Figure 2.

To test the hypotheses, the paths of the latent ERNs in the higher-order model of the ERNs (i.e., task-specific and general latent ERN) with the personality traits and pathological dimensions were to be estimated separately for each trait and dimension. The significance and the effect sizes of the paths between the hypothesized specific ERN and trait/dimension relationships explicated above were the interest of this set of hypotheses. I also conducted additional analyses prior to arriving to these specific hypotheses. Specifically, I examined the zero-order correlations of the observed scores among ERNs, personality traits, and pathological dimensions. I also correlated the latent scores saved from the CFAs conducted for each model separately. These were conducted to provide context as to whether the observed relationships were due to the specific statistical method taken to reach the final model used for testing the hypotheses.

A power analysis using the SEM framework, archival data of the Arrow task, and archival data using domain scores from a shorter FFM measures (i.e., the Five-Factor Model; Rating Form; Mullins-Sweatt, Jamerson, Samuel, Olson, & Widiger, 2006) indicated that I would need 124 participants to detect the ERN higher order structure as well as the SEM path coefficients of interest. In addition, due to the multiple comparisons that were to be conducted, I used a conservative $p < .001$ as an indicator of significance for the significance testing (i.e., equivalent to Bonferroni adjustment for 50 comparisons).

METHODS

Participants

A total of 99 undergraduate students participated in this study for course credit. Only participants who endorsed lifetime psychotherapy or pharmacotherapy for mental illness on a prescreening measure at the start of each semester were allowed to participate in the present project. Two participants were excluded because they could not complete the laboratory tasks due to technical issues. For one participant, the incorrect version of the Arrow task was administered, but the data from the rest of the protocol were administered correctly and thus included in the analyses. Four participants were excluded due to answering incorrectly to more than half of the validity items (four out of six) embedded within the self-report questionnaires. Therefore, the final sample consisted of 93 participants (Mean age = 19.18; 78% White, 14% Asian, 1% Black or African American, 1% American Indian or Alaskan Native, 5% Multi-racial; 4% Hispanic or Latino/a; 59% Female).

Laboratory Tasks

Arrow Flanker Task

An arrow flanker task (Eriksen & Eriksen, 1974) was used to elicit the ERNs as commonly examined (Endrass et al., 2010; Olvet & Hajcak, 2008). On each trial, five arrowheads were presented in the center of the screen and participants were instructed to respond to the direction of the center arrowhead. There were four equiprobable stimuli: two compatible (<<<<< or >>>>>) and two incompatible (<<><< or >><>>). Ten blocks of 30 trials were used (i.e., 300 trials total). The initial presentation time of the stimuli was 200 ms and was adjusted after each block, including the practice block, to keep the accuracy for each participant between 75-90% (i.e., presentation time were lengthened 20ms to increase accuracy and shortened 20ms to decrease accuracy). Compared to Stroop and Go/No-Go tasks, this task elicited highly stable ERNs over the course of the task and made it an ideal task to identify its ERN's relationships with personality traits (Meyer, Riesel, & Proudfit, 2013).

Interpersonal Flanker Task

Pictures of faces with neutral expressions were used to elicit ERNs in an interpersonal context. This task was based on a task that related ERNs to psychopathy (Munro et al., 2007), but was modified to remove emotionality (i.e., angry and fearful faces). Such emotionality was the target of the two tasks described below. On each trial, three gray-scaled pictures were presented in the center of the screen and participants were instructed to identify the orientation of the center picture. The initial stimuli presentation time was longer (i.e., 400 ms) than the arrow flanker task to accommodate the increased stimuli complexity as was done in Munro et al. (2007). The same stimuli presentation time adjustment algorithm was used as the arrow flanker task, except the adjustments were made in 40ms increments to reflect the initial presentation time difference. There were four equiprobable stimuli: two compatible (i.e., upright-upright-upright faces or inverted-inverted-inverted faces of the same actor) and two incompatible (i.e., inverted-upright-inverted faces or upright-inverted-upright faces of the same actor). The stimuli were drawn from the NimStim Face Stimuli Set (Tottenham et al., 2009). The catalog numbers of the pictures used in this task are listed in Table 1.

Negative Emotionality Flanker Task

A negative emotionality flanker task was used to elicit ERNs using pictures with negative and neutral emotional valence. On each trial, three gray-scaled pictures were presented in the center of the screen and participants were instructed to categorize the picture of the center picture by valence. The same initial stimuli presentation time (i.e., 400ms) and stimuli presentation time adjustment algorithm as the interpersonal flanker task were used. There were four equiprobable stimuli: two compatible (i.e., negative-negative-negative or neutral-neutral-neutral images) and two incompatible (i.e., neutral-negative-neutral images or negative-neutral-negative images). Within a trial, the same picture was used for the same valence (e.g., pictures of guns on both sides of a picture of a house in a negative-neutral-negative trial). The present study used stimuli from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2005). The catalog numbers of the 25 pictures used in this task are listed in Table 1.

Positive Emotionality Flanker Task

A positive emotionality flanker task was used to elicit ERNs using pictures with positive and neutral emotional valence. The procedure was exactly the same as the negative emotionality flanker task, except negative images was replaced with positive images from the International Affective Picture System (Lang et al., 2005). The catalog numbers of the 25 pictures used in this task are listed in Table 1.

Task Order

The Arrow flanker task was always administered first. The order of task administration of the remaining three tasks was randomized for each participant.

ERP Data Recording and Processing

While participants performed the laboratory tasks, the continuous EEG signal were recorded from 64 Ag/AgCl active scalp electrodes using the actiCAP and actiCHamp system (Brain Products). The signal were digitized at 24-bit resolution with a sampling rate of 500 Hz, and electrode impedances were kept below 30 kOhm. Off-line analysis were performed in Brain Vision Analyzer Software (Brain Products). All data were re-referenced to the averaged mastoid and band-pass filtered with cutoffs of 0.1 to 30 Hz. The signal were segmented at -400 to 800 ms surrounding behavioral response for ERN. Data were corrected for blinks and eye movements using a regression based method (Gratton, Coles, & Donchin, 1983), and artifacts were rejected using a semi-automated procedure and visual inspection. ERNs were averaged separately for each task and baseline corrected (-400 to -200 ms). ERNs were scored as the differences in mean activity between correct and error trials at 10-110 ms on error trials at FC1. The time window and electrode location were chosen to maximize the consistency across tasks in capturing the ERN at its maximal time and location (Figure 3).

Self-Report Measures

General FFM Measure

General personality traits were assessed using the International Personality Item Pool-NEO (IPIP-NEO; Goldberg, 1999). The IPIP-NEO is a 120-item self-report measure that assesses the five broad domains and the 30 facets of the FFM. Each facet is assessed by four items and each domain is assessed by 24 items.

Maladaptive FFM Measure

Maladaptive personality traits were assessed using a shortened version of the Personality Inventory for DSM-5 (Krueger, Derringer, Markon, Watson, & Skodol, 2012; Maples et al., 2015). The shortened PID-5 assesses the five broad domains (Negative Affectivity, Detachment, Psychoticism, Antagonism, Disinhibition) and the 25 finer facets. Each facet is assessed by four items and the number of facets underlying each domain vary across domains. The exact specification is given in Maples et al. (2015). Evidence suggests that four of the five PID-5 domains share the same latent constructs as FFM measures, including the IPIP-NEO (Suzuki, Griffin, & Samuel, 2016; Suzuki, Samuel, Pahlen, & Krueger, 2015).

Externalizing Behavior Measure

The 100-item version of the Externalizing Spectrum Inventory (ESI; Hall et al., 2007; Krueger et al., 2007) was used to assess the general externalizing behaviors and the 23 specific externalizing traits (e.g., Alcohol Use, Drug Use).

Internalizing Behavior Measure

The Inventory of Depression and Anxiety Symptoms (IDAS; Watson et al., 2007) was used to assess the broad internalizing behaviors. The IDAS is a 64-item self-report measure that assesses two broad internalizing tendencies (General Depression and Dysphoria) and 10 specific internalizing traits (e.g., Social Anxiety, Well-Being).

RDoC Dimensions

RDoC dimensions often lacked specific self-report measures. Therefore, personality traits and pathological dimensions with the closest descriptions were used to assess each relevant RDoC dimension. Specifically, sustained Threat was assessed by

FFM N and low IDAS Well-Being. Reward Learning was assessed by FFM E, 100-ESI Alcohol Use and Drug Use, and low IDAS General Depression. Performance Monitoring was hypothesized to be captured by FFM C. Although the multiple traits and dimensions were used to assess RDoC dimensions, they were analyzed separately. I made this decision because the RDoC dimensions descriptions that I based the personality traits and pathological dimensions to use were tentative. If different relationships emerge, examining different aspects of the RDoC dimensions could aid in the refinement of the RDoC dimension descriptions and understanding.

Analytic Plan

Tasks in which participants performed at less than 70% correct response rate were first removed. Further, outlying trial-by-trial ERP data (i.e., +/- three standard deviations) within each participant, within each task (e.g., only focusing on ERPs from the Arrow task), and within each condition (i.e., ERPs from error and correct trials separately) were excluded (e.g., ERP that was three SD above or below the average of the error trial ERPs within Arrow task for participant 3). After the removal of the outliers, the reaction time (RTs) differences between correct and error trials and compatible and incompatible trials as well as accuracy differences between compatible and incompatible trials were analyzed to examine whether the tasks had the properties expected from traditional flanker tasks.

ERNs were calculated by subtracting the average of the ERP from the remaining correct trials from the average of the ERP from the remaining error trials for each unit separately (e.g., unit 1 was calculated by subtracting the average of correct trial ERPs from the first 60 trials from the average of error trial ERPs in the first 60 trials). Five units were chosen, because the algorithm employed in the tasks, on average, elicited at least six ERNs for each unit, which was more than the minimal five ERNs to be reliable (Foti et al., 2013). After these calculations, between-participant outliers (+/- three standard deviations) for the unit and grand ERNs were excluded. Descriptive statistics of ERNs, personality traits, and pathological dimensions were examined for gross deviation from normality. Correlations among these average scores derived from the observed responses were calculated. This represented a naïve approach to examining the relationships because it has not tested or accounted for the assumption of unidimensionality of each construct.

In order to examine the relationships among the general and task-specific ERNs, confirmatory factor analyses (CFAs) were used. First, the five observed ERN units were specified to load onto task-specific latent ERNs separately (i.e., total of four CFAs). The model fit indices were used as indicators of existence of the latent ERNs. Specifically, general cutoffs used to indicate adequate fit were: comparative fit index (CFI) $\geq .90$, Tucker-Lewis index (TLI) $\geq .90$, and root mean square error of approximation (RMSEA) $\leq .08$ (Hu & Bentler, 1999). The task-specific ERN models identified through CFA were further tested in a single model together to examine whether they loaded onto one higher-order general latent ERN. This higher-order general latent ERN model was compared against a model without any task-specific ERNs (i.e., all ERN units directly loading onto a single general latent ERN) to test the necessity of the intermediate task-specific ERNs. In addition to the three indices explicated above, two indicators were used to test for the necessity of task-specific ERNs: the chi-square differences and change in CFI between the models with and without the task-specific ERNs. If chi-square is statistically significant and change in CFI is larger than .01, the necessity of the tasks-specific ERNs was supported. Single-factor CFAs were conducted for personality traits and pathological dimensions as specified by the measure, as well. For example, the CFA for FFM N constituted examining whether the six FFM N facets as indicated by the model correlated in a way that indicated a single underling latent construct. The latent task-specific ERNs, general ERNs, trait, and dimension scores for each participant were estimated using the regression approach. The zero-order correlations among these latent scores were calculated. This is an improvement to examining the relationships using averaged observed scores, because the assumption of unidimensionality has been tested or accounted for in the values used to calculate the correlations.

Once the unidimensional ERN, personality trait, and pathological dimension structures were identified, the properties of the latent general and the task-specific ERN constructs were examined using structural equation modeling (SEM). Specifically, one of the traits (or dimensions) from the personality (or pathological) measures were added to the model as an additional variable correlating to the general or one of the task-specific ERNs within an SEM framework. The same procedure was repeated for all trait/dimension and ERN combinations to evaluate the specific hypotheses made. Although the correlations calculated at the end of the previous steps reflect the same relationships with varying degrees of assumptions, the analyses conducted at this step were the proposed analyses and reflect the a priori hypotheses made prior to data collection.

All analyses were conducted in R, using the “psych” package for descriptive statistics and correlation analyses, and the “lavaan” package for CFAs and SEM analyses.

For the CFA and SEM analyses, the “mimic = mplus’ option and robust maximum likelihood estimator were used. These settings were chosen to maximize the data usage (i.e., avoid list-wise deletion) and make the analyses robust to deviations from normality. The latent scores were saved using the regression method using the “regression” option in “lavaan”. Also, ERNs are negative values, meaning that a more negative correlation indicates enhanced ERN or “stronger” relationship whereas positive correlation indicates blunted ERN.

RESULTS

All participants performed at above 70% accuracy for the Arrow, Interpersonal, and Negative tasks. For the Positive task, four participants performed below 70% and their data from the Positive task were excluded from further analyses. In addition, three specific ERN data were removed due to the inability to link the behavioral and the ERP data.

The reaction times (RTs) of correct, error, compatible, and incompatible trials; accuracies of overall, compatible trials, and incompatible trials; and the average stimuli presentation times for the fours tasks are presented on Table 2. The RT differences between (1) correct and error trails and (2) compatible and incompatible trials as well as (3) accuracy differences between compatible and incompatible trials for each task were tested to examine whether they showed differences as expected from flanker tasks. All tasks showed expected faster RT on error trials than correct trials and on compatible trials than incompatible trials, except Negative task. As expected, accuracy was higher for compatible trials than incompatible trials in the Arrow and Interpersonal tasks. However, accuracy differences between these trial types were not significant for Negative and Positive tasks ($p = .009$ and $p = .061$, respectively). I further examined the accuracy differences across the tasks. A repeated measures analysis of variance (ANOVA) indicated that at least two tasks statistically significantly differed from each other in accuracy [$F(3, 269) = 43.83$, $p < .001$]. Post-hoc analyses indicated that Arrow task had greater accuracy than the remaining three tasks (all $p < .001$) and these three tasks did not differ from each other

The descriptive statistics and final sample sizes for the unit and overall ERN amplitudes (in microvolts) for the tasks are presented in Table 3, the descriptive statistics for the NEO domain and facets are presented in Table 4, and the descriptive statistics for the pathological dimensions are presented in Table 5. Alpha coefficients of reliability are also presented when calculations were possible. All ERN, FFM, and PID-5 dimensions were within reasonable skew of +/- 2 (Curran, West, & Finch, 1996; Ryu, 2011). All except Arrow task unit 5, Negative task unit 4, and Positive task unit 2 were within reasonable kurtosis of +/- 2. More severe deviations from normality were observed for ESI Irresponsibility, Destructive Aggression, Physical Aggression, Theft, Marijuana problems, and Alcohol problems as well as for IDAS Suicidality. Although transformations to normalize these data were considered, I decided against this in favor of keeping the meaning of the scales consistent with previous literature. In addition, the estimator planned to be used was robust to non-normality (i.e., robust maximum likelihood), so the potential complication in the interpretation of transformed variable did not outweigh the mathematical benefit. I also tested whether the overall ERN amplitudes reported in Table 3 differed across tasks. A repeated measures ANOVA indicated that ERN amplitudes statistically significantly differed [$F(3, 264) = 14.28$, $p < .001$]. However, post-hoc analyses did not identify a single pair that differed in ERN amplitudes (Interpersonal and Positive, $p = .004$; Arrow and Positive, $p = .023$; Interpersonal and Negative, $p = .032$; Arrow and Negative, $p = .10$; other two pairs, $p > .90$). This pattern of non-significant pair-wise relations, but statistical significance using all four tasks, likely indicated that ERN amplitudes from the Arrow and Interpersonal tasks generally had lower amplitude than Negative and Positive tasks.

Observed Score Correlations

The correlations among the average scores of the ERNs, personality traits, and pathological dimensions using the observed scores are presented in Table 6. The ERN average scores correlated at least .50 among themselves, indicating that they are likely assessing similar constructs. The self-report measures generally showed the expected correlation patterns across instruments. For example, FFM Agreeableness (A) and Conscientiousness (C) were consistently negatively correlated with the ESI domains and FFM Neuroticism (N) domain positively correlated with the IDAS domains. FFM and PID-5 generally showed the pattern as indicated in the past (e.g., Suzuki et al., 2016), although Conscientiousness correlated with all five domains. The pathological measures correlated strongly with each other as well.

The correlations of the ERNs with personality traits and pathological dimensions were much less robust and none reached statistical significance. The strongest correlation of ERNs with any of these measures was $r = |.20|$ (Positive task with PID-5 Psychoticism and negatively with PID-5 Negative Affectivity). Focusing on relationships that were hypothesized for the SEM model, the Interpersonal task somewhat related to FFM Extraversion (E) and A ($r = |.10|$) and the Arrow task related to FFM C as expected, although other relationships of similar strength existed. Therefore, the pattern of the correlations for each task (i.e., examining within a column) as well as personality traits (i.e., examining within a row) were not as expected in these exploratory analyses. Perhaps the consistent relationships that can be gleaned from this table are that FFM A related traits (ESI Callousness, PID-5 Antagonism) related to the Negative and Arrows task as well as FFM Openness (O) and Psychoticism related to the Positive task.

Confirmatory Factor Analyses

The correlations across ERN units that were used in the subsequent CFAs and SEM analyses are presented in Table 7. To examine the ERNs as measurement models of individual differences, simple first-order CFAs were conducted for each ERP task. The results are presented in Table 8. The results indicated that the Arrow and Interpersonal tasks had adequate fit. The Negative task had a good fit according to CFI and adequate fit according to TLI, but not according to the RMSEA. None of the fit indices suggested adequate fit for the Positive task. Since the CFAs and SEM analyses that followed required an adequate fitting CFA model of the tasks, I decided to exclude Positive tasks from the remaining analyses. This was based on the observation that this task considerably differed in fit indices from others as well as the lack of one of the effects expected from a flanker task (i.e., accuracy did not differ between the compatible and incompatible trials). Based on these information, this task was likely an anomaly among the four tasks.

At the same time, I explored whether common approaches used in personality research to reach adequate fit could improve the fit of the Positive task ERNs. Specifically, I tried (1) dropping the least loading unit, (2) allowing residual variances covary based on what modification indices suggest, and (3) allowing conceptually similar units (in this case, those close in presentation time) to covary. The fit indices from these analyses are presented in the last three rows of Table 8. The results indicated that the Positive task could be improved to reach good fit. However, no conceptually satisfying relationships emerged from these approaches and thus appeared to capitalize more on chance than on meaningful improvement to the model. Thus, the decision to exclude the Positive ERN from further analyses was retained.

Next, whether the three remaining task-specific ERNs could be explained by one overarching general ERN construct was examined in a higher-order CFA model of the individual units. The results are presented in Table 9. This model resulted in adequate fit, indicating that the latent ERNs of the three tasks could be explained by one underlying latent construct. Because a more complicated model generally fit better, this model was also tested against a simpler, more parsimonious model without any task-specific latent ERNs. Specifically, all ERN units were specified to load onto a single general ERN without any intermediate constructs. If the task-specific latent ERNs are not needed and all ERNs could be explained by a single ERN, then the differences in chi-square and CFI would not be substantial between these models. In other words, the improvement in the model fit was worth the usage of the additional degrees of freedom to explain the more complicated model (i.e., the model with task-specific ERNs). The fit of this model is presented in the second row and the differences in the fit statistics are presented in the bottom row of Table 9. The results indicated that the removal of task-specific ERNs reduced the fit substantially. Therefore, unique ERN variances within each task that are not shared by other tasks existed.

A similar set of analyses were performed for personality traits and pathological dimensions. The results of the CFAs for each FFM domain are presented in Table 10. At the domain level, FFM N had good fit. FFM E had adequate model fit according to CFI, but not according to TLI or RMSEA. FFM O, A, and C did not fit adequately. For these domains, I used the modification indices to allow covariances across facets. This difference in approach of reaching adequate model fit compared to the ERN was based on two primary reasons. First, unlike the ERN models, most of the personality scales did not reach adequate fit and would have resulted in excluding most scales from the analyses if the same approach was taken. Second, the personality and pathological models have stronger theoretical reason and more empirical research indicating that the specified scales tend to covary than there is evidence for the ERN models (for which such literature is lacking). This provided some confidence that I was not capitalizing purely on chance. The results of these modifications are presented in the last four rows of Table 10. Table 11 presents the results of the same set of analyses on the pathological dimensions. PID-5 Psychoticism domain had only three facets, and thus was a just-identified model and no further modification was made. None of the remaining dimensions reached adequate fit without modification and, thus, the modifications were conducted.

Latent Score Correlations

Latent scores based on the simple first-order factor CFAs (only task-specific latent ERNs, personality traits, and pathological dimensions), and higher-order CFA (model with overall/general and intermediate task-specific latent ERNs) that have been conducted thus far were saved. Using these saved scores, the zero-order correlations between the latent scores were calculated (these were exploratory analyses). The results are presented in Tables 12 (FFM traits) and 13 (pathological dimensions). The relationships did not become dramatically stronger from that of the observed scores presented in Table 6, except for a few relationships. Specifically, FFM N and Arrow task correlated a little stronger in the single factor ERN model, all correlations with the Interpersonal task became smaller, and the correlation between FFM A and Negative task diminished. The relationships between the estimated latent scores of ERNs and the pathological dimensions became much stronger compared to the FFM traits, with several reaching correlations of r = .20 or larger. For example, the IDAS and Interpersonal task relationship increased in strength. Interestingly, in contrast to the FFM A trait itself, the A-related traits (ESI Callous Aggression and PID-5 Antagonism) generally correlated with the Arrow and Negative tasks strongly, such that more agreeable individual have enhanced ERNs (and more antagonistic individual have blunted ERNs).

Next, the relationships of ERNs with personality traits and pathological dimensions were examined using SEM. These were the analyses planned a priori and included the specific hypotheses made. This was conducted using the higher-order model for the ERNs with three tasks and one of the personality trait or pathological dimension model. Specifically, these two models were combined while allowing the personality trait or pathological dimension to correlate with one of the latent ERNs (i.e., general, Arrow, Interpersonal, or Negative). The paths between the trait/dimension and ERN that were not of interest for the specific analysis (e.g., when examining the relationship between ERN Arrow and FFM N, the paths from FFM N to ERN Interpersonal, Negative, and general) were restricted to zero. In addition, these correlations were converted from the *t*-values estimated for the SEM path of interest. These combined models generally fit adequately when a personality trait was added (average RMSEA = .047, CFI = .915, TLI = .902), but not when a pathology dimension was added (average RMSEA = .050, CFI = .898, TLI = .884). However, to keep the results comparable to the previous exploratory analyses and to avoid the complication of allowing covariances between non-reasonable variables (e.g., covariance between an ERN unit and a pathological dimension scale), the fit was not further improved for these models. The results for the FFM are presented in Table 14 and results for the pathological dimensions are presented in Table 15. These generally remained similar, but smaller, effects as in the previous analyses. Surprisingly, PID-5 Psychoticism remained related to the Negative task relatively consistently across the analysis methods.

The results thus far have focused on the broader dimensions of personality traits and pathological dimensions. Specific ESI and IDAS traits predicted to reflect RDoC dimensions were also subjected to the same analyses, except that these were single observed scores and no modifications were made. Only the relationships of traits with hypotheses were examined. The results are presented in Table 16 and 17. These facet-level analyses indicate more different relationship patterns than the domain-level analyses did. Specifically, IDAS Well-Being was generally related to the Arrow and Negative tasks whereas ESI Drug Use scale was consistently *not* related to the Negative task, while it tended to relate with the Interpersonal task.

Some post-hoc power analyses were conducted for the zero-order correlations. The achieved power to detect a correlation of $r = .17$ was .38. To detect an $r = .17$ correlation as statistically significant with .80 power, I would have needed 266 participants. Additional power analyses were not conducted for the SEM models because of the complexity of the interpretations across different specifications (e.g., different degrees of freedom and paths for FFM N and E) and because of the negligible value that such analyses would add given the generally similar results with the zero-order correlations.

Summary of the Hypothesis Tests

Two broad sets of hypotheses were made for the present project. The first was that ERN units from a given task tended to go together and the covariances could be explained by the latent task-specific construct. This was supported for Arrow, Interpersonal, and Negative tasks, but not for the Positive task. The follow-up hypothesis was that these task-specific ERNs could be in turn explained by a common underlying general ERN. This was supported when the three tasks that reached adequate fit were modeled. The final model with factor loadings and path coefficients are presented in Figure 4. In sum, most of the first set of hypotheses were supported.

The second broad set of hypotheses predicted the specific relationships of latent ERNs with the latent personality traits and pathological dimensions in SEM framework (Figure 2). The results are presented in Tables 14, 15, and 17 (shaded cells). Because of the lack of fit of the Positive task, this set of hypotheses was slightly modified and could not be tested exactly as was stated a priori. Nonetheless, the path coefficients of the remaining 19 hypotheses ranged from a correlation-equivalent of $r = -.11$ (between Arrow and FFM C) to $r = .11$ (between Negative and IDAS Well Being) and none of the relationships were statistically significant at alpha of .05 even prior to controlling for multiple comparisons. A more liberal interpretation indicated that the relationships between FFM C-related traits and the Arrow task in the direction that were expected. Also, when examining the correlations in context of non-hypothesized correlations, FFM E and Interpersonal task had the strongest correlations with each other than with any other FFM trait or task. Similarly, IDAS Well Being and Negative task had the strongest correlations with each other within Table 17.

DISCUSSION

The fields of clinical psychology and psychiatry are moving away from categorical understanding of mental illness and towards a dimensional conceptualization with multi-method approach. Within this context, better understanding of the neurophysiological processes as well as self-reported traits using each other as contextualizing indicators may aid in our understanding of such transdiagnostic constructs. The current project examined the relationships between a well-studied neurophysiological indicator of error monitoring and self-reported personality traits as well as pathological dimensions. Specifically, the ERN was elicited using four different stimuli that were hypothesized to represent different “contexts” and to modulate the ERNs in theoretically predicted manner. The overall research question was that whether the ERNs elicited from different tasks were eliciting the same or similar ERNs and how they differed. The ERNs were to be contextualized using self-report measures that were designed to capture a wide range of personality and transdiagnostic dimensions. A few caveats should be noted. First, the final sample size was 93, which was less than the number indicated by the power analyses of the hypotheses (124). This lack of sample size likely contributed to the general lack of power as well as correlations not stabilizing. In addition, different analytic approaches were used on the same data to provide context for the hypothesized relationships as well as to provide the current best estimates of the relationships and nuances of ERP and self-reported measures. Although many relationships seem to fluctuate somewhat across the analytic method, these are not independent. Finally, the effect sizes were generally small and none of them were statistically significant. The results should be evaluated with these issues in mind.

The ERN as a Measurement Model

Subjecting the ERNs to CFAs indicated that at least two tasks (Arrow and Interpersonal) elicited ERNs that were clearly consistent across the entirety of the task. The Negative task was adequate. The Positive task, on the other hand, did not do as well when examined as a measurement model. Further, the three task-specific ERNs that fit adequately could be explained by a single underlying ERN. However, a single underlying ERN alone was not sufficient to explain the covariance pattern of the units and the intermediate task-specific ERNs were necessary, indicating meaningful differences across tasks. These indicate that, although all tasks were likely getting to the same process (e.g., error-monitoring), the method used to elicit them mattered. The results support the motivation of this project and provide evidence that researchers should be conscious of the tasks they use and that the relationships of ERNs (and possibly ERPs in general) with external criteria may differ depending on the task they use.

The lack of unidimensional fit of the five units of the Positive task is worth exploring. First, this indicates that not all tasks that have the flanker design work as intended. Therefore, researchers should be conscious of what tasks they use and tasks' psychometric properties. More importantly, this indicates that the psychometric properties of ERP tasks should be evaluated and considered carefully prior to the evaluation of their relationships to external criteria. If new ERP tasks were to be constructed based on traditionally used tasks, findings from further analyses on the Positive task may provide some insight into how they may or may not work. Specifically, some exploratory adjustments to the Positive task model led to adequate fit for this task. However, making sense out of these modifications was difficult. Specifically, the second unit (trials 61through 120) was the only one that did not go along with the other units in the Positive task. Unlike the first or the last unit (e.g., still getting accustomed to the task or fatigue), it is hard to imagine why this particular unit was not correlating with other units as expected from the CFA model. Allowing residual correlations did not provide a discernible pattern either. Therefore, these may simply be due to random error and researchers should be careful when such approach is taken to reach adequate fit. Also, qualitatively, the Positive task was composed of pictures of cute targets (furred animals and babies) and heterosexual erotic pictures. The latter set of pictures may have been perceived by some participants as neutral, instead of positive. Indeed, some participants explicitly stated they did not view the erotic pictures as positive. The analyses on the behavioral data (reaction times and accuracy) indicated that the Positive task had about the same difficulty as the other picture-based tasks. However, it did lack the accuracy differences expected from a flanker task, while the expected reaction time difference was observed. This may indicate that, although having compatible pictures made the task easier to process the three pictures, participants had to really focus on the center picture for incompatible trials and take their time. This difference in the task may have resulted in more error variance that consequently led to the non-expected pattern of covariances across units. Although to a lesser extent, a similar pattern was observed for the Negative tasks, as well. Therefore, judging whether a picture is negatively-valenced or positively-valenced is likely harder than judging whether an arrow is pointing left or right or whether a picture of a face is upright or inverted. This implies that the Positive task was at least different from the other tasks and potentially more complicated than the other tasks. This differences in complication (or whether it was a flanker task) could have influenced whether participants perceived a trial as an error even at the pre-conscious level (e.g., participant did not know that an error was made).

The Relationships of ERNs With Personality Traits and Pathological Dimensions

The relationships between ERN and personality traits as well as pathological dimensions were generally inconclusive. None of the zero-order correlations were statistically significant and the CFAs and SEM analyses did not strengthen the relationships as hoped. The hypothesis-driven analyses indicated that FFM C and PID-5 Disinhibition were the strongest relationships among the relationships hypothesized and both were in the expected directions. Since these effect sizes were small ($|r| = .11$ at most), caution must be taken. However, the long history of Arrow task to elicit ERNs make this finding more important than the other exploratory tasks constructed for this project. Specifically, Suzuki and colleagues (2018) conducted similar latent and correlational analyses using different ERPs, including ERNs from an Arrow task. Using about 160 participants, they found that the ERN was generally *positively* associated with the FFM traits, with the FFM O having the strongest relationship ($r = .16$). FFM C had the weakest relationship ($r = .09$). The correlations in the opposite directions for similar relationships between these two projects may appear puzzling at first. Besides the possibility that the results were due to the error, such difference may be explained by the slight differences in the Arrow tasks that the two projects used. Specifically, in this project, stimuli presentation time was adjusted based on performance, but not in their study. The time adjustment may have made the two tasks sufficiently different enough to achieve different results. Specifically, compared to the other study where presentation time was held constant, the Arrow task in this project was likely more challenging for participants who performed well and was easier for participants who did not perform well. In other words, the task in the other study may have been too easy for higher C participants who lost interest or stopped paying attention, which may have led to the blunted ERN in the their study. Even such slight differences in task construction may contribute to the reversal of the relationship of ERNs to other individual difference indicators. This even further highlights the importance of researchers being conscious of the tasks they use to elicit ERPs.

This was the first study to explore the relationships among multiple ERN tasks and a set of comprehensive self-report measures simultaneously. The results from the present study are the current best estimate and the knowledge we have regarding these nuanced relationships and more liberal and exploratory interpretations context are warranted. The results from the exploratory analyses suggest that Agreeableness-related traits seem to have some consistent relationships with the Arrow and Negative tasks. Although the relationships for the FFM A disappeared when examining the latent relationships, this approach yielded stronger relationships for the pathological traits (ESI Callous Aggression and PID-5 Antagonism), resulting in the largest set of correlations in the present project (above r = .20). Although these were not significant and still relatively small correlations, the consistency across measures may indicate some relationship between Antagonism and ERNs. This may be related to the Negative task including several pictures involving bodily injuries of others and the difficulty to empathize for individuals high on Antagonistic traits. This finding is also consistent with past research indicating that higher externalizing individuals tend to have blunted ERN (Hall, et al., 2007). Combined with the generally weaker association with FFM C and Disinhibition (traits also thought to constitute the externalizing spectrum), the present findings suggest that the relationship between ERN and externalizing traits could be explained specifically by the Antagonism-related traits.

At the same time, it is puzzling to find that the Antagonism-related traits did not relate only to the Interpersonal task. This task was a modification of the task used by Munro and colleagues (2007) that found different relationships with traditional symbol-based flanker (i.e., letters of the alphabet) and the flanker task with facial pictures. However, in this project, the findings were the opposite. One possible explanation for the differences in the relationship with the facial picture task may be due to the content of the facial pictures used. Specifically, Munro and colleagues (2007) used pictures with facial expressions (e.g., angry). In this project, I removed the emotionality implied by the facial task by using neutral pictures and assessed emotionality with the other two tasks (i.e., Negative and Positive tasks). This may indicate that the relationship between ERNs and Antagonism-related traits are moderated by the emotionality of the stimuli rather than the stimuli themselves being faces. Given that Extraversion-related traits did not have as strong relationship with this task either, the influence of interpersonal traits in general may be more subtle or nonexistent at the stage of error-monitoring process that ERNs reflect. Alternatively, the differences in the findings could be due to the task difference of the symbol-based task (i.e., arrows were used in this project). This possibility of different properties among symbol-based tasks may be a potential route for future research to further understand the relationships between ERNs and tasks. At the least, these findings indicate the potential importance of the properties of the stimuli used to elicit ERNs and how decomposition of such properties may inform the processes that ERNs reflect.

Another relatively consistent relationship was that of between PID-5 Psychoticism and the Negative task. This relationship is puzzling but maybe worth investigating further in the future. However, given the generally stronger relationship of the PID-5 domains (including Antagonism) and the ERNs, there may be something about the traits that this measure assesses, or something related to the items or the wording of the measure that made them more relevant to the variances of ERNs. This could be an avenue of continued investigation.

In sum, the ERN tasks have somewhat different personality and pathological profiles. Particularly the Interpersonal task stood out among the tasks used in this project. At the very least, these results add to the literature suggesting that there are task-specific variances in ERNs and that assuming ERNs to be invariable across task is not a good assumption. The results from this project are also our current best estimate of such relationships and how much the tasks make a difference in individual differences research using ERPs.

Limitations

The major limitation of this project is the sample size. CFAs and SEMs are large sample size techniques and we did not reach adequate power to detect the observed zero-order correlations. Collecting ERP data is very labor intensive (e.g., approximately three hours/participant for collecting data for this project) and is limited by equipment (one ERP testing lab used for this study) and research assistant (RA) availabilities (required two RAs to be available during the 2-hour slot). Although all efforts were made to collect as many participants and we had more than 150 slots to collect participants, many participants cancelled at the last minute or did not show up for the study (approximately

75% slot utilization rate). This difficulty and the high risk of examining ERP tasks for the sole purpose of their utility as measurement models may be causing the relative lack of studies examining the relationships between ERPs and dimensional traits. Nonetheless, the results from the current project are the only and best estimates of the relationships among four different ERN tasks and a wide-range of personality traits as well as pathological dimensions using a relatively large sample size.

Relatedly, the achieved power was low. For example, the zero-correlations that provided the most optimistic estimate (r = .23) achieved a power of .61. Sample size needed to detect this effect with a power of .80 was 143. Given the generally low observed correlations (around .20, in which case the required sample size was 191) as well as the number of comparisons that will likely be made in similar analysis of ERNs with comprehensive personality and pathology measures, the number of participants typically used in personality research may be needed. Alternatively, examining the relative strengths of correlations within context of other correlations, as was done with the exploratory part of this project, may be suitable as well. This will require sufficient sample size for all if not most correlations to stabilize. Regardless of the approach taken, sample sizes of 250 or more are necessary (Schönbrodt & Perugini, 2013). Despite this limitation, the sample size of the current project was larger than most ERP research that was reviewed (often around or below 50) and the limitation is an issue with the broader literature than specifically with this project. Although such sample sizes will likely take an intensive data collection (e.g., 20 hours per week for a full year) to reach sufficient sample size, given the correlations found in his project, such approach appears inevitable for a continued investigation of the relationships between ERPs and dimensional personality and pathology.

Also noteworthy is that the power analysis was based on archival data, which only included a (slightly different) Arrow task and did not include the three new tasks. The four ERN models were assumed to have the same properties in the power analysis. Given that the Arrow task had the best psychometric property, this may have led to the overestimation of the power for the paths to be estimated. Also, despite the complexity of the personality and pathology models (e.g., Hopwood and Donnellan, 2010), each trait and dimension was modeled separately. This may have contributed to the generally lower estimation of the paths. Analyses (e.g., exploratory SEM) that account for such nuances of the measures may be worth pursuing in the future. However, comprehensive examination of ERPs is rare and most ERN research reviewed earlier focused on specific traits. The current project provided an opportunity to examine the relative strengths of the relationships by using measures that capture a wide range of personality and pathology.

In addition, the sample used for this project consisted entirely of undergraduate students. Although all participants had some form of treatment history, this may only be a biased sample of the clinical population (e.g., high functioning), the ultimate target population of this line of research and RDoC. Although we examined dimensional constructs that were thought to be relatively immune to this issue (O’Connor, 2002), we can only draw firm and generalizable conclusion regarding clinical phenomena when the entirety of such population is examined.

Finally, there is an obvious potential confound for the need of task-specific ERNs. Each task was administered separately and the higher correlations of units within each task may simply be due to temporal closeness. If the tasks produced clearly different personality profiles, this may have not been an issue. However, since such results were not as clear, the possibility of this confound remains. A potential solution to this issue is to administer the blocks of the four tasks completely randomly in a “single” task. However, that would require giving participants one instruction with four conditions (e.g., if the center arrow is point left, if the center picture is negative, positive, or upright human face, click left on the mouse). This likely will make the task unreasonably complicated and difficult.

Potential Issues of Examining the Relationships Between ERNs and Self-Reported Traits/Dimensions and Future Directions

Potential issues independent of the present project also deserve mention. First, there is likely a ceiling for the correlations that constructs assessed through different methods can achieve. Constructs assessed using different methods are known to relate weaker than those assessed using similar methods (Campbell & Fiske, 1959). For example, meta-analytic evidence (Lauriola, Panno, Levin, & Lejuez, 2014) found that the correlations between self-reported sensation seeking and observed risky behavior (two constructs thought to be highly related) had a small correlation (approximately $r = .14$). In retrospect, given such likely small correlations, CFAs and SEMs (statistical techniques based on correlations) may not have been suitable techniques to examine these particular relationships. Experimenting with other statistical techniques, such as multiple regression (e.g., regressing ERN tasks on personality traits) and multilevel modeling (e.g., nesting tasks within participants), may be worthwhile investigations in the future.

The specificity of the constructs may be another potential issue that caused the small correlations. ERNs are thought to reflect error-monitoring, which is a fairly specific process. On the other hand, the traits and dimensions examined in this project were generally broad. Using much finer traits/dimensions, such as the final sets of analyses examining ESI and IDAS facets, will likely provide stronger relationships and better insight (e.g., Weinberg et al., 2017). A similar thought could be applied to the ERNs. For the tasks that involved pictures, 25 pictures were used. Although the working assumption was that pictures within tasks were equivalent, there may have been variations and individual differences in participant responses across pictures that contributed to variances not accounted by the analyses. For example, within the positive task, there were generally two sets of pictures: cute things and heterosexual erotic pictures. Traits like warmth may have related to the former stronger than the latter and excitement seeking may have related to the latter than the former. Examining such specific relationships may aid in clarifying the puzzling lack of relationship between the two methods that have adequate measurement property.

The stronger correlations of ERNs with pathological dimensions than with personality traits are also an interesting, albeit weak, pattern. One possibility that this pattern indicates is the curvilinear relationship between ERNs and individual differences dimensions. Specifically, the ERNs may be relatively invariable across individuals in the middle, but increase or decrease dramatically only towards the extremes of the spectrum. Visually, putting the individual differences dimension on the vertical axis and the ERNs on the horizontal axis, it will form an “S” or an inverse “S” shape. For example, past studies have found that ERNs are enhanced among individuals who are anxious but blunted among individuals who are depressed (Weinberg, Klein, & Hajcak, 2012) and these two may be getting at two different ends of the “S” curve.

Summary

The current project examined the relationships among ERNs elicited from four flanker tasks that differed in stimuli and their relationships to a broad range of personality traits and pathological dimensions using a relatively larger sample size than previously used. The ERNs generally could be explained by one underlying latent ERN, but also indicated different task-specific ERNs. The relationships to personality traits and pathological dimensions indicate that the relationships are generally small. Although inconclusive, ERNs elicited from different tasks seemed to have different relationships to different traits and dimensions. The latent construct approached worked well to assess the ERNs as measurement models as well as the relationships among ERNs. However, given the small observed correlations, this approach may not be appropriate to estimate paths between ERNs and traits/dimensions within the same analyses or will require larger sample sizes.

ERNs and self-report measures appear to be good measurement models to assess individual differences, providing optimism for some relationships between these two methods of individual difference assessment. This project was novel in that it used four tasks (including two new tasks) that were theoretically constructed, assessed personality and psychopathology comprehensively, and used a relatively large sample size compared to previous research in this area. Future research should examine the utility of other promising statistical and designing approaches to examining the relationship of ERNs with personality traits and pathological dimensions. Further investigation of the ERN task properties and their refinement for better assessment of individual differences will likely benefit the field, as well.

LIST OF REFERENCES

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5.* Washington, DC: American Psychiatric Association.

Campbell, D. T., & Fiske, D. W. (1959). Convergent and discriminant validation by the multitrait-multimethod matrix. *Psychological Bulletin*, *56*, 81-105. doi:10.1037/h0046016

Chiu, P. H., & Deldin, P. J. (2007). Neural evidence for enhanced error detection in major depressive disorder. *American Journal of Psychiatry*, *164*, 608-616. doi:10.1176/ajp.2007.164.4.608

Curran, P. J., West, S. G., & Finch, J. F. (1996). The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychological Methods, 1*, 16-29. doi:10.1037/1082-989X.1.1.16

Cuthbert, B. N., & Insel, T. R. (2013). Toward the future of psychiatric diagnosis: The seven pillars of RDoC. *BMC Medicine*, *11*, 126. doi:10.1186/1741-7015-11-126

Digman, J. M. (1990). Personality structure: Emergence of the five-factor model. *Annual Review of Psychology*, *41*, 417-440.

Endrass, T., Schuermann, B., Kaufmann, C., Spielberg, R., Kniesche, R., & Kathmann, N. (2010). Performance monitoring and error significance in patients with obsessive-compulsive disorder. *Biological Psychology*, *84*, 257-263. doi:10.1016/j.biopsycho.2010.02.002

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, *16*, 143-149. doi:10.3758/BF03203267

Foti, D., Kotov, R., & Hajcak, G. (2013). Psychometric considerations in using error-related brain activity as a biomarker in psychotic disorders. *Journal of Abnormal Psychology*, *122*, 520-531. doi:10.1037/a0032618

Franken, I. H. A., van Strien, J. W., Franzek, E. J., & van de Wetering, B. J. (2007). Error-processing deficits in patients with cocaine dependence. *Biological Psychology*, *75*, 45-51. doi:10.1016/j.biopsycho.2006.11.003

Goldberg, L. R. (1999). A broad-bandwidth, public domain, personality inventory measuring the lower-level facets of several five-factor models. *Personality Psychology in Europe*, *7*, 7-28.

Gratton, G., Coles, M. G. H., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology*, *55*, 468-484. doi:10.1016/0013-4694(83)90135-9

Hajcak, G., & Simons, R. F. (2002). Error-related brain activity in obsessive–compulsive undergraduates. *Psychiatry Research*, *110*, 63-72. doi:10.1016/S0165-1781(02)00034-3

Hall, J. R., Bernat, E. M., & Patrick, C. J. (2007). Externalizing psychopathology and the error-related negativity. *Psychological Science*, *18*, 326-333. doi:10.1111/j.1467-9280.2007.01899.x

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*, 1-55. doi:10.1080/10705519909540118

Hyman, S. E., Malenka, R. C., & Nestler, E. J. (2006). Neural mechanisms of addiction: The role of reward-related learning and memory. *Annual Review of Neuroscience*, *29*, 565-598. doi:10.1146/annurev.neuro.29.051605.113009

Insel, T., Cuthbert, B., Garvey, M., Heinssen, R., Pine, D. S., Quinn, K., . . . Wang, P. (2010). Research Domain Criteria (RDoC): Toward a new classification framework for research on mental disorders. *The American Journal of Psychiatry*, *167*, 748-751. doi: 10.1176/appi.ajp.2010.09091379

Kessler, R. C., Chiu, W. T., Demler, O., & Walters, E. E. (2005). Prevalence, severity, and comorbidity of 12-month dsm-iv disorders in the national comorbidity survey replication. *Archives of General Psychiatry*, *62*, 617-627. doi:10.1001/archpsyc.62.6.617

Kotov, R., Gamez, W., Schmidt, F., & Watson, D. (2010). Linking "big" personality traits to anxiety, depressive, and substance use disorders: A meta-analysis. *Psychological Bulletin*, *136*, 768-821. doi:10.1037/a0020327

Krueger, R. F., Derringer, J., Markon, K. E., Watson, D., & Skodol, A. E. (2012). Initial construction of a maladaptive personality trait model and inventory for DSM-5. *Psychological Medicine*, *42*, 1879-1890. doi:10.1017/S0033291711002674

Krueger, R. F., Markon, K. E., Patrick, C. J., Benning, S. D., & Kramer, M. D. (2007). Linking antisocial behavior, substance use, and personality: An integrative quantitative model of the adult externalizing spectrum. *Journal of Abnormal Psychology, 116*, 645-666. doi:10.1037/0021-843X.116.4.645

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2005). *International affective picture system (IAPS): Technical manual and affective ratings*. Gainesville, FL: University of Florida.

Lauriola, M., Panno, A., Levin, I. P., & Lejuez, C. W. (2014). Individual differences in risky decision making: A meta-analysis of sensation seeking and impulsivity with the balloon analogue risk task. *Journal of Behavioral Decision Making*, *27*, 20-36. doi:10.1002/bdm.1784

Luu, P., Collins, P., & Tucker, D. M. (2000). Mood, personality, and self-monitoring: Negative affect and emotionality in relation to frontal lobe mechanisms of error monitoring. *Journal of Experimental Psychology: General*, *129*, 43-60. doi:10.1037/0096-3445.129.1.43

Maples, J. L., Carter, N. T., Few, L. R., Crego, C., Gore, W. L., Samuel, D. B., . . . Miller, J. D. (2015). Testing whether the DSM-5 personality disorder trait model can be measured with a reduced set of items: An item response theory investigation of the personality inventory for DSM-5. *Psychological Assessment*, *27*, 1195-1210. doi:10.1037/pas0000120

McCrae, R. R., & Costa, P. T. (1989). The structure of interpersonal traits: Wiggins's circumplex and the five-factor model. *Journal of Personality and Social Psychology*, *56*, 586-595. doi:10.1037/0022-3514.56.4.586

McCrae, R. R., & Costa, P. T. (2010). *NEO Inventories for the NEO personality inventory-3 (NEO PI-3), NEO Five-Factor inventory-3 (NEO-FFI-3) and NEO personality inventory-revised (NEO PI-R): Professional manual*. Odessa, FL: Psychological Assessment Resources.

Meyer, A., Riesel, A., & Proudfit, G. H. (2013). Reliability of the ERN across multiple tasks as a function of increasing errors. *Psychophysiology*, *50*, 1220-1225. doi:10.1111/psyp.12132

Miller, J. D., Lynam, D. R., & Jones, S. (2008). Externalizing behavior through the lens of the Five-Factor Model: A focus on agreeableness and conscientiousness. *Journal of Personality Assessment*, *90*, 158-164. doi:10.1080/00223890701845245

Munro, G. E. S., Dywan, J., Harris, G. T., McKee, S., Unsal, A., & Segalowitz, S. J. (2007). ERN varies with degree of psychopathy in an emotion discrimination task. *Biological Psychology, 76*, 31-42. doi:10.1016/j.biopsycho.2007.05.004

National Institute of Mental Health. (2015, January 15). *Annual total direct and indirect costs of serious mental illness* (2002). Retrieved from http://www.nimh.nih.gov/health/statistics/cost/index.shtml

National Institute of Mental Health. (2018, May 30). *NIMH » RDoC matri*x. Retrieved May 30, 2018, from https://www.nimh.nih.gov/research-priorities/rdoc/constructs/rdoc-matrix.shtml

O'Connor, B. P. (2002). The search for dimensional structure differences between normality and abnormality: A statistical review of published data on personality and psychopathology. *Journal of Personality and Social Psychology, 83*, 962-982. doi:10.1037/0022-3514.83.4.962

Olvet, D. M., & Hajcak, G. (2008). The error-related negativity (ERN) and psychopathology: Toward an endophenotype. *Clinical Psychology Review, 28,* 1343-1354. doi:10.1016/j.cpr.2008.07.003

Ozer, D. J., & Benet-Martínez, V. (2006). Personality and the prediction of consequential outcomes. *Annual Review of Psychology*, *57*, 401-421. doi:10.1146/annurev.psych.57.102904.190127

Pailing, P. E., & Segalowitz, S. J. (2004). The error-related negativity as a state and trait measure: Motivation, personality, and ERPs in response to errors. *Psychophysiology*, *41*, 84-95. doi:10.1111/1469-8986.00124

Proudfit, G. H., Inzlicht, M., & Mennin, D. (2013). Anxiety and error monitoring: The importance of motivation and emotion. *Frontiers in Human Neuroscience*, *7*, 636. doi:10.3389/fnhum.2013.00636

Riesel, A., Endrass, T., Kaufmann, C., & Kathmann, N. (2011). Overactive error-related brain activity as a candidate endophenotype for obsessive-compulsive disorder: Evidence from unaffected first-degree relatives. *American Journal of Psychiatry*, *168*, 317-324. doi:10.1176/appi.ajp.2010.10030416

Riesel, A., Weinberg, A., Endrass, T., Meyer, A., & Hajcak, G. (2013). The ERN is the ERN is the ERN? Convergent validity of error-related brain activity across different tasks. *Biological Psychology*, *93*, 377-385. doi:10.1016/j.biopsycho.2013.04.007

Sanislow, C. A., Pine, D. S., Quinn, K. J., Kozak, M. J., Garvey, M. A., Heinssen, R. K., . . . Cuthbert, B. N. (2010). Developing constructs for psychopathology research: Research domain criteria. *Journal of Abnormal Psychology*, *119*, 631-639. doi:10.1037/a0020909

Schönbrodt, F. D., & Perugini, M. (2013). At what sample size do correlations stabilize? *Journal of Research in Personality, 4*7, 609-612. doi: 10.1016/j.jrp.2013.05.009

Suzuki, T., Griffin, S. A., & Samuel, D. B. (2016). Capturing the DSM-5 Alternative Personality Disorder Model traits in the Five-Factor Model's nomological net. *Journal of Personality, 85*(2), 220-231. doi:10.1111/jopy.12235

Suzuki, T., Samuel, D. B., Pahlen, S., & Krueger, R. F. (2015). DSM-5 Alternative Personality Disorder Model traits as maladaptive extreme variants of the Five-Factor Model: An item-response theory analysis. *Journal of Abnormal Psychology*, *124*, 343-354. doi:10.1037/abn0000035

Tops, M., Boksem, M. A. S., Wester, A. E., Lorist, M. M., & Meijman, T. F. (2006). Task engagement and the relationships between the error-related negativity, agreeableness, behavioral shame proneness and cortisol. *Psychoneuroendocrinology*, *31*, 847-858. doi:10.1016/j.psyneuen.2006.04.001

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., . . . Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, *168*, 242-249. doi:10.1016/j.psychres.2008.05.006

Vrieze, E., Pizzagalli, D. A., Demyttenaere, K., Hompes, T., Sienaert, P., de Boer, P., . . . Claes, S. (2013). Reduced reward learning predicts outcome in major depressive disorder. *Biological Psychiatry*, *73*, 639-645. doi:10.1016/j.biopsych.2012.10.014

Watson, D., & Clark, L. A. (1992). On traits and temperament: General and specific factors of emotional experience and their relation to the Five-Factor Model. *Journal of Personality*, *60*, 441-476. doi:10.1111/j.1467-6494.1992.tb00980.x

Watson, D., O'Hara, M. W., Simms, L. J., Kotov, R., Chmielewski, M., McDade-Montez, E. A., . . . Stuart, S. (2007). Development and validation of the Inventory of Depression and Anxiety Symptoms (IDAS). *Psychological Assessment*, *19*, 253-268. doi:10.1037/1040-3590.19.3.253

Weinberg, A., Klein, D. N., & Hajcak, G. (2012). Increased error-related brain activity distinguishes generalized anxiety disorder with and without comorbid major depressive disorder. *Journal of Abnormal Psychology*, *121*, 885-896. doi:10.1037/a0028270

Weinberg, A., Kotov, R., & Proudfit, G. H. (2014). Neural indicators of error processing in generalized anxiety disorder, obsessive-compulsive disorder, and major depressive disorder. *Journal of Abnormal Psychology*, *124*, 172-185. doi:10.1037/abn0000019

Weinberg, A., Meyer, A., Hale-Rude, E., Perlman, G., Kotov, R., Klein, D. N., & Hajcak, G. (2016). Error-Related Negativity (ERN) and sustained threat: Conceptual framework and empirical evaluation in an adolescent sample. *Psychophysiology*, *53*(3), 372-385. doi: 10.1111/psyp.12538

Weinberg, A., Riesel, A., & Hajcak, G. (2011). Integrating multiple perspectives on error-related brain activity: The ERN as a neural indicator of trait defensive reactivity. *Motivation and Emotion*, *36*, 84-100. doi:10.1007/s11031-011-9269-y

Widiger, T. A., & Clark, L. A. (2000). Toward DSM-V and the classification of psychopathology. *Psychological Bulletin*, *126*, 946-963. doi:10.1037/0033-2909.126.6.946

Widiger, T. A., & Trull, T. J. (2007). Plate tectonics in the classification of personality disorder: Shifting to a dimensional model. *American Psychologist*, *62*, 71-83. doi:10.1037/0003-066X.62.2.71

APPENDIX A

Table 1

List of the Catalog Numbers of the Stimuli Used in the Interpersonal, Negative, and Positive Tasks

Task	Catalog Numbers
Interpersonal	01F, 02F, 03F, 05F, 07F, 08F, 09F, 10F, 13F, 14F, 16F, 19F, 20M, 21M, 22M, 26M, 27M, 30M, 31M, 35M, 37M, 40M, 41M, 42M, and 45M (Practice: 06F, 15F, 24M, and 38M)
Negative	Negative: 1120, 1301, 1304, 1930, 3001, 3015, 3016, 3019, 3051, 3061, 3062, 3140, 3150, 3168, 3185, 3195, 3261, 6231, 6242, 6244, 6315, 6370, 6560, 6561, and 9425 (Practice: 1525, 3030, 6230, and 6313)
	Neutral: 5390, 5510, 5520, 5740, 7000, 7006, 7010, 7041, 7050, 7055, 7062, 7090, 7096, 7100, 7150, 7170, 7185, 7490, 7495, 7504, 7546, 7590, 7595, 7710, and 9360 (Practice: 5726, 7165, 7489, and 7545)
Positive	Positive: 1710, 1722, 2045, 2058, 2071, 2150, 2160, 2208, 2209, 2303, 2345, 2347, 4608, 4656, 4658, 4659, 4660, 4664, 4687, 4689, 4693, 4694, 4697, 4698, and 4810 (Practice: 1463, 2040, 4652, and 4800)
	Neutral: 5395, 5471, 5530, 5531, 5731, 7002, 7004, 7025, 7034, 7035, 7040, 7053, 7056, 7061, 7077, 7081, 7095, 7161, 7175, 7491, 7500, 7547, 7560, 7700, and 9468 (Practice 5750, 7078, 7136, and 7510)

Table 2

Descriptive Statistics of Behavioral Responses to the Tasks

Task	Variable (Unit)	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis
Arrow	Correct RT (msec)	91	401.95	41.25	398.29	310.32	549.70	0.57	0.83
	Error RT (msec)	91	324.60	40.31	320.76	250.47	600.83	3.58	21.94
	Compatible RT (msec)	91	369.99	40.24	366.14	281.91	523.82	0.82	1.62
	Incompatible RT (msec)	91	422.31	46.39	415.87	320.07	607.62	0.72	1.44
	Overall Accuracy (%)	91	0.89	0.04	0.89	0.78	0.98	-0.21	0.19
	Compatible Accuracy (%)	91	0.97	0.03	0.97	0.81	1.00	-1.50	2.87
	Incompatible Accuracy (%)	91	0.82	0.07	0.82	0.60	0.98	-0.22	0.16
	Presentation Time (msec)	91	154.00	31.40	152.00	90.17	264.05	0.43	0.67
Interpersonal	Correct RT (msec)	93	409.85	56.06	398.82	319.99	609.50	1.19	1.55
	Error RT (msec)	93	374.96	57.79	370.49	266.16	606.20	1.14	2.70
	Compatible RT (msec)	93	402.51	57.13	392.24	319.51	618.10	1.27	1.93
	Incompatible RT (msec)	93	415.36	57.76	407.40	320.76	620.08	1.17	1.68
	Overall Accuracy (%)	93	0.86	0.04	0.86	0.74	0.97	0.02	0.29
	Compatible Accuracy (%)	93	0.88	0.04	0.87	0.75	0.97	-0.27	0.34
	Incompatible Accuracy (%)	93	0.84	0.05	0.85	0.70	0.97	-0.14	0.25
	Presentation Time (msec)	93	354.73	58.73	360.14	180.68	508.00	-0.56	0.63

(*table continues*)

Task	Variable (Unit)	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis
Negative	Correct RT (msec)	92	488.40	66.25	489.00	349.84	659.45	0.12	-0.20
	Error RT (msec)	92	447.29	73.86	439.16	308.97	755.00	1.09	2.29
	Compatible RT (msec)	92	483.35	66.61	480.60	350.42	641.82	0.19	-0.24
	Incompatible RT (msec)	92	487.52	67.88	488.48	347.60	695.71	0.27	0.13
	Overall Accuracy (%)	92	0.85	0.05	0.84	0.72	0.98	0.15	-0.12
	Compatible Accuracy (%)	92	0.85	0.06	0.85	0.71	0.98	-0.03	-0.21
	Incompatible Accuracy (%)	92	0.84	0.06	0.84	0.70	0.98	0.17	-0.48
	Presentation Time (msec)	92	369.99	83.89	362.01	180.07	605.32	0.01	-0.03
Positive	Correct RT (msec)	89	456.11	55.52	448.94	356.39	621.37	0.70	0.40
	Error RT (msec)	89	413.93	56.64	405.87	301.60	573.52	0.59	-0.07
	Compatible RT (msec)	89	450.94	55.76	444.24	347.07	622.24	0.71	0.48
	Incompatible RT (msec)	89	457.25	55.87	447.35	356.59	610.34	0.62	0.25
	Overall Accuracy (%)	89	0.86	0.05	0.85	0.76	0.98	0.36	-0.28
	Compatible Accuracy (%)	89	0.86	0.05	0.87	0.74	0.99	0.03	-0.56
	Incompatible Accuracy (%)	89	0.86	0.05	0.85	0.73	0.97	0.23	-0.32
	Presentation Time (msec)	89	358.96	72.30	376.11	180.00	480.27	-0.50	-0.64

Table 3

Descriptive Statistics of the Error-Related Negativity Units

Task	Unit	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis	Alpha
Arrow	All	91	-6.55	4.95	-6.14	-20.98	3.83	-0.62	0.55	0.70
	1	87	-7.38	7.68	-7.32	-27.85	15.64	-0.01	0.79	
	2	90	-6.62	7.33	-7.18	-24.85	14.90	0.23	0.36	
	3	90	-5.84	6.91	-5.91	-21.66	18.35	0.25	0.93	
	4	88	-6.73	6.29	-6.37	-24.97	7.86	-0.65	0.97	
	5	88	-6.97	6.82	-6.73	-34.93	8.61	-1.28	3.82	
Interpersonal	All	92	-6.20	3.98	-5.53	-20.53	3.62	-0.79	1.37	0.73
	1	91	-6.54	5.38	-6.20	-22.84	6.16	-0.71	0.65	

(*table continues*)

Task	Unit	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis	Alpha
Interpersonal	2	93	-6.20	5.83	-5.42	-26.59	5.62	-0.61	0.41	
	3	90	-6.30	5.04	-6.23	-22.14	8.65	-0.17	0.83	
	4	92	-6.39	5.27	-6.11	-19.01	4.30	-0.17	-0.66	
	5	91	-6.42	5.39	-6.26	-24.94	8.14	-0.42	1.09	
Negative	All	89	-7.92	4.23	-7.67	-19.71	3.69	-0.55	0.67	0.72
	1	89	-7.73	5.25	-8.63	-20.34	3.98	0.22	-0.54	
	2	87	-8.04	6.15	-7.51	-24.06	8.32	-0.42	0.28	
	3	90	-6.63	6.58	-5.94	-22.19	16.18	0.19	0.88	
	4	88	-7.19	6.72	-7.33	-32.02	18.71	0.44	4.71	
	5	86	-8.28	5.18	-8.33	-21.68	4.82	-0.09	-0.31	

(*table continues*)

Task	Unit	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis	Alpha
Positive	All	88	-8.41	4.20	-7.58	-22.47	-0.17	-0.72	0.54	0.71
	1	87	-7.17	6.26	-5.76	-25.15	4.12	-0.74	0.31	
	2	87	-9.06	5.31	-9.32	-32.61	1.05	-1.02	2.96	
	3	87	-9.28	7.46	-7.88	-30.28	14.37	-0.61	1.47	
	4	88	-9.26	6.67	-8.64	-29.04	6.31	-0.38	0.35	
	5	87	-7.63	5.57	-7.01	-22.63	7.98	-0.17	0.21	

Note. *N* = sample size; *M* = mean; *S*D = standard deviation; Med = median; Min = minimum value; Max = maximum value; All = average of all involved trials; The units for M, SD, Med, Min, and Max were microvolts (μV).

Table 4

Descriptive Statistics of the Five-Factor Model Personality Traits

Domain	Facet Name (Facet Number)	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis	Alpha
N	All	93	3.01	0.55	3.00	1.79	4.17	-0.15	-0.67	0.87
	Anxiety (1)	93	3.61	0.84	3.75	1.00	5.00	-0.84	0.92	0.78
	Anger (2)	93	2.79	0.97	2.75	1.00	5.00	-0.03	-0.56	0.87
	Depression (3)	93	2.88	1.07	3.00	1.00	5.00	0.14	-0.91	0.91
	Self-Consciousness (4)	93	2.86	0.66	3.00	1.25	4.25	-0.16	-0.44	0.44
	Immoderation (5)	93	3.19	0.76	3.25	1.25	5.00	0.02	-0.55	0.65
	Vulnerability (6)	93	2.74	0.70	2.75	1.00	4.25	-0.15	-0.76	0.58
E	All	93	3.45	0.59	3.50	2.12	4.83	-0.09	-0.53	0.90
	Friendliess (1)	93	3.58	0.82	3.75	1.00	5.00	-0.48	0.10	0.80

(*table continues*)

Domain	Facet Name (Facet Number)	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis	Alpha
E	Gregariousness (2)	93	2.97	1.14	3.00	1.00	5.00	-0.13	-1.24	0.90
	Assertiveness (3)	93	3.34	0.86	3.25	1.25	5.00	-0.07	-0.72	0.86
	Activity Level (4)	93	3.35	0.70	3.50	1.50	5.00	-0.13	-0.03	0.59
	Excitement-Seeking (5)	93	3.66	0.75	3.75	1.75	5.00	-0.45	-0.18	0.69
	Cheerfulness (6)	93	3.79	0.78	4.00	1.75	5.00	-0.54	-0.41	0.78
O	All	93	3.46	0.53	3.46	2.17	4.96	0.24	0.07	0.84
	Imagination (1)	93	3.89	0.86	4.00	1.50	5.00	-0.59	-0.36	0.81
	Artistic Interests (2)	93	3.67	0.85	3.75	1.75	5.00	-0.45	-0.50	0.68
	Emotionality (3)	93	3.70	0.87	3.75	1.25	5.00	-0.31	-0.52	0.77
	Adventurousness (4)	93	2.88	0.83	2.75	1.25	5.00	0.34	-0.12	0.75

(*table continues*)

Domain	Facet Name (Facet Number)	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis	Alpha
O	Intellect (5)	93	3.70	0.85	3.75	2.00	5.00	-0.15	-1.00	0.77
	Liberalism (6)	93	2.88	0.97	2.75	1.00	5.00	0.09	-0.38	0.74
A	All	93	3.81	0.40	3.83	2.50	4.79	-0.39	0.37	0.79
	Trust (1)	93	3.44	0.78	3.75	1.75	4.75	-0.34	-0.91	0.81
	Morality (2)	93	3.68	0.60	3.75	2.25	5.00	-0.08	-0.43	0.50
	Altruism (3)	93	4.34	0.50	4.25	3.00	5.00	-0.64	-0.08	0.61
	Cooperation (4)	93	4.00	0.79	4.00	2.00	5.00	-0.49	-0.69	0.75
	Modesty (5)	93	3.43	0.88	3.25	1.50	5.00	0.00	-0.62	0.75
	Sympathy (6)	93	4.00	0.66	4.00	2.25	5.00	-0.25	-0.64	0.71

(*table continues*)

Domain	Facet Name (Facet Number)	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis	Alpha
C	All	93	3.51	0.50	3.54	2.12	4.46	-0.54	0.26	0.87
	Self-Efficacy (1)	93	3.82	0.55	3.75	2.25	5.00	-0.44	0.30	0.71
	Orderliness (2)	93	3.35	0.86	3.25	1.25	5.00	-0.19	-0.61	0.76
	Dutifulness (3)	93	4.15	0.54	4.25	2.50	5.00	-0.54	0.12	0.68
	Achievement-Striving (4)	93	3.92	0.70	3.75	1.25	5.00	-0.74	1.05	0.68
	Self-Discipline (5)	93	2.74	0.98	3.00	1.00	4.75	-0.04	-1.08	0.88
	Cautiousness (6)	93	3.06	0.93	3.25	1.00	5.00	-0.31	-0.44	0.88

Note. *N* = sample size; *M* = mean; *SD* = standard deviation; Med = median; Min = minimum value; Max = maximum value; Ne = Neuroticism; E = Extraversion; O = Openness to Experience; A = Agreeableness; C = Conscientiousness; All = average of all involved trials.

Table 5

Descriptive Statistics of the Pathological Dimensions

Measure	Domain/Facet	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis	Alpha
ESI	Relational Aggression	93	1.52	0.63	1.33	1.00	3.33	1.37	0.95	0.84
	Physical Aggression	93	1.23	0.40	1.00	1.00	3.25	2.23	6.13	0.55
	Destructive Aggression	93	1.18	0.49	1.00	1.00	3.25	2.87	7.16	0.91
	Empathy	93	3.62	0.46	4.00	2.00	4.00	-0.96	0.13	0.49
	Blame Externalization	93	1.68	0.75	1.50	1.00	4.00	0.91	0.00	0.84
	Alienation	93	2.13	0.80	2.00	1.00	4.00	0.65	-0.07	0.68
	Alcohol Problems	93	1.30	0.61	1.00	1.00	3.67	2.24	4.43	0.80
	Alcohol Use	93	2.59	1.13	2.50	1.00	4.00	-0.16	-1.46	0.90
	Marijuana Problems	93	1.28	0.66	1.00	1.00	4.00	2.44	5.00	0.91
	Marijuana Use	93	1.89	1.04	1.50	1.00	4.00	0.83	-0.72	0.95
	Drug Problems	93	1.22	0.55	1.00	1.00	3.43	2.84	7.36	0.90

(*table continues*)

Measure	Domain/Facet	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis	Alpha
ESI	Drug Use	93	1.94	0.91	1.62	1.00	4.00	0.80	-0.62	0.88
	Theft	93	1.15	0.36	1.00	1.00	2.60	2.62	6.09	0.66
	Fraud	93	1.22	0.36	1.00	1.00	2.67	2.18	4.66	0.63
	Honesty	93	3.23	0.67	3.00	1.50	4.00	-0.47	-0.69	0.74
	Irresponsibility	93	1.15	0.36	1.00	1.00	3.33	3.85	17.29	0.83
	Dependability	93	3.53	0.52	3.50	2.50	4.00	-0.57	-1.08	0.39
	Problematic Impulsivity	93	1.64	0.56	1.57	1.00	3.29	0.91	0.28	0.77
	Planful Control	93	3.13	0.58	3.00	2.00	4.00	-0.13	-0.56	0.55
	Impatient Urgency	93	2.30	0.83	2.33	1.00	4.00	0.09	-0.86	0.86
	Rebelliousness	93	1.52	0.60	1.25	1.00	3.25	1.15	0.54	0.82
	Boredom Proneness	93	2.62	0.93	2.50	1.00	4.00	-0.07	-1.12	0.85
	Excitement Seeking	93	2.04	0.92	2.00	1.00	4.00	0.65	-0.55	0.82
	Callous Aggression	93	1.97	0.29	1.91	1.50	2.89	0.99	0.71	0.86

(*table continues*)

Measure	Domain/Facet	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis	Alpha
ESI	Substance Abuse	93	1.54	0.52	1.38	1.00	3.02	1.20	0.53	0.96
	Total	93	1.73	0.37	1.64	1.27	2.82	1.08	0.46	0.96
IDAS	Lassitude	93	2.95	0.71	3.00	1.17	4.83	0.08	-0.15	0.66
	Insomnia	93	2.37	0.88	2.33	1.00	4.83	0.67	0.16	0.80
	Suicidality	93	1.34	0.63	1.00	1.00	4.67	2.96	9.94	0.89
	Appetite Loss	93	2.06	1.12	1.67	1.00	5.00	0.94	-0.04	0.91
	Appetite Gain	93	2.16	0.88	2.00	1.00	4.67	0.56	-0.41	0.67
	Ill Temper	93	1.59	0.64	1.40	1.00	3.60	1.32	0.99	0.79
	Well Being	93	3.01	0.77	3.00	1.62	5.00	0.40	-0.22	0.88
	Social Anxiety	93	2.12	0.84	2.00	1.00	4.20	0.59	-0.53	0.78
	Panic	93	1.71	0.71	1.50	1.00	4.00	1.18	0.67	0.87
	Traumatic Intrusions	93	2.05	1.01	1.75	1.00	5.00	0.94	-0.02	0.82
	General Depression	93	2.59	0.61	2.45	1.50	4.10	0.54	-0.38	0.87

(*table continues*)

Measure	Domain/Facet	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis	Alpha
IDAS	Dysphoria	93	2.66	0.72	2.50	1.30	4.30	0.49	-0.57	0.82
	Total	93	2.24	0.49	2.14	1.39	3.70	0.66	0.02	0.94
PID	Anxiousness	93	1.91	0.72	2.00	0.00	3.00	-0.54	-0.37	0.83
	Emotional Lability	93	1.22	0.78	1.25	0.00	2.75	0.10	-0.89	0.83
	Hostility	93	0.84	0.75	0.75	0.00	2.75	0.72	-0.32	0.87
	Perseveration	93	1.32	0.62	1.25	0.00	3.00	0.24	-0.64	0.69
	Restricted Affectivity	93	4.03	0.79	4.25	2.00	5.00	-0.69	-0.37	0.84
	Separation Insecurity	93	1.56	0.74	1.50	0.00	3.00	-0.11	-0.54	0.74
	Submissiveness	93	1.63	0.59	1.75	0.25	3.00	-0.14	-0.34	0.71
	Anhedonia	93	0.80	0.69	0.75	0.00	2.75	0.81	0.04	0.82
	Depressivity	93	0.61	0.71	0.25	0.00	2.75	1.08	0.13	0.88
	Intimacy Avoidance	93	0.74	0.67	0.75	0.00	3.00	0.95	0.60	0.79
	Suspiciousness	93	0.85	0.55	0.75	0.00	2.25	0.54	-0.37	0.60

(*table continues*)

Measure	Domain/Facet	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis	Alpha
PID	Withdrawal	93	0.80	0.64	0.75	0.00	2.50	0.64	-0.22	0.80
	Eccentricity	93	1.51	0.92	1.75	0.00	3.00	-0.09	-1.12	0.90
	Perceptual Dysregulation	93	0.61	0.59	0.50	0.00	2.25	0.74	-0.25	0.70
	Unusual Beliefs and Experiences	93	0.88	0.70	1.00	0.00	2.50	0.30	-1.01	0.68
	Attention Seeking	93	1.29	0.83	1.25	0.00	3.00	0.18	-0.96	0.89
	Callousness	93	0.27	0.43	0.00	0.00	1.75	1.72	2.28	0.83
	Deceitfulness	93	0.73	0.56	0.50	0.00	2.25	0.66	-0.38	0.71
	Grandiosity	93	0.35	0.48	0.25	0.00	2.25	1.54	2.09	0.77
	Manipulativeness	93	0.86	0.63	0.75	0.00	2.50	0.69	-0.29	0.75
	Distractibility	93	1.79	0.74	1.75	0.25	3.00	-0.04	-1.00	0.84
	Impulsivity	93	1.09	0.74	1.00	0.00	3.00	0.57	-0.35	0.84
	Irresponsibility	93	0.48	0.51	0.50	0.00	2.75	1.45	3.23	0.66
	Rigid Perfectionism	93	3.77	0.72	3.75	2.25	5.00	-0.09	-1.00	0.79

(*table continues*)

Measure	Domain/Facet	*N*	*M*	*SD*	Med	Min	Max	Skew	Kurtosis	Alpha
PID	Risk Taking	93	0.98	0.76	1.00	0.00	3.00	0.66	-0.24	0.86
	Negative Affectivity	93	1.35	0.39	1.36	0.32	2.14	-0.19	-0.46	0.83
	Detachment	93	0.76	0.47	0.70	0.00	1.90	0.46	-0.68	0.88
	Psychoticism	93	1.00	0.63	1.00	0.00	2.50	0.21	-0.82	0.88
	Antagonism	93	0.70	0.42	0.60	0.05	2.15	0.59	0.05	0.88
	Disinhibition	93	1.11	0.44	1.10	0.15	2.10	0.26	-0.48	0.85

Note. *N* = sample size; *M* = mean; *SD* = standard deviation; Med = median; Min = minimum value; Max = maximum value; ESI = The 100-items Externalizing Spectrum Inventory; IDAS = The Inventory for Depression and Anxiety Symptoms; PID = The Personality Inventory for DSM-5; All = average of all involved trials.

Table 6

Correlations Among Error-Related Negativity and Self-Reported Traits/Dimension Based on the Average of Observed Values

		ERN				FFM				
		Arrow	Interpersonal	Negative	Positive	N	E	O	A	C
ERN	Interpersonal	0.62								
	Negative	0.53	0.50							
	Positive	0.57	0.73	0.70						
FFM	N	0.07	0.10	-0.08	-0.07					
	E	-0.05	-0.10	0.00	-0.09	-0.35				
	O	-0.13	-0.02	0.03	0.12	-0.01	0.09			
	A	-0.07	-0.11	-0.14	-0.07	-0.06	0.10	0.30		
	C	-0.15	-0.11	0.00	-0.16	-0.23	0.25	-0.11	0.20	
ESI	Callous Aggression	0.13	0.03	0.14	0.10	0.19	0.05	0.00	-0.30	-0.37
	Substance Abuse	-0.05	0.02	-0.02	0.00	0.28	-0.08	-0.07	-0.35	-0.45
	Total	0.00	0.03	0.03	0.04	0.28	-0.05	-0.05	-0.37	-0.47
IDAS	General Depression	-0.08	-0.05	-0.07	-0.05	0.52	-0.24	0.25	0.04	-0.33
	Dysphoria	-0.10	-0.07	-0.09	-0.07	0.56	-0.21	0.17	0.00	-0.38
	Social Anxiety	-0.08	-0.05	-0.08	-0.20	0.53	-0.42	-0.10	-0.13	-0.14
	Panic	-0.05	-0.11	-0.02	-0.03	0.30	-0.09	0.12	0.03	-0.17

(*table continues*)

		ERN				FFM				
		Arrow	Interpersonal	Negative	Positive	N	E	O	A	C
IDAS	Traumatic Intrusions	-0.17	-0.07	-0.10	-0.04	0.22	-0.09	0.18	-0.02	-0.22
	Total	-0.10	-0.05	-0.08	-0.08	0.57	-0.28	0.17	-0.05	-0.34
PID	Negative Affectivity	0.06	-0.02	-0.14	-0.17	0.71	-0.15	0.02	0.06	-0.29
	Detachment	-0.13	0.03	-0.04	0.07	0.50	-0.61	0.09	-0.19	-0.34
	Psychoticism	-0.08	0.03	0.12	0.17	0.08	-0.06	0.37	-0.16	-0.38
	Antagonism	0.11	0.00	0.13	0.05	0.16	0.09	-0.06	-0.65	-0.35
	Disinhibition	0.03	0.02	-0.02	0.09	0.01	0.03	0.25	-0.10	-0.75

(*table continues*)

		ESI			IDAS					
		Callous Aggression	Substance Abuse	Total	General Depression	Dysphoria	Social Anxiety	Panic	Traumatic Intrusions	Total
ESI	Callous Aggression									
	Substance Abuse	0.55								
	Total	0.76	0.96							
IDAS	General Depression	0.4	0.31	0.38						
	Dysphoria	0.41	0.34	0.4	0.95					

(*table continues*)

		ESI			IDAS					
		Callous Aggression	Substance Abuse	Total	General Depression	Dysphoria	Social Anxiety	Panic	Traumatic Intrusions	Total
IDAS	Social Anxiety	0.24	0.25	0.27	0.51	0.54				
	Panic	0.35	0.27	0.32	0.67	0.64	0.58			
	Traumatic Intrusions	0.33	0.21	0.27	0.62	0.58	0.31	0.57		
	Total	0.46	0.39	0.46	0.95	0.91	0.65	0.78	0.67	
PID	Negative Affectivity	0.24	0.18	0.22	0.45	0.46	0.35	0.30	0.23	0.47
	Detachment	0.21	0.30	0.30	0.55	0.47	0.45	0.31	0.39	0.61
	Psychoticism	0.44	0.26	0.35	0.29	0.31	0.18	0.38	0.36	0.37
	Antagonism	0.59	0.40	0.51	0.20	0.21*	0.10	0.24	0.18	0.25
	Disinhibition	0.45	0.43	0.48	0.23	0.28*	0.02	0.17	0.27	0.25

(*table continues*)

	PID			
	Negative Affectivity	Detachment	Psychoticism	Antagonism
Detachment	0.35			
Psychoticism	0.12	0.31		
Antagonism	0.29	0.20	0.39	
Disinhibition	0.10	0.19	0.50	0.35

Note. ERN = error-related negativity; FFM = five-factor model; N = Neuroticism; E = Extraversion; O = Openness to Experience; A = Agreeableness; C = Conscientiousness; ESI = The 100-items Externalizing Spectrum Inventory; IDAS = The Inventory for Depression and Anxiety Symptoms; PID = The Personality Inventory for DSM-5; Underlined = relationship between ERN and personality trait or pathological dimnesion $|r|$ above .10.

Table 7

Correlations of Error-Related Negativity Among the Units Within Each Task

Arrow	1	2	3	4
2	0.39			
3	0.32	0.38		
4	0.42	0.39	0.49	
5	0.11	0.19	0.26	0.39
Interpersonal	1	2	3	4
2	0.53			
3	0.28	0.32		
4	0.31	0.43	0.43	
5	0.31	0.33	0.33	0.29
Negative	1	2	3	4
2	0.46			
3	0.21	0.47		
4	0.30	0.30	0.36	
5	0.18	0.46	0.32	0.36
Positive	1	2	3	4
2	0.45			
3	0.24	0.45		
4	0.41	0.27	0.41	
5	0.21	0.25	0.20	0.52

Table 8

Fit Indices From the Confirmatory Factor Analysis of Task Error-Related Negativity

Task	Structure	*N*	χ^2	*df*	*p*	CFI	TLI	RMSEA	90 % CI	AIC	BIC	Units Involved
Arrow	All	91	3.616	5	0.606	1.000	1.061	0.000	0.000, 0.146	2930.014	2967.677	
Interpersonal	All	93	6.417	5	0.268	0.983	0.966	0.054	0.000, 0.159	2772.245	2810.234	
Negative	All	90	7.643	5	0.177	0.955	0.909	0.086	0.000, 0.201	2766.210	2803.708	
Positive	All	88	29.815	5	< .001	0.797	0.593	0.200	0.134, 0.271	2777.464	2814.624	
Positive	Drop	88	0.296	2	0.863	1.000	1.101	0.000	0.000, 0.113	2251.912	2281.640	2
	Time	88	3.103	1	0.078	0.981	0.807	0.137		2766.854	2813.924	1 - 2, 2 - 3, 3 - 4, 4 - 5
	Correlate	88	0.770	2	0.680	1.000	1.080	0.000	0.000, 0.168	2763.260	2807.852	2 - 4, 4 - 5, 2 – 3

Note. N = sample size; χ^2 = chi-square; *df* = degrees of freedom; *p* = statistical significance; CFI = comparative fit index; TLI = Tucker Lewis index; RMSEA = root mean square error average; CI = confidence interval; AIC = Akaike information criteria; BIC = Bayesian information criteria.

Table 9

Fit Indices From the Confirmatory Factor Analysis of Task Error-Related Negativity Higher-Order Model

Approach	*N*	Chi-Sq	*df*	*p*	CFI	TLI	RMSEA	90 % CI	AIC	BIC
All*	93	220.051	166	0.003	0.883	0.866	0.061	0.037, 0.082	11100.077	11262.164
No Positive	93	105.545	87	0.086	0.935	0.921	0.050	0.000, 0.081	8396.439	8518.004
Single Latent	93	127.104	90	0.006	0.868	0.846	0.070	0.038, 0.097	8414.759	8528.726
Difference	93	21.559	3	< .001	-0.067					

Note. *N* = sample size; χ^2 = chi-square; *df* = degrees of freedom; *p* = statistical significance; CFI = comparative fit index; TLI = Tucker Lewis index; RMSEA = root mean square error average; CI = confidence interval; AIC = Akaike information criteria; BIC = Bayesian information criteria; * = Positive task latent variance is negative.

Table 10

Fit Indices From the Confirmatory Factor Analysis of Personality Domains

Domain	Structure	*N*	Chi-Sq	*df*	*p*	CFI	TLI	RMSEA	90 % CI	AIC	BIC	Facets Involved
N	All	93	10.839	9	< .001	0.985	0.975	0.047	0.000, 0.130	1265.765	1311.352	
E	All	93	17.481	9	0.042	0.938	0.897	0.107	0.020, 0.181	1253.562	1299.149	
O	All	93	20.050	9	0.018	0.865	0.775	0.108	0.043, 0.173	1388.189	1433.776	
A	All	93	65.320	9	< .001	0.637	0.396	0.223	0.174, 0.275	1117.598	1163.185	
C	All	93	29.649	9	0.001	0.839	0.732	0.160	0.098, 0.225	1156.593	1202.180	
E	Correlate	93	8.133	8	0.421	0.999	0.998	0.015	0.000, 0.134	1245.481	1293.600	3 - 4
O	Correlate	93	8.985	7	0.254	0.976	0.948	0.052	0.000, 0.138	1382.311	1432.963	4 - 6, 3 - 5
A	Correlate	93	1.611	4	0.807	1.000	1.062	0.000	0.000, 0.087	1080.701	1138.951	2 - 4, 1 - 5, 2 - 5, 4 - 5, 1 - 3
C	Correlate	93	9.634	7	0.210	0.976	0.949	0.069	0.000, 0.166	1141.459	1192.111	3 - 4, 3 – 5

Note. *N* = sample size; χ^2 = chi-square; *df* = degrees of freedom; *p* = statistical significance; CFI = comparative fit index; TLI = Tucker Lewis index; RMSEA = root mean square error average; CI = confidence interval; AIC = Akaike information criteria; BIC = Bayesian information criteria; N = Neuroticism; E = Extraversion; O = Openness to Experience; A = Agreeableness; C = Conscientiousness.

Table 11

Fit Indices From the Confirmatory Factor Analysis of Pathological Dimensions

	Domain	Structure	*N*	Chi-Sq	*df*	*p*	CFI	TLI	RMSEA	90 % CI	AIC	BIC
ESI	CA	Corr	93	99.403	69	0.010	0.926	0.902	0.070	0.036, 0.100	2084.303	2210.933
	SU*	Corr	93	28.870	19	0.068	0.979	0.959	0.080	0.000, 0.136	1129.518	1218.159
	Total*	Corr	93	277.486	193	< .001	0.929	0.906	0.070	0.050, 0.087	3016.723	3285.179
IDAS	Total	Corr	93	45.602	33	0.071	0.931	0.905	0.070	0.000, 0.115	2075.514	2156.557
PID	N	Corr	93	11.664	12	0.473	1.000	1.007	0.000	0.000, 0.110	1332.263	1390.513
	De	Corr	93	2.063	4	0.724	1.000	1.050	0.000	0.000, 0.132	804.162	844.684
	A	Corr	93	2.633	3	0.452	1.000	1.010	0.000	0.000, 0.155	711.702	754.756
	Di+	Corr	93	1.415	3	0.702	1.000	1.078	0.000	0.000, 0.133	915.560	958.615

(*table continues*)

	Domain	Structure	Facets Involved
ESI	CA	Corr	8 Covariances
	SU*	Corr	7 Covariances
	Total*	Corr	17 Covariances
IDAS	Total	Corr	Appetite Loss and Social Anxiety, Insomnia and Panic
PID	N	Corr	Perseveration and Restricted Affectivity, Anxiousness and Separation Insecurity
	De	Corr	Anhedonia and Depressivity
	A	Corr	Callousness and Grandiosity, Attention Seeking and Grandiosity
	Di+	Corr	Distractibility and Risk Taking, Distractibility and Irresponsibility

Note. N = sample size; χ^2 = chi-square; df = degrees of freedom; p = statistical significance; CFI = comparative fit index; TLI = Tucker Lewis index; RMSEA = root mean square error average; CI = confidence interval; AIC = Akaike information criteria; BIC = Bayesian information criteria; ESI = 100-items Externalizing Spectrum Inventory; IDAS = the Inventory for Depression and Anxiety Symptoms; PID = the Personality Inventory for DSM-5; CA = Callous-Aggressive; SU = Substance Use. N = Negative Affectivity; De = Detachment; P = Psychoticism; A = Antagonism; Di = Disinhibition; Corr = Correlated; * = Settled with a model with non-positive definite residual covariances.

Table 12

Correlations Between Saved Latent Error-Related Negativity and Latent Personality Domains

		Simple CFA			Higher-Order Without Positive			
	Domain	Arrow	Interpersonal	Negative	Arrow	Interpersonal	Negative	General
Simple CFA	N	<u>0.12</u>	0.03	-0.06	0.07	0.05	-0.01	0.05
Correlate	E	0.03	-0.08	0.02	0.01	-0.05	0.01	-0.01
Correlate	O	<u>-0.11</u>	-0.02	-0.03	-0.09	-0.06	-0.07	-0.08
Correlate	A	-0.07	0.02	0.00	-0.05	-0.01	-0.02	-0.03
Correlate	C	<u>-0.16</u>	-0.04	-0.01	<u>-0.11</u>	-0.07	-0.04	-0.09

Note. CFA = confirmatory factor analysis; N = Neuroticism; E = Extraversion; O = Openness to Experience; A = Agreeableness; C = Conscientiousness; Underlined = |*r*| above .10; Areas not shaded indicate correlations that should be interpreted (i.e., between constructs using the same approach to find the best fit when necessary); Areas shaded are correlations that should not be interpreted, but is provided for context.

Table 13

Correlations Between Saved Latent Error-Related Negativity and Latent Pathological Dimensions

			Simple			Higher-Order Without Positive			
			Arrow	Interpersonal	Negative	Arrow	Interpersonal	Negative	General
Correlate		Total	<u>0.20</u>	-0.01	<u>0.19</u>	<u>0.14</u>	0.05	<u>0.15</u>	<u>0.11</u>
Correlate	ESI	CA	**<u>0.21</u>**	0.00	**<u>0.23</u>**	<u>0.16</u>	0.07	<u>0.19</u>	<u>0.14</u>
Correlate		SU	0.02	-0.08	0.00	-0.05	-0.07	-0.03	-0.06
Correlate	IDAS		-0.01	<u>-0.12</u>	0.02	-0.06	-0.09	-0.03	-0.07
Correlate		NA	0.09	-0.07	<u>-0.11</u>	0.01	-0.05	-0.08	-0.03
Correlate		De	-0.09	-0.08	-0.03	<u>-0.11</u>	-0.09	-0.07	-0.10
Simple	PID	Psy	0.03	-0.02	<u>0.18</u>	0.03	0.01	<u>0.13</u>	0.04
Correlate		A	**<u>0.21</u>**	-0.01	<u>0.19</u>	<u>0.15</u>	0.07	<u>0.18</u>	<u>0.13</u>
Correlate		Di	0.09	-0.05	0.10	0.04	-0.01	0.06	0.03

Note. CFA = confirmatory factor analysis; ESI = 100-items Externalizing Spectrum Inventory; IDAS = the Inventory for Depression and Anxiety Symptoms; PID = the Personality Inventory for DSM-5; CA = Callous-Aggressive; SU = Substance Use. NA = Negative Affectivity; De = Detachment; Psy = Psychoticism; A = Antagonism; Di = Disinhibition; Corr = Correlated. Underlined = $|r|$ above .10; Bolded and underlined = $|r|$ above .20. Areas not shaded indicate correlations that should be interpreted (i.e., between constructs using the same approach to find the best fit when necessary); Areas shaded are correlations that should not be interpreted, but is provided for context.

Table 14

Correlation Estimated From Path-Coefficient t-Values Between Latent Error-Related Negativities and Personality Domains (Estimated From Facets) Within a Structural Equation Model

	Domain	Arrow	Interpersonal	Negative	Overall
Simple CFA	N	.09	.00	-.09	.04
Correlate	E	.07	-.08	.03	-.01
	O	-0.07	-0.03	-0.01	-0.05
	A	-0.05	0.04	0.01	-0.02
	C	-0.11	0.02	0.04	-0.06

Note. CFA = confirmatory factor analysis; N = Neuroticism; E = Extraversion; O = Openness to Experience; A = Agreeableness; C = Conscientiousness; Underlined = |*r*| above .10.

Table 15

Correlation Estimated From Path-Coefficient t-Values Between Latent Error-Related Negativities and Personality Domains (Single Observed Score) Within a Structural Equation Model

		Arrow	Interpersonal	Negative	Overall
ESI		0.07	-0.04	0.03	0.05
IDAS		0.03	-0.06	0.02	-0.02
PID	NA	0.10	-0.06	-0.09	-0.02
	De	-0.06	-0.01	0.01	-0.07
	P	-0.04	-0.07	0.18	0.03
	A	0.12	-0.09	0.10	0.09
	Di	0.07	-0.08	-0.07	0.02

Note. ESI = The 100-items Externalizing Spectrum Inventory; IDAS = The Inventory for Depression and Anxiety Symptoms; PID = The Personality Inventory for DSM-5; NA = Negative Affectivity; De = Detachment; P = Psychoticism; A = Antagonism; Di = Disinhibition; Corr = Correlated. Underlined = |*r*| above .10.

Table 16

The Analyses of Specific ESI and IDAS Scales

		Simple CFA			Higher-Order Without Positive			
		Arrow	Interpersonal	Negative	Arrow	Interpersonal	Negative	Overall
ESI	Alcohol Use	-0.05	-0.07	-0.08	-0.08	-0.08	-0.10	-0.09
	Drug Use	-0.05	-0.11	-0.03	-0.09	-0.10	-0.06	-0.09
IDAS	Well Being	0.14	0.06	0.15	0.14	0.10	0.15	0.13
	General Depression	-0.04	-0.12	-0.05	-0.09	-0.12	-0.10	-0.11

Note. ESI = The 100-items Externalizing Spectrum Inventory; IDAS = The Inventory for Depression and Anxiety Symptoms; Underlined = |*r*| above .10.

Table 17

Correlation Estimated From Path-Coefficient t-Values Between Latent Error-Related Negativities and Specific ESI and IDAS Scales Within a Structural Equation Model

		Higher-Order Without Positive			
		Arrow	Interpersonal	Negative	Overall
ESI	Alcohol Use	0.02	0.04	-0.02	-0.09
	Drug Use	0.01	-0.03	0.03	-0.08
IDAS	Well Being	0.10	-0.03	0.11	0.07
	General Depression	0.03	-0.05	-0.02	-0.08

Note. ESI = The 100-items Externalizing Spectrum Inventory; IDAS = The Inventory for Depression and Anxiety Symptoms; Underlined = |*r*| above .10.

APPENDIX B

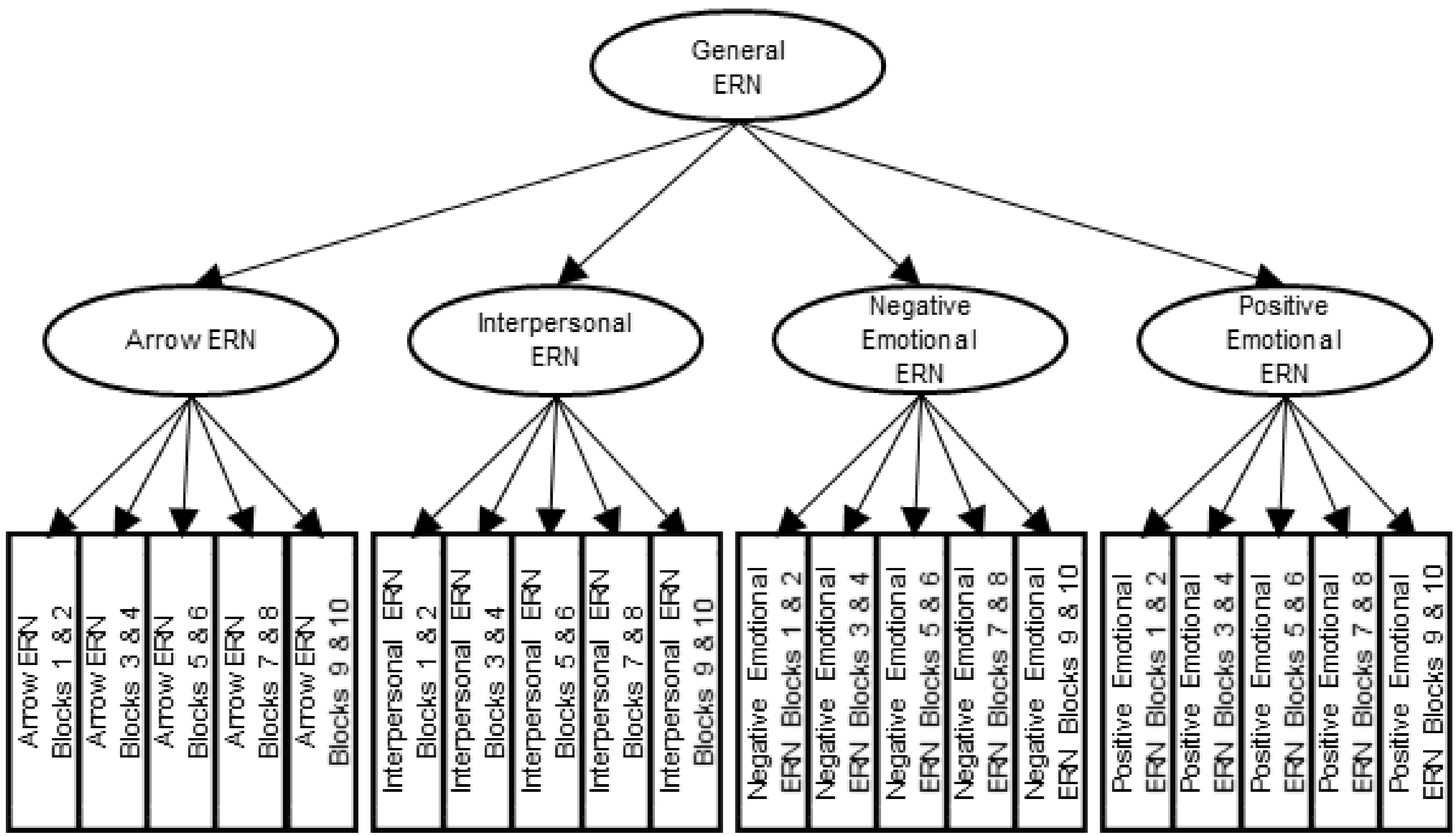

Figure 1. The hypothesized relationships among general error-related negativity (ERN), task-specific ERNs (ovals), and observed ERN block pairs (rectangles).

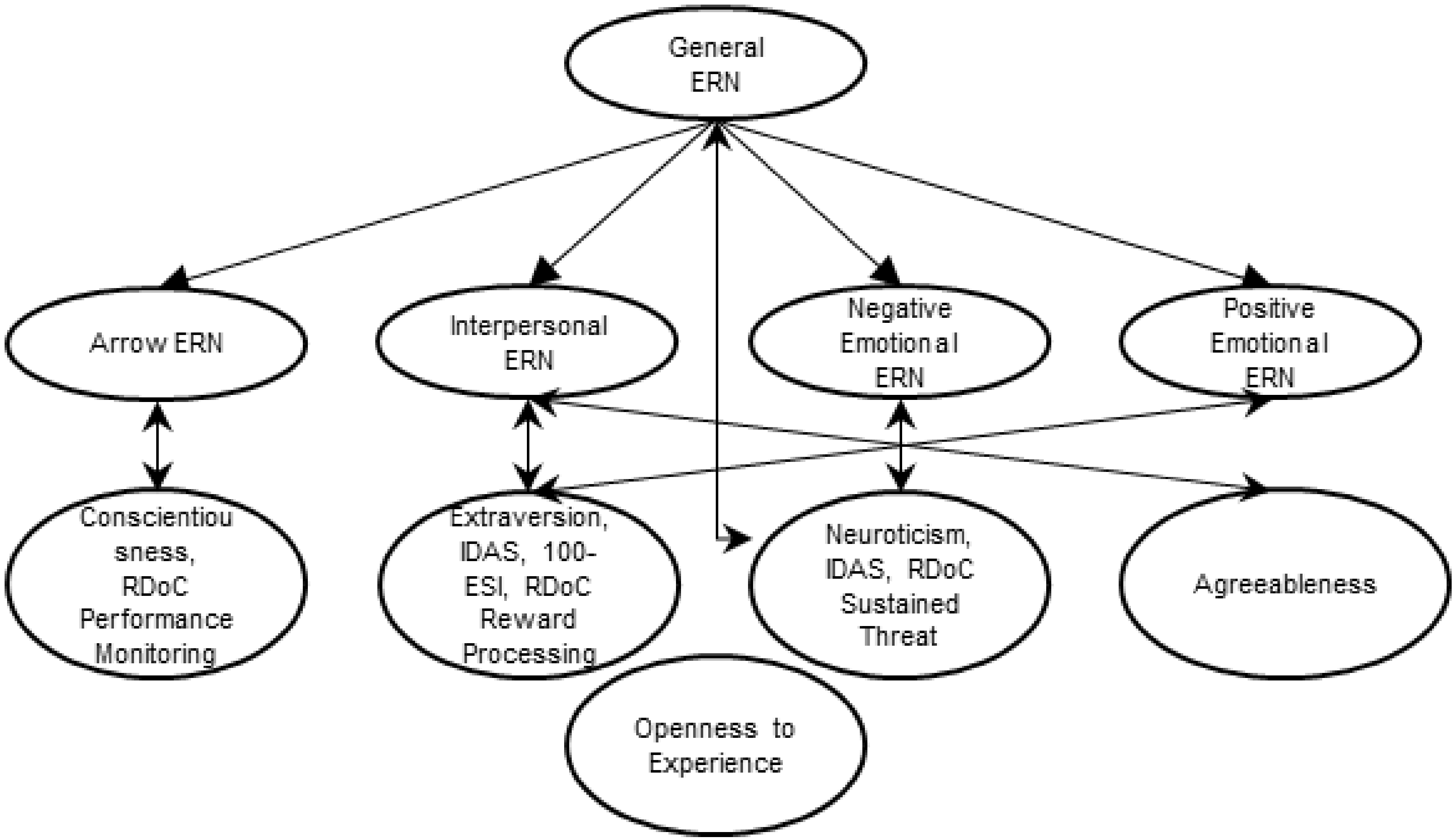

Figure 2. A model for the expected relationships among the five-factor model traits, maladaptive dimensions, RDoC constructs, general error-related negativity (ERN), and task-specific ERNs.

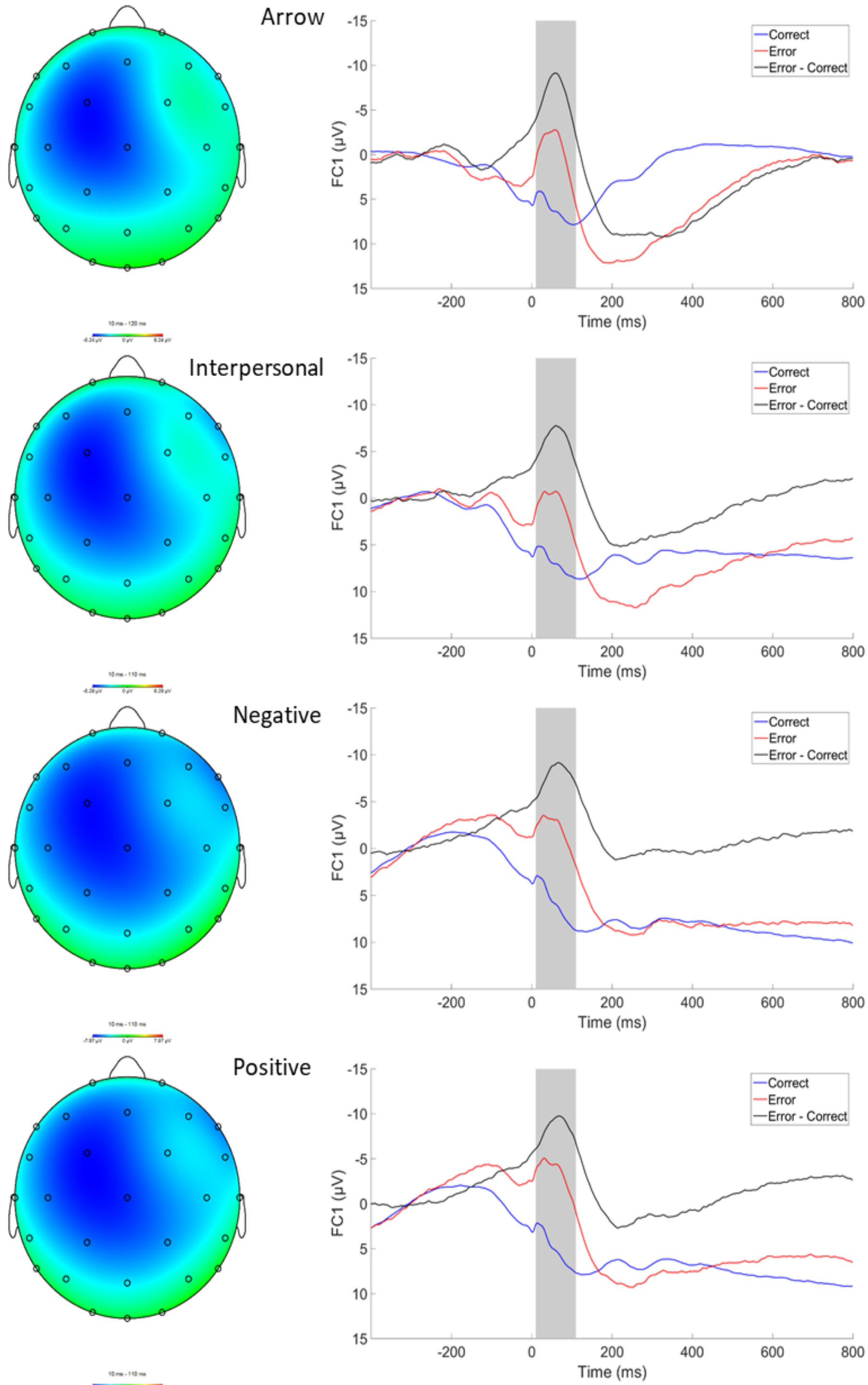

Figure 3. The scalp distribution and time-window of error-related negativities from the Arrow (top), Interpersonal (second), Negative (third), and Positive (last) tasks. On the head map (left), darker blue indicates more negativity. On the moment-to-moment recording of the event-related potentials (right), correct trials are indicated in blue, Error trials are indicated in red, the differences (ERN) are indicated in black lines, and the grey area indicate the 10ms to 110ms window.

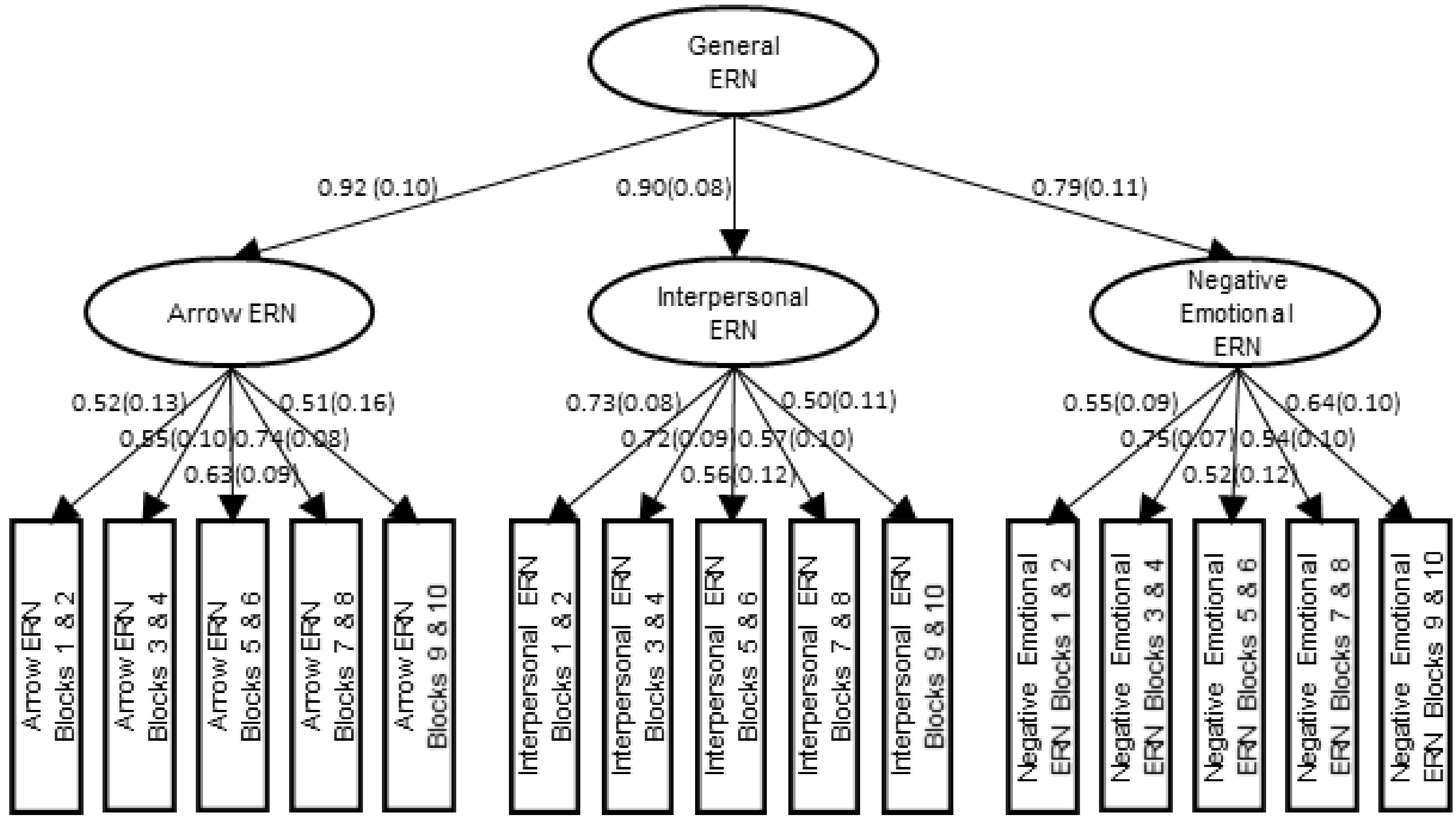

Figure 4. The identified relationships among general error-related negativity (ERN), task-specific ERNs (ovals), and observed ERN block pairs (rectangles) with factor loadings and path coefficients (standard errors in parentheses).