RESPONSE MODULATION DEFICITS IN PSYCHOPATHY: EVIDENCE FROM STIMULUS AND RESPONSE PROCESSING

By

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CHAPTER I

Introduction

Psychopathy is a pervasive personality disorder characterized by low anxiety, manipulativeness, and interpersonal dominance as well as impulsivity, aggression, and low constraint. These individual traits can be separated into two orthogonal factors (Benning, Patrick, Hicks, Blonigen, & Krueger, 2003): fearless dominance (FD; characterized by low anxiety, manipulativeness, and social potency) and impulsive antisociality (IA; characterized by impulsivity, aggression, and low self control).[1] Many deficits have been associated with psychopathic personality traits including reduced fear potentiated startle (Benning, Patrick, & Iacono, 2005; Patrick, Bradley, & Lang, 1993), and a reduced ability to identify emotional faces (Dadds, Jambrak, Pasalich, Hawes, & Brennan, 2011; Kosson, Suchy, Mayer, & Libby, 2002). However, one key behavioral deficit is the reduced ability to adapt behavior in response to changing circumstances or previous errors (Edens & McDermott, 2010; Kosson, Smith, & Newman, 1990).

Response Modulation

According to the response modulation hypothesis (RMH; Patterson & Newman, 1993), psychopaths' deficits in adapting to changing circumstances result from an inability to process peripheral cues that signal the need to change behavior in the midst of a dominant response. In their initial description of the RMH, Patterson & Newman describe this deficit as a common process, or set of processes, in many disorders of disinhibition and suggest that it includes first a dominant response set or goal directed behavior followed by some type of corrective information that must be concurrently attended. One particular example of this response modulation is when that corrective information signals the need to suspend the goal directed behavior and inhibit the dominant response. The reduced ability to shift attention to the cue leads to a subsequent failure to suspend the dominant response. Response modulation deficits in psychopathy have been shown using cued reaction time tasks (Howland, Kosson, Patterson, & Newman, 1993), flanker tasks (Zeier, Maxwell, & Newman, 2009), and stroop tasks (Vitale, Brinkley, Hiatt, & Newman, 2007). The RMH does not posit any deficits in overall stimulus processing, cognitive control, or any deficits related to the dominant response set.

Stimulus Processing

In additions to deficits in response modulation, various cognitive processing deficits have also been associated with psychopathic personality traits. In particular there has been much work done regarding the P3 (or P300) ERP component in relation to psychopathy (Carlson, Thái, & McLarnon, 2008; Kiehl, Bates, Laurens, Hare, & Liddle, 2006; Kiehl, Hare, Liddle, & McDonald, 1999; Patrick & Bernat, 2009; Raine & Venables, 1988). This work has used a variety of tasks including the rotated heads task (Carlson et al., 2008), the visual oddball task (Kiehl et al., 1999) and auditory oddball tasks (Kiehl et al., 2006) with mixed results. While the majority of studies have shown reduced P3 amplitude in psychopaths as well as in other externalizing psychopathologies such as substance abuse (Carlson, Iacono, & McGue, 2002) and conduct disorder (Iacono, Carlson, Malone, & McGue, 2002), some have shown increased amplitude (Raine & Venables, 1988) while others have shown no differences (Jutai, Hare, &

Connolly, 1987). Some of the more recent work (Carlson et al., 2008; Patrick & Bernat, 2009) has shown a specific relationship between the impulsive and antisocial factor of psychopathy and reduced frontal P3 amplitude.

This reduced P3 amplitude is thought to indicate a form of reduced executive function, particularly a reduced ability to ignore information that is task irrelevant or distracting. Previous studies have also shown that reduced P3 amplitude and longer latencies of the N2/P3 complex are related to a less efficient inhibition process during a stop signal task as well as to individual differences in impulsivity (Dimoska, Johnstone, & Barry, 2006; Kok, Ramautar, De Ruiter, Band, & Ridderinkhof, 2004). If psychopaths do exhibit a reduced ability to ignore irrelevant information, perhaps leading to a less efficient inhibition process, in addition to deficits in their ability to process peripheral cues that are relevant, these deficits may interact in such a way that makes it even more difficult for them to recognize the need to change their behavior. However, the interaction of these deficits has yet to be explored.

Error Processing

Research has also shown that disorders characterized by behavioral disinhibition such as antisocial personality disorder are related to reduced error monitoring as indicated by reduced error related negativity (ERN) amplitude following errors (Dimoska, Johnstone, & Barry, 2006; Hall, Bernat, & Patrick, 2007). This failure to engage cognitive control following errors may also lead to a reduced capacity to adapt behavior accordingly (Hall, Bernat, & Patrick, 2007). Furthermore, if cues to alter behavior are not processed well, as suggested by the RMH, it may be difficult for psychopaths to recognize that an error has been made. Thus, reduced processing of peripheral cues signaling the need to change behavior and reduced error processing following an incorrect response may act together to produce psychopaths' reduced ability to adapt their behavior to changing circumstances.

Current Study

Therefore, the current study investigates the relationship between the processing of task relevant stimuli and peripheral cues, stopping a prepared response, and the recognition of errors, paying particular attention to how these processes differ with respect to psychopathic personality traits. A stop signal (SS) task was chosen for this purpose because of the strong theoretical basis behind this model of behavioral inhibition. The race model (Boucher, Palmeri, Logan, & Schall, 2007; Logan & Cowan, 1984) states that activation and inhibition processes work simultaneously in the brain, competing for access to the motor cortex to initiate or inhibit an action. As an index of the efficiency of the inhibition process stop signal reaction time (SSRT) is measured as the relative finishing time of the stop process with longer SSRTs reflecting poor inhibitory efficiency (Logan, Schachar, & Tannock, 1997).

Additionally, because of the aforementioned emotional deficits in psychopathy we used a lexical decision SS task that included pleasant, neutral, and aversive words as the go portion of the task to examine whether go stimulus valence influenced the relationship between psychopathy and stopping behavior. Furthermore, although the implications of the SS are made explicit at the outset of the task, an auditory SS was used and presented on only 20% of trials to make it more peripheral to the primary go task and better fit the parameters set by the RMH. Because the SS was presented in an alternate modality and because of its rarity, it required a "shift of attention from the effortful organization and implementation of goal-directed behavior to its evaluation" (Newman, Schmitt, & Voss, 1997, p. 564) and therefore could act as a peripheral cue to test the RMH.

In addition to the behavioral data available from the SS task such as SSRT, event related brain potentials (ERPs) provide details about how each stimulus is processed and the temporal sequence of events from stimulus to behavioral response, and outcome monitoring. To fully dissociate these processes, an ERP component that resolves prior to participants' response or their mean SSRT, such as the N1, must be used to assess processing of the SS itself. A separate, later component such as the ERN can be used as a measure of subsequent outcome or error processing. The N1 is known to be related to auditory sensory gating and typically occurs between 50ms and 150ms following stimulus onset (Houston & Stanford, 2001; Lijffijt et al., 2009), well before the average SSRTs reported in previous SS research (Avila & Parcet, 2001; Dimoska & Johnstone, 2007; Dimoska et al., 2006; Kok et al., 2004; Wodushek & Neumann, 2003). N1 amplitude is also sensitive to attention (Näätänen & Picton, 1987) and should therefore be reduced in individuals who are less able to process peripheral cues as those high in IA. The P3 component has also been used to assess processing of both the go and stop stimulus in previous studies (Dimoska et al., 2006) and has been shown to be related to individual differences in impulsivity.

Finally, because psychopathy is related to increased alienation and lower achievement (Benning et al., 2003), these individuals may be less motivated to perform well or provide consistent effort on laboratory tasks. However, the impact of participant engagement in relationship to psychopathy, response modulation deficits, and the ERP measures discussed here has not been directly examined. Participant motivation has been shown to influence measures of response inhibition such as SSRT (Leotti & Wager, 2010) suggesting that effort may influence relationships between psychopathy and the measures discussed above.

Impulsive antisociality was expected to be related to an overall impulsive response style as indicated by faster lexical decision (LD) reaction time (RT), reduced LD and SS accuracy, and longer SSRT. Additionally, based on the RMH, participants high in IA were expected to show reduced processing of the SS, as shown by reduced N1 and P3 amplitude, and were expected show reduced processing of errors, as indicated by reduced ERN amplitude. Hypotheses regarding IA and processing of the go stimulus were less clear. Based on the RMH, no deficits were expected in the processing of the go stimulus. However, based on the majority of previous studies showing reduced P3 amplitude in psychopathy it was expected that, overall, IA would be related to reduced P3 amplitude following the onset of the go stimulus. Finally, based on the RMH, the degree to which IA was related to reduced ERN amplitude should be mediated by how well individuals processed the SS (N1 amplitude).

CHAPTER II

Method

Participants

Participants were adults screened from the Vanderbilt University emergency room (*N* = 1258) who completed the Multidimensional Personality Questionnaire - Brief Form (MPQ-BF; Patrick, Curtin, & Tellegen, 2002) while in the E.R. and received $5.00 for their participation. FD and IA scores were estimated from the MPQ using established regression equations (Benning et al., 2003). Participants whose FD or IA score fell in the top, middle, or bottom 10% of scores from the sample as a whole were selected for participation in the study and were contacted to complete the task at a later date. Participants were oversampled from the extreme 10% of each factor's distribution in this way to ensure an adequate representation of both high and low scores on both factors. FD and IA scores on the factor for which participants were not selected were free to vary.

Eighty-nine participants (44% men; 70% white, 27% black) who met the screening criteria agreed to participate. Participants' mean age was 36 years (*SD* = 12), their mean annual income was $25,339 (*SD* = $35,519), and 57% reported being currently unemployed. Participants' median education level was "some college".

Participant Exclusion

Seven participants were excluded because of invalid MPQ profiles or because their scores at screening and test (the MPQ was also completed in the labratory) placed them in different 10% groups, indicating extreme instability in scores between administrations. An additional 4 participants were excluded due to computer malfunction. Twelve participants were excluded either because their LD accuracy was below 50% (n = 3) or their SS accuracy was below 39% (a level reflecting worse performance than expected by chance with $\alpha = .01$), leaving a sample of 66 participants in the final analyses.

Participants who were excluded because of bad performance did not differ in their levels of fearless dominance (FD), $t(81) = -0.45$, $p = .657$, or impulsive antisociality (IA), $t(76) = 0.18$, $p = .860$, from participants who were included in this study. The mean fearless dominance score was -0.14 (SD = 0.79) for included participants and -0.02 (SD = 0.90) for excluded participants. The mean impulsive antisociality score was -.18 (SD = 0.71) for included participants and -0.22 (SD = 0.70) for excluded participants.

Distribution of Fearless Dominance and Impulsive Antisociality Scores

Because participants were only selected based on either their FD or IA score and not both, the score on the factor for which they were not selected was free to vary. This resulted in an approximately normal distribution of FD and IA scores (See Figures 1 and 2 respectively). Additionally, FD and IA correlated in expected ways with scores from the Triarchic Psychopathy Inventory (Patrick, Fowles, & Krueger, 2009) indicating that they were accurately estimated by the MPQ and adequately represented in our sample (see Table 1). Table 1 also provides test-retest correlations between the screening and laboratory sessions for FD and IA.

Psychophysiology

EEG was recorded at 2000 Hz using the standard 10-20 system with a Neuroscan SynAmps^2 64 channel Ag-AgCl Quik-Cap and a .05-500 Hz online bandpass filter. Data

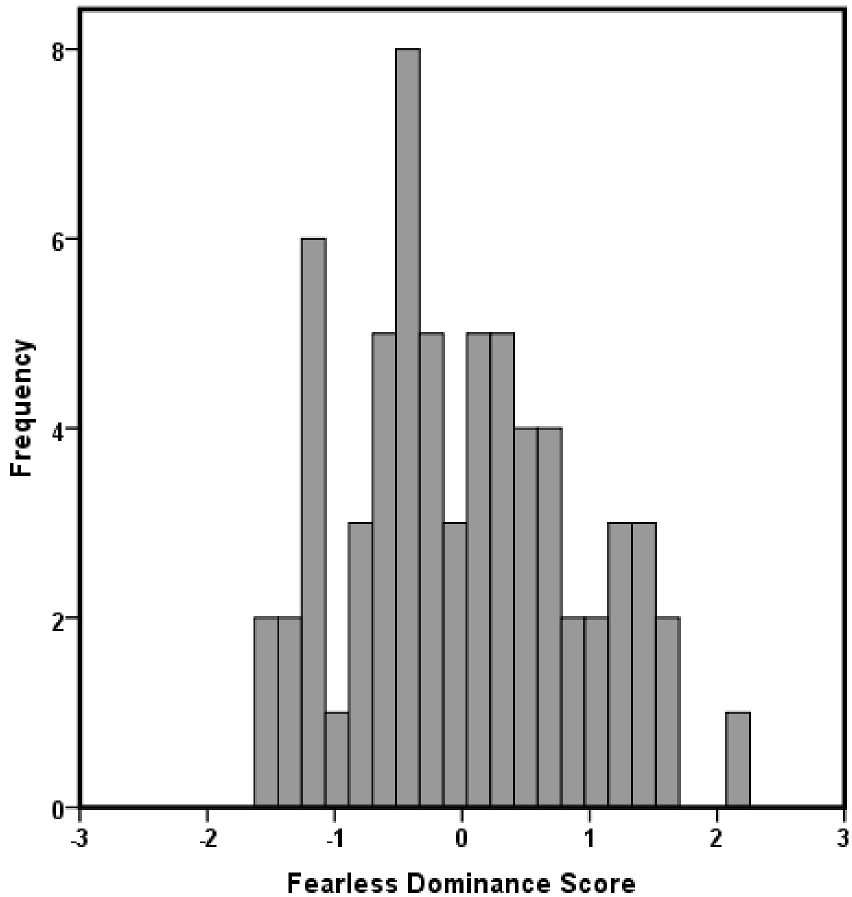

Figure 1. Histogram of fearless dominance Z-scores obtained in the laboratory for the sample as a whole.

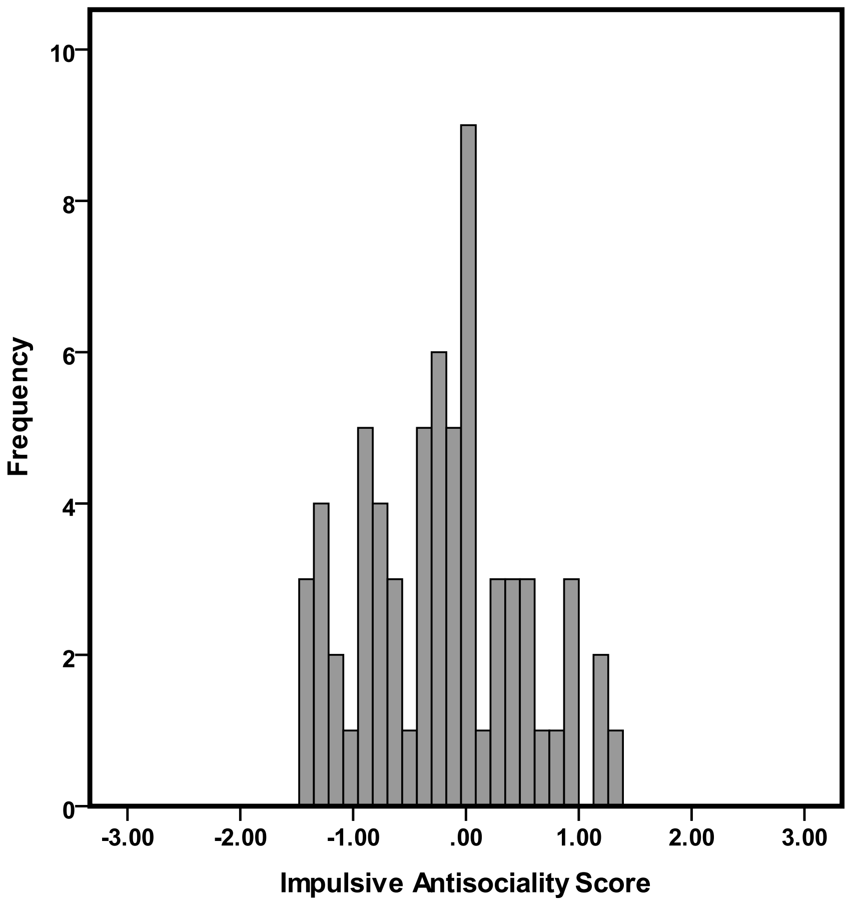

Figure 2. Histogram of impulsive antisociality Z-scores obtained in the laboratory for the sample as a whole.

Table 1

Correlations among Fearless Dominance, Impulsive Antisociality and Triarchic Psychopathy Inventory Subscales

	FD Lab	IA Lab	Boldness	Meanness	Disinhibition
FD Screen	(.92**)	-.17	-	-	-
IA Screen	-.12	(.83**)	-	-	-
Boldness	.78**	-.25	1	-	-
Meanness	.10	.44**	.13	1	
Disinhibition	-.46**	.52**	-.41**	.27*	1

Note: * $p < .05$, ** $p < .01$. FD = Fearless Dominance, IA = Impulsive Antisociality. (Test-retest correlations between FD and IA obtained at screening and test). The Triarchic Psychopathy Inventory was only administered in the laboratory.

were analyzed after applying an offline 20 Hz lowpass filter and excluding epochs with EEG activity >|100| μV. The P3 component following the go stimulus (Text P3) was defined as the maximum positive voltage peak 450 ms to 800 ms post text relative to a pre-stimulus baseline of -200 ms to -1 ms and was maximal at FZ. SS N1 was defined as the maximum negative voltage peak from 50 ms to 200 ms following SS onset relative to a pre-stimulus baseline of -200 ms to -1 ms and was maximal at FZ. The P3 following the stop signal (SS P3) was defined as the maximum positive voltage peak 325 ms to 450 ms post SS onset and was maximal at CZ. The ERN was defined as the maximum negative voltage peak from 0 ms to 100 ms post-response relative to a pre-response baseline of -200 ms to -50 ms and was maximal at FZ.

Procedure

Following informed consent participants again completed the MPQ in addition to other questionnaires while electrodes were attached. The MPQ was administered in the lab to ensure stability of scores between administrations. FD and IA scores estimated from the laboratory administration of the MPQ are used in all analyses. Following the questionnaires participants completed four tasks, one of which was the task described in this report. A public speaking task was always presented first followed by the remaining three tasks in counterbalanced order.

The task consisted of 600 trials (25 blocks of 24 trials) on which participants were presented with a string of white text in the center of a black screen and asked to indicate if the text was a word (75%) or non-word (25%) by pressing the W (with the left index finger) or N (with the right index finger) key respectively. The words used were drawn from the Affective Norms for English Words (ANEW; Bradley & Lang, 1999) and included pleasant, neutral, and aversive words in equal numbers. All words ranged from 3-7 characters in length. Pleasant and aversive words were equally distant from neutral words in valence, and both were equally more arousing than neutral words. Words were all balanced for mean character length and frequency of use. Non-words were formed by replacing one vowel in each word.

The text was presented for 1500 ms followed by a fixation cross for 500 ms. Responses were allowed during both the text and fixation (2000 ms total). Participants were instructed to respond as quickly as possible while still being accurate. Additionally, participants were instructed between blocks to speed up or slow down their responses if their SS accuracy was greater than 60% or less than 40%, respectively.

On 20% of trials an auditory SS was presented between 0 ms and 1000 ms after word onset. Participants were instructed to withhold their response if they heard this tone. Stop signal delay (SSD) varied dynamically across the experiment to achieve an overall SS accuracy of 50% such that the SS delay decreased 50 ms following a failure to inhibit and increased 50 ms following a successful inhibition.

A post-task questionnaire assessed participants' engagement in the task. Four questions assessed overall engagement, effort to make correct LD, effort to inhibit responses following a SS, and perceived importance of the task on a 1 (*not at all*) to 9 (*most possible*) Likert scale. The study took approximately 3 hrs and participants received $50.00 as compensation. All procedures were approved by the Vanderbilt University IRB.

CHAPTER III

Results

Lexical Decision Stop Signal (LDSS) Task Characteristics

Although the lexical decision component of the LDSS task used in the current study increased the complexity of the go task over more traditional letter discriminations (X vs. O) and resulted in longer RTs than typically reported, the mean SSRTs found here did not differ significantly from those found by Wodushek & Neumann (2003) in a sample of adults with ADHD [$t(109) = 1.31$, $p = .19$ for the samples as a whole]. Our high IA group did not differ significantly from their high ADHD symptom group, $t(54) = 1.17$, $p = .25$, and our low IA group did not differ significantly from their low ADHD symptom group, $t(53) = 0.69$, $p = .49$. This indicates that the increased complexity of the go task did not have a significant effect on the stopping process and that SSRT is a valid index of that process in this task.

Behavioral

To examine the relationship between the two factors of psychopathy and task performance, correlations were computed between participants' FD and IA scores, reaction time, LD accuracy, SS inhibition accuracy, SS delay and SSRT. Means and standard deviations for these measures can be seen in Table 2. IA showed significant relationships with LD accuracy, SS accuracy, SS delay and SSRT (see Table 3). The relationship between IA and these measures also showed a similar pattern across word valences as well as non-words (see Table 4) and was not a result of the trend toward

Table 2

LDSS Behavioral Data for the Sample as a Whole and by Median Split on Impulsive Antisociality Score

	Whole Sample		Low IA (n = 33)		High IA (n = 33)	
Variable	Mean	(SD)	Mean	(SD)	Mean	(SD)
LD Reaction Time (ms)	921	(123)	935	(137)	907	(105)
SS Delay (ms)	631	(204)	688	(187)	574	(207)
SSRT (ms)	291	(139)	247	(81)	334	(170)
LD Accuracy	.86	(.01)	.89	(.09)	.83	(.11)
SS Accuracy	.52	(.06)	.53	(.07)	.50	(.05)

Note: LD = lexical decision, SS = stop signal, SSRT = stop signal reaction time. IA = impulsive antisociality.

Table 3

Correlations among Impulsive Antisociality, Fearless Dominance, Behavioral Measures, and ERPs

	Fearless Dominance		Impulsive Antisociality	
Variable	Zero Order	Partial	Zero Order	Partial
Behavioral Measures				
Reaction Time	.07	.04	-.14	-.14
LD Accuracy	.03	.07	-.29*	-.19
SS Accuracy	.10	.08	-.30*	-.29*
SS Delay	.11	.09	-.31*	-.32*
SSRT	-.09	-.09	.32*	.31*
ERPs				
Incorrect LD ERN	.00	.01	.31*	.28*
Correct LD ERN	.09	.14	.30*	.32*
SS Error ERN	-.06	.02	.30*	.29*
SS N1	.08	.12	.39**	.37**
SS P3	.02	.19	-.25*	-.25*

Note: + $p < .10$, * $p < .05$, ** $p < .01$. LD = lexical decision, SS = stop signal, SSRT = stop signal reaction time. SS P3 is for SS following words only at CZ. All other ERPs are following all stimuli at FZ. Partial correlations control for participants' responses to "How engaged were you in this task?" and "How hard did you try to respond word or non-word correctly?" Because the ERN and N1 are negative going waves, positive correlations indicate smaller absolute amplitude.

Table 4

Correlations among FD, IA, and Behavioral Performance Measures by Word Valence and Word vs. Non-Word

	Pleasant Words	Aversive Words	Neutral Words	All Words	All Non-words
			LD Reaction Time		
FD	.03	.05	.03	.04	.16
IA	-.17	-.14	-.12	-.14	-.11
			LD Accuracy		
FD	-.01	.02	.04	.01	.03
IA	-.21+	-.25*	-.24*	-.25*	-.26*
			SS Accuracy		
FD	.09	-.04	-.11	-.03	.25*
IA	-.07	-.20	.01	-.12	-.37**
			SS Delay		
FD	.11	.12	.12	.11	.11
IA	-.31*	-.31*	-.30*	-.31*	-.30*
			SSRT		
FD	-.12	-.14	-.13	-.13	-.03
IA	.32**	.29*	.34**	.32**	.32**

Note: +*p* < .10, **p*<.05, ***p*<.01. FD = Fearless Dominance, IA = Impulsive Antisociality, LD = Lexical Decision, SS = Stop Signal, SSRT = Stop Signal Reaction Time.

faster RTs. Consistent with previous research (Avila & Parcet, 2001; Howland et al., 1993; Roussy & Toupin, 2000) these results indicate a generally impulsive response style for those high in IA rather than a specific deficit related to a particular part of the task. The significantly longer SSRTs indicate that, for these individuals, the stopping process needs more of a head start to successfully inhibit the response (Logan et al., 1997). No significant correlations were found between FD and behavioral performance.

Event Related Potentials

Go stimulus processing

Prior to examining the possible effects of the go stimulus on response modulation differences in basic processing of the text based on word valence and lexical (word vs. non-word) status were assessed using paired samples *t*-tests in the sample as a whole (see Table 5 for differences by component and electrode). These analyses revealed that P3 amplitude was larger following non-words than following words at FZ, CZ, and PZ. P3 following non-words also showed a significantly longer peak latency than P3 following words at all three electrodes [FZ, $t(65) = 4.16$, $p < .001$; CZ, $t(65) = 6.35$, $p < .001$; PZ, $t(65) = 5.56$, $p < .001$] indicating that non-words were more difficult to process and more salient than words. The effects of word valence on P3 amplitude were minimal with P3 following aversive words being larger than neutral at FZ and CZ, but not PZ. Similarly, P3 latency following neutral words was significantly longer than following pleasant words at FZ, $t(65) = 2.12$, $p = .038$, and PZ, $t(65) = 2.07$, $p = .043$, but not CZ.

P3 amplitude following all words as well as non-words was also significantly correlated with RT at PZ (see Table 6). However, contrary to previous research, neither FD nor IA correlated with P3 amplitude or latency for any stimulus type. The associated

Table 5

Mean Differences in Peak Amplitude of Stimulus Locked Components as a Function of Word Valence and Word vs. Non-word

Electrode	Pleasant - Neutral	Pleasant - Aversive	Neutral - Aversive	Words - Non-words
		Text P1		
FZ	-0.07 (0.18)	-0.37 (0.22)	-0.30 (0.26)+	-0.15 (0.16)
CZ	0.06 (0.16)	-0.13 (0.15)	-0.18 (0.17)	-0.00 (0.17)
PZ	-0.02 (0.17)	0.09 (0.17)	0.11 (0.13)	-0.06 (0.13)
OZ	-0.28 (0.10)**	-0.27 (0.14)*	0.01 (0.14)	-0.04 (0.12)
		Text N1		
FZ	-0.01 (0.17)	-0.13 (0.17)	-0.12 (0.20)	-0.08 (0.21)
CZ	0.16 (0.16)	0.07 (0.15)	-0.09 (0.15)	-0.01 (0.21)
PZ	0.24 (0.16)	0.22 (0.17)	-0.02 (0.16)	0.03 (0.15)
OZ	-0.23 (0.11)	-0.23 (0.16)	-0.00 (0.13)	0.08 (0.11)
		Text P2		
FZ	0.45 (0.19)*	-0.09 (0.20)	-0.54 (0.18)**	-0.13 (0.16)
CZ	0.21 (0.18)	-0.00 (0.24)	-0.22 (0.17)	-0.18 (0.19)
PZ	0.06 (0.17)	0.06 (0.18)	0.01 (0.13)	-0.05 (0.17)
OZ	-0.18 (0.11)	-0.20 (0.15)	-0.01 (0.17)	-0.10 (0.11)
		Text N2		
FZ	0.68 (0.19)**	-0.06 (0.22)	-0.74 (0.17)**	-0.07 (0.27)
CZ	0.75 (0.21)**	0.03 (0.23)	-0.72 (0.19)***	0.57 (0.29)+
PZ	0.50 (0.20)*	0.05 (0.19)	-0.44 (0.15)**	0.59 (0.25)*
OZ	-0.24 (0.11)*	-0.24 (0.15)	-0.00 (0.16)	0.62 (0.15)***
		Text P3		
FZ	0.37 (0.31)	-0.36 (0.21)+	-0.73 (0.34)*	-2.16 (0.34)***
CZ	0.38 (0.31)	-0.05 (0.35)	-0.43 (0.19)*	-1.89 (0.39)***
PZ	0.41 (0.34)	-0.01 (0.23)	-0.42 (0.22)	-1.22 (0.27)***
OZ	-0.28 (0.15)+	-0.28 (0.17)+	-0.00 (0.16)	-0.45 (0.25)+
		SS N1		
FZ	-1.02 (0.46)*	-1.00 (0.41)*	0.02 (0.38)	0.40 (0.56)
CZ	-0.25 (0.35)	-0.40 (0.38)	-0.15 (0.35)	-0.23 (0.62)
PZ	-0.36 (0.34)	-0.46 (0.29)	-0.10 (0.35)	-0.20 (0.34)
OZ	0.03 (0.48)	-0.16 (0.28)	-0.19 (0.36)	-0.31 (0.30)
		SS P3		
FZ	-0.94 (0.75)	-0.53 (0.51)	0.40 (0.62)	3.47 (0.99)**
CZ	-0.24 (0.54)	-0.29 (0.41)	-0.05 (0.56)	2.96 (0.87)**
PZ	-0.44 (0.68)	-0.68 (0.55)	-0.24 (0.48)	1.73 (0.58)**
OZ	-1.07 (0.58)+	-1.06 (0.41)	0.01 (0.43)	0.15 (0.36)

Note: Values are mean differences (S.E.) in microvolts. +$p < .1$, *$p < .05$, **$p < .01$, ***$p < .001$.

Table 6

Correlations among Stimulus Locked ERPs, FD, IA and Behavioral Performance

	Text P1	Text N1	Text P2	Text N2	Word P3	Non-word P3	SS N1	Word SS P3
FD	.40**	.19	-.30*	.04	-.08	-.09	.08	.18
IA	-.03	.12	*(-.36**)*	*(-.26*)*	-.16	-.21+	.39**	-.24*
RT	-.30*	.14	-.27*	-.25*	-.30*	-.24*	-.15	.05
LD Accuracy	.15	-.07	.04	.17	-.03	.18	-.39**	.11
SS Accuracy	.09	.03	.04	-.17	-.02	.10	-.25*	.39**
SSD	-.16	-.14	-.10	-.22+	-.23+	-.08	-.39**	.24+
SSRT	-.02	.08	-.08	.11	.09	-.09	.42***	-.30*

Note: +p < .10, *p < .05, **p < .01, **p < .001. LD = Lexical Decision, SS = Stop Signal, SSD = Stop Signal Delay SSRT = Stop Signal Reaction Time. All correlations are with peak amplitude. Components following all stimuli unless otherwise noted. Correlations are at the following locations: P1 at PZ, N1 at PZ, P2 at FZ, N2 at PZ, P3 at PZ, SS N1 at FZ and SS P3 at FZ. (*Text P2 and N2 correlated with IA at OZ.)*

waveforms can be seen in Figures 3 (shown with a median split on IA scores) and 4 (median split on FD).

After examining the waveforms it appeared that some early sensory and attentional components may have also been sensitive to lexical status and word valence as well as individual differences in FD and IA. Additionally, previous research suggests that emotional information contained in text stimuli may begin to be processed at this early stage (see Kissler, Assadollahi, & Herbert, 2006 for a review). Therefore, exploratory analyses were conducted to examine these differences in the P1 (maximal at OZ between 75 ms and 130 ms), N1 (maximal at CZ between 100 ms and 175 ms), P2 (maximal at FZ between 175 ms and 300 ms), and N2 (maximal at OZ between 325 ms and 475 ms) components.

P1 amplitude was larger following aversive and neutral words than following pleasant words but N1 amplitude did not differ as a function of word valence or lexical status. P2 amplitude was larger following pleasant and aversive words than following neutral words. Therefore both the P1 and P2 appear to be sensitive to word valence, although in slightly different ways while the N1 component is not. The latency of these early components was not related to text type in any way.

The N2 differed from the P1 and P2 components in that it appeared to show a different pattern of modulation at anterior versus posterior electrodes. Although the exact pattern of this modulation is not entirely clear, a general trend for valence modulations at anterior electrodes and word/non-word modulations at posterior electrodes is observed. At FZ, CZ, and PZ, larger N2 amplitude was observed following neutral words as compared to pleasant and aversive words while N2 was larger following non-words than

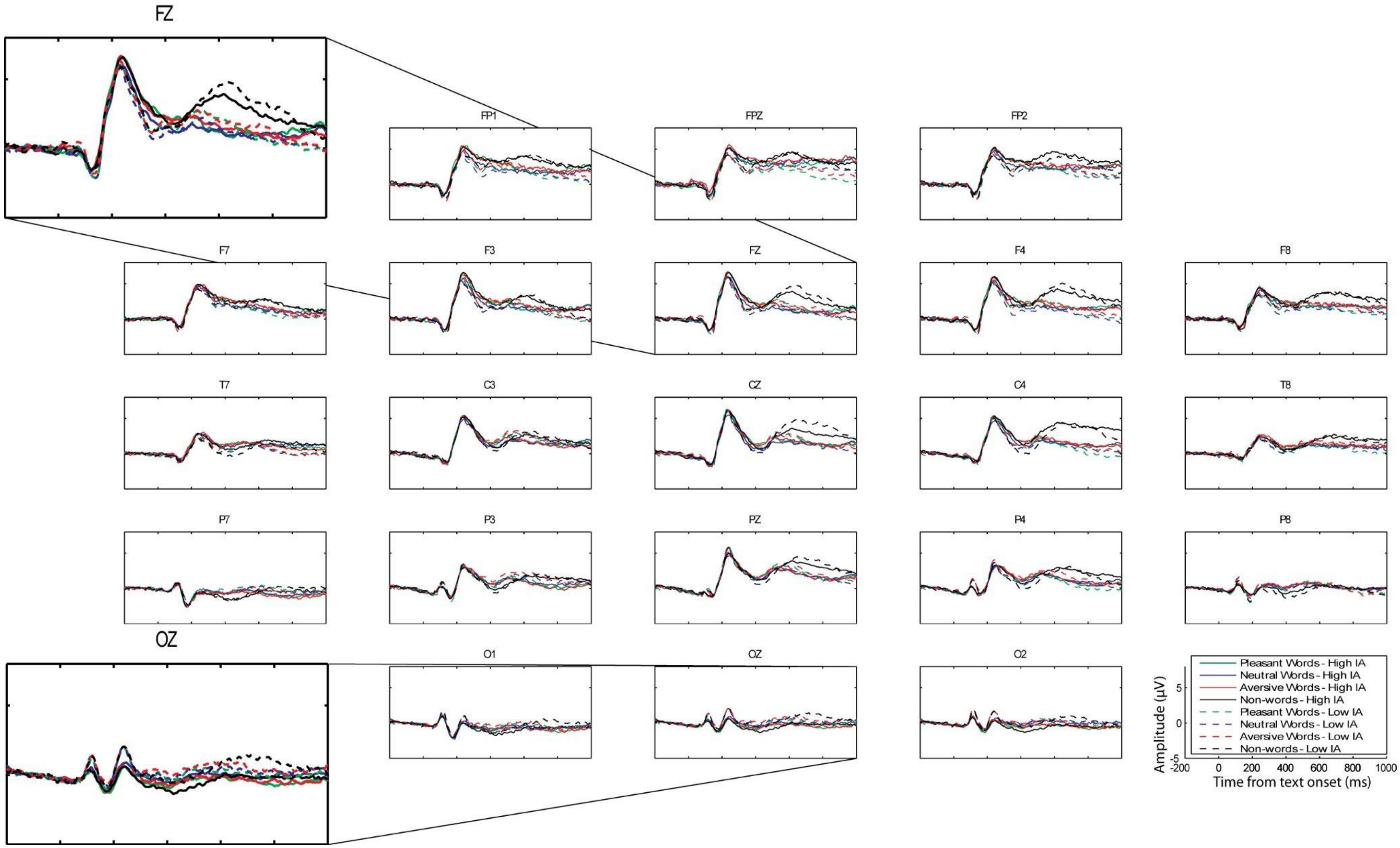

Figure 3. Grand average waveforms following text onset for pleasant, neutral, and aversive words, and non-words. Waveforms are shown median split on impulsive antisociality (IA) score. Highlighted electrodes emphasize the word v. non-word differences in P3 amplitude (at FZ) as well as the reduction in P2 amplitude for those high in IA (at OZ).

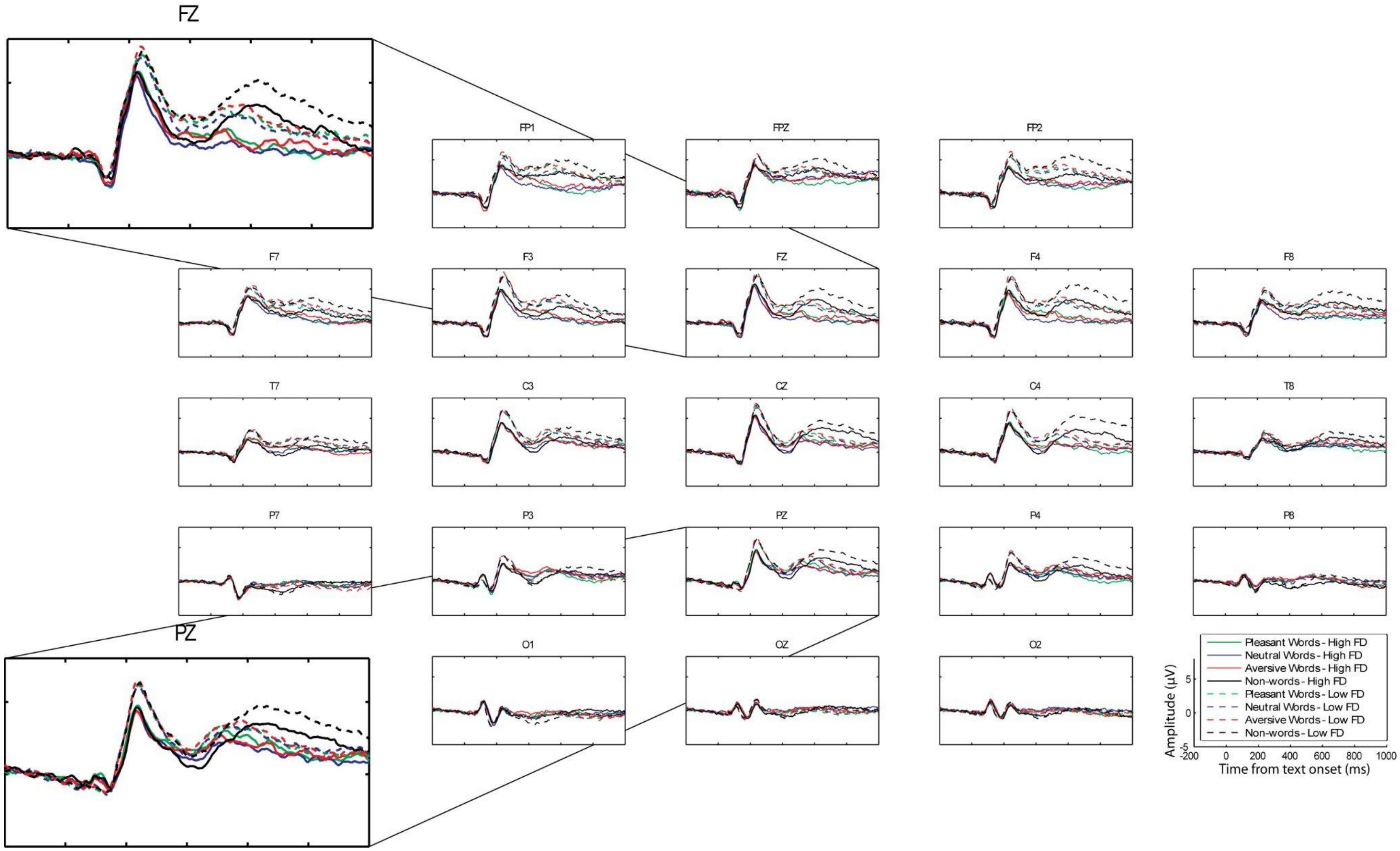

Figure 4. Grand average waveforms following text onset for pleasant, neutral, and aversive words, and non-words. Waveforms are shown median split on fearless dominance (FD) score. Highlighted electrodes emphasize the word v. non-word differences in P3 amplitude as well as the larger P1 amplitude (at PZ) and the reduction in P2 amplitude (at FZ) for those high in FD.

following words, regardless of valence, at OZ. These differences indicate that even in early sensory and attentional processing the brain is beginning to differentiate between types of lexical stimuli. However, the exact pattern of this differentiation is complex and bears further investigation.

Because of the early differentiation shown by these components, correlations were also computed between P1, N1, P2, and N2 peak amplitudes, FD and IA, and task performance variables (see Table 6). P1 amplitude following all text was positively correlated with FD and negatively correlated with RT at PZ. P1 amplitude was not correlated with IA. P2 amplitude following all text was negatively correlated with FD and RT at FZ and was negatively correlated with IA at OZ. P2 amplitude was not correlated with RT at OZ. N2 amplitude was negatively correlated with RT at PZ but was only significantly related to IA following non-words at OZ. N2 amplitude did not correlate significantly with FD. P1, P2, and N2 latencies did not correlate with behavior or FD and IA.

Stop signal processing

As with initial text processing, paired samples *t*-tests were used to assess differences in N1 and P3 amplitude in response to the SS following each word valence and non-words. N1 amplitude was found to be significantly reduced when the SS followed aversive and neutral words compared to pleasant words at FZ. N1 latency was also significantly shorter for SS following non-words compared to words, $t(65) = 2.15$, $p = .035$. Behaviorally, N1 amplitude was positively correlated with SSRT and negatively correlated with LD accuracy, SS accuracy, and SSD (see Table 6). IA also correlated with shallower N1 peak amplitude following all SS regardless of lexical status or word valence indicating reduced processing of the SS. No significant correlations were found between FD and N1 amplitude.

SS P3 amplitude was significantly smaller for SS following non-words compared to words regardless of valence indicating a possible reduction in available processing capacity as a result of the increased difficulty of processing the non-words themselves. SS P3 was also positively correlated with LD accuracy and negatively correlated with SSRT but not SSD (see Table 6). IA was negatively correlated with SS P3 amplitude for SS following words but not non-words (see Table 3). This difference between words and non-words for IA is likely because SS P3 was already reduced following non-words and exhibited a floor effect where a further reduction was not possible. No significant correlations were found between SS P3 and FD. Together, reductions in both the N1 and SS P3 components indicate reduced processing of the SS for those high in IA. The associated waveforms can be seen in Figure 5 (median split on IA) and Figure 6 (median split on FD).

Error processing

Also shown in Table 3, IA correlated with shallower ERN peak amplitude following incorrect LD, correct LD, and SS inhibition errors, indicating that IA was associated with broadly reduced outcome monitoring. No significant correlations were found between FD and ERN amplitude.[2] The associated waveforms can be seen in Figure 7, median split on IA.

Participant Engagement

Participants' overall engagement and level of effort on the LD portion of the task were correlated with IA at a trend level (see Table 7) such that those high in IA were less

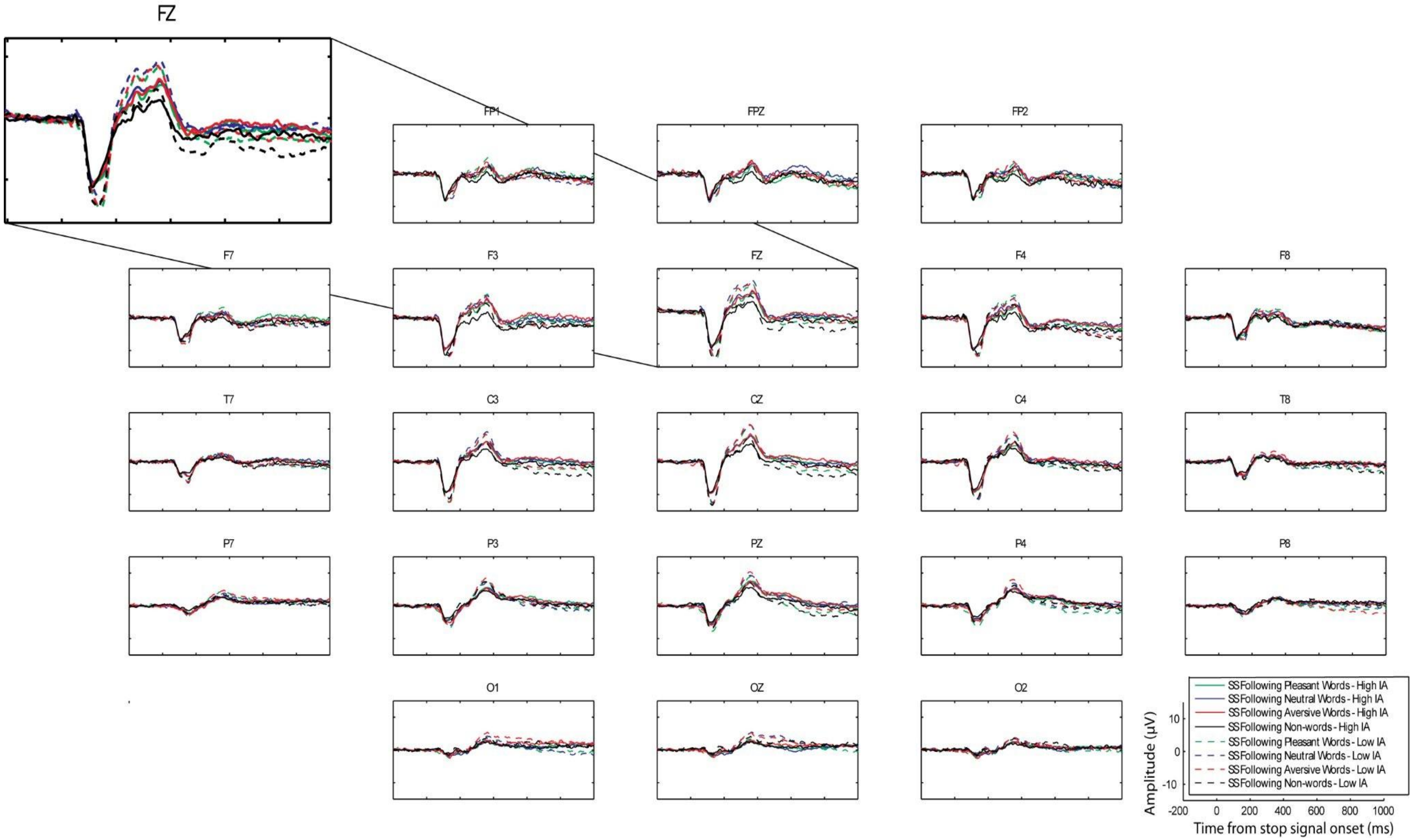

Figure 5. Grand average waveforms following stop signal (SS) onset by preceding pleasant, neutral, aversive, and non-words. Waveforms are shown median split on impulsive antisociality (IA) score. The highlighted electrode shows reductions in SS P3 amplitude for SS following non-words as well as a reduction in N1 amplitude following all SS and a reduction in SS P3 following words for those high in IA at FZ.

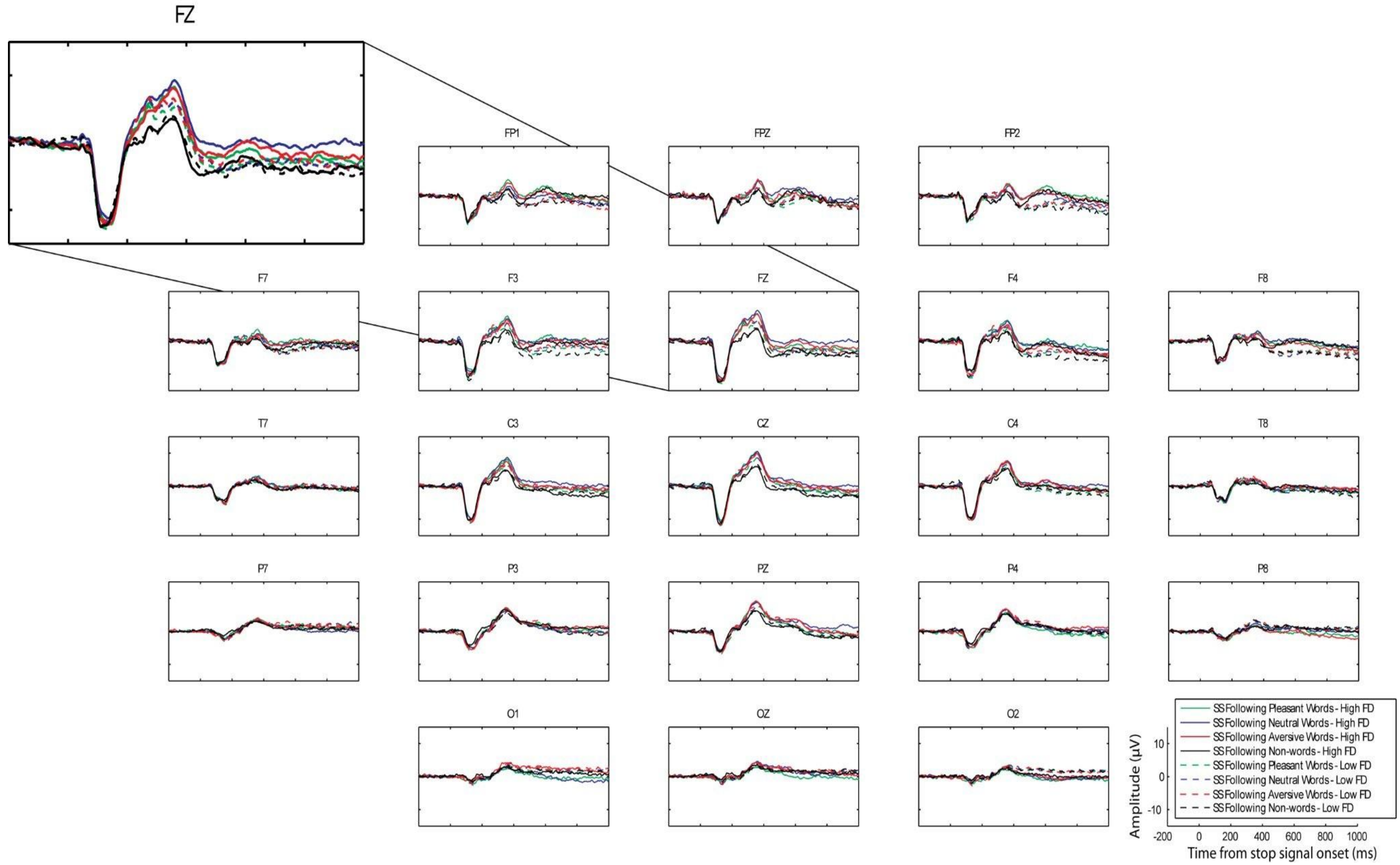

Figure 6. Grand average waveforms following stop signal (SS) onset by preceding pleasant, neutral, aversive, and non-words. Waveforms are shown median split on fearless dominance (FD) score. The highlighted electrode shows reductions in SS P3 amplitude for SS following non-words. There are no differences in SS processing for FD.

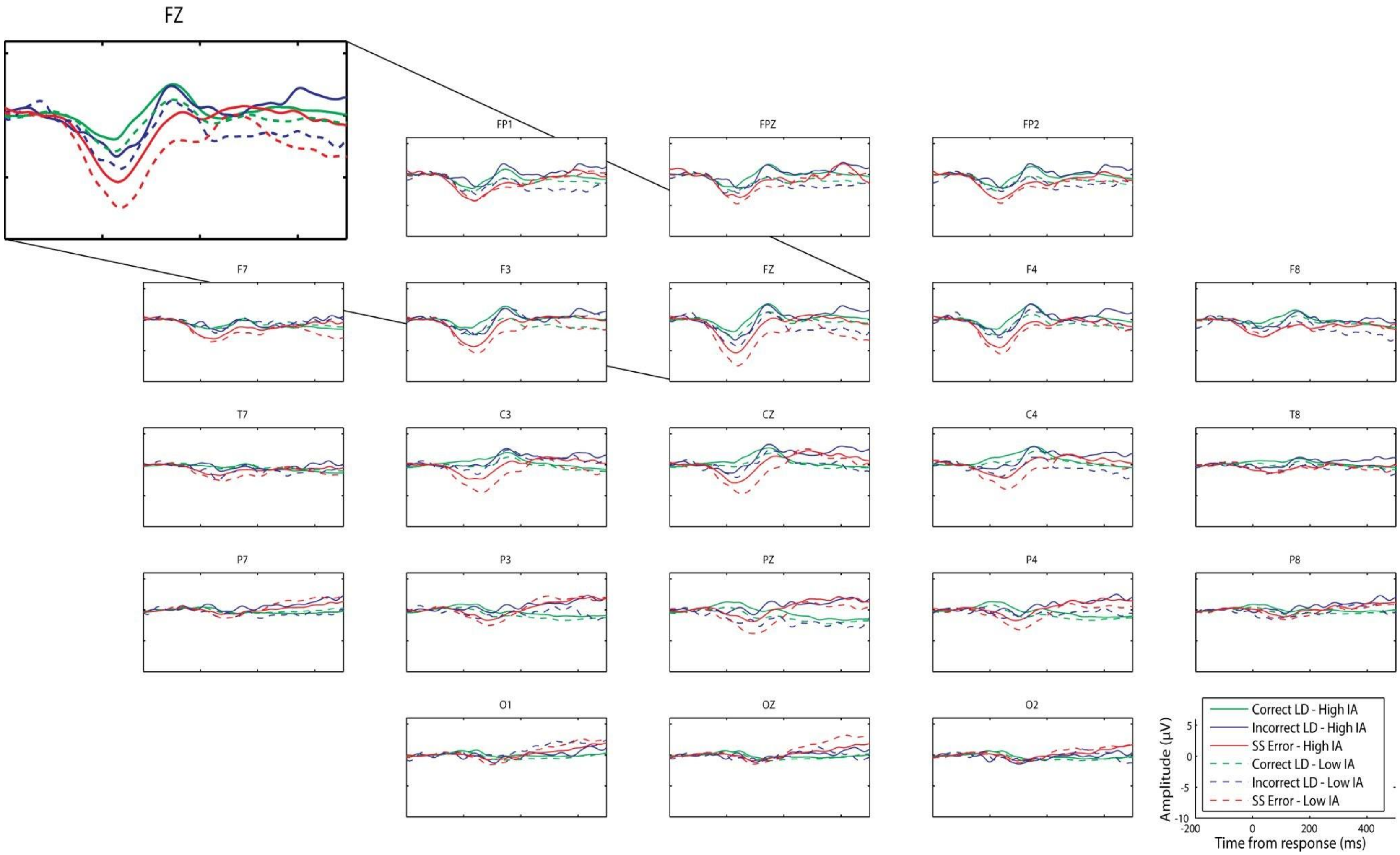

Figure 7. Grand average waveforms following correct lexical decisions (LD), incorrect LD, and incorrect stop signal (SS) responses. Waveforms are shown median split on impulsive antisociality (IA) score. The highlighted electrode shows the reduction in ERN amplitude following all responses for those high in IA.

Table 7

Correlations between Task Engagement and Fearless Dominance, Impulsive Antisociality, Behavioral Measures, and ERP Responses

Question	Psychopathy Scores		Behavioral Measures				
	FD Score	IA Score	RT	LD Accuracy	SS Accuracy	SS Delay	SSRT
Overall Engagement	.13	-.21^{+}	-.03	.37**	.09	.05	-.11
Task Importance	.09	-.16	.11	.21^{+}	-.08	.07	.00
LD Effort	-.18	-.22^{+}	-.11	.46**	.02	-.04	-.05
SS Effort	-.10	-.14	.09	.14	.11	.05	.01
	ERP Responses						
	Word P3	Non-word P3	SS P3	SS N1	Incorrect LD ERN	Correct LD ERN	SS Error ERN
Overall Engagement	-.05	.15	.02	-.22^{+}	-.15	-.06	-.25*
Task Importance	-.09	.06	.09	-.02	.10	.01	-.06
LD Effort	-.03	.14	.01	-.01	-.12	.08	.00
SS Effort	.16	.21	.-.01	-.03	-.07	.05	.05

Note: +*p* < .10, ** *p* < .01. LD = lexical decision, FD = fearless dominance, IA = impulsive antisociality, RT = reaction time, SS = stop signal, SSRT = stop signal reaction time. Overall Engagement = "How engaged were you in this task?", Task Importance = "How important did you think this task was?", LD Effort = "How hard did you try to respond word or non-word correctly?", SS Effort = "How hard did you try to avoid making a mistake like responding when you shouldn't have?".

engaged overall. Therefore, these engagement responses were entered as control variables in partial correlations between FD, IA, and the behavioral and ERP measures to determine if engagement influenced these relationships. As shown in Table 3, after controlling for overall engagement and LD effort all relationships between IA and SS and response related ERP magnitudes remained significant. IA also remained significantly related to all behavioral measures except for LD accuracy, which became non-significant (p = .13). Controlling for engagement did not appreciably change the relationships between FD and any of the ERP or behavioral measures.

Mediation of ERN Deficits by Stimulus Processing

To examine whether deficient processing of the text stimuli or the stop signal in IA mediated the deficits in outcome monitoring, bootstrapped mediation analyses (Preacher & Hayes, 2008) were performed. In these three analyses, those components that showed significant correlations with IA (Text P2, SS N1, and SS P3) were entered in separate analyses as mediators of the IA → ERN relationship for each of the three ERN amplitudes. As shown in the left half of Table 8, participants' SS N1 amplitude significantly mediated the effects of IA on ERN following correct LD, incorrect LD, and SS errors. Word P2 amplitude also significantly mediated the relationship between IA and ERN following incorrect LD. SS P3 did not significantly mediate the relationship between IA and ERN.

However, because ERN amplitudes following each type of response were all significantly correlated (rs > .32, ps < .01), it was unclear if the response to one condition drove the relationships between IA and the other conditions. Therefore, to generate new variables that represented the unique variance associated with each ERN, separate linear

Table 8

Mediation of the Relationship between IA and ERN Amplitude by Text P2, Word P3, SS N1, and SS P3 Amplitudes

Response Type	Point Estimate	95% C.I.	Point Estimate	95% C.I.
	Raw ERN by Word P2		Unique ERN Variance by Word P2	
Incorrect LD	**1.02**	**[0.27, 2.48]**	0.89	[-0.22, 2.18]
Correct LD	0.12	[-0.19, 0.48]	-0.04	[-0.38, 0.15]
SS Error	0.18	[-0.23, 0.66]	-0.07	[-0.55, 0.16]
	Raw ERN by SS N1		Unique ERN Variance by SS N1	
Incorrect LD	**0.80**	**[0.15, 1.77]**	-0.08	[-0.82, 0.62]
Correct LD	**0.55**	**[0.28, 1.03]**	0.07	[-0.21, 0.45]
SS Error	**1.42**	**[0.79, 2.25]**	**0.86**	**[0.38, 1.63]**
	Raw ERN by SS P3		Unique ERN Variance by SS P3	
Incorrect LD	0.14	[-0.51, 1.28]	0.11	[-0.34, 1.20]
Correct LD	0.04	[-0.17, 0.39]	0.02	[-0.08, 0.33]
SS Error	0.04	[-0.12, 0.49]	-0.01	[-0.27, 0.10]

Note: LD = lexical decision, SS = stop signal, C.I. = confidence interval. Text P2 is the peak amplitude following all text stimuli. Word P3 is the peak amplitude following words only. SS N1 is the peak amplitude following all SS. SS P3 is the peak amplitude following all word SS. Bold values indicate significant mediation.

regressions were conducted with each ERN as the dependant variable and the other two as predictors. The unstandardized residuals were saved from these analyses as a measure of the unique variance in each ERN not accounted for by the other two ERNs. As displayed in Table 9, the SS error ERN significantly predicted each LD ERN, and the two LD ERNs independently predicted SS ERN. IA was no longer significantly correlated with the unique variance associated with ERN following incorrect LD (r = .17), correct LD (r = .15), or SS errors (r = .10). FD was still not correlated with any ERN amplitude.

These residuals were then subjected to the same mediation analyses, which revealed that N1 amplitude only mediated the relationship between IA and the unique variance in the ERN following SS errors (displayed in the right half of Table 8). This indicates a specific relationship between SS processing and subsequent processing of SS inhibition errors that is deficient in IA. Word P2 did not mediate the relationship between IA and the unique variance associated with ERN following LD errors.

Because of this specific relationship between IA and processes related to the SS, the same bootstrapped mediation analyses were conducted on the relationship between IA and each behavioral measure, separately controlling for N1 amplitude to the SS and ERN following SS errors. Text P2 and SS P3 were also included as mediators between IA and behavioral performance in separate analyses in order to rule out any other possible effects of stimulus processing. Table 10 shows that N1 and SS ERN amplitude significantly mediated the relationship between IA and LD accuracy, SSD, and SSRT; text P2 and SS P3 did not. Together these results indicate that deficits in initial SS processing in IA influence subsequent error processing and stopping behavior and that deficits in error monitoring also influence overall task performance.

Table 9

Summary of Regression Analysis Predicting ERN Amplitudes

Independent Variable	Dependent Variable				
	B	SE(B)	β	*t*	Sig. (*p*)
	Incorrect LD ERN				
Correct LD ERN	.262	.278	.120	.942	.349
SS Error ERN	.517	.176	.374	2.93	.005
	Correct LD ERN				
Incorrect LD ERN	.049	.051	.106	.942	.349
SS Error ERN	.312	.071	.492	4.39	.000
	SS Error ERN				
Incorrect LD ERN	.214	.073	.296	2.93	.005
Correct LD ERN	.699	.159	.444	4.39	.000

Note: LD = lexical decision, SS = stop signal. Residuals from these analyses were used in mediation analyses as indicators of the unique variance associated with each ERN.

Table 10

Mediation of the Relationship between IA and Behavioral Performance Measures by Text P2, SS N1, SS P3, and ERN Amplitude

Behavioral Measure	Point Estimate	95% C.I.	Point Estimate	95% C.I.
	Behavior by Text P2 Amplitude		Behavior by SS P3 Amplitude	
Accuracy	-0.01	[-0.03, 0.00]	-0.00	[-0.10, 0.00]
SS Accuracy	0.00	[-0.01, 0.01]	0.00	[-0.00, 0.01]
SS Delay	10.83	[-9.38, 55.46]	3.19	[-12.39, 32.50]
SSRT	0.95	[-16.38, 17.60]	-1.90	[-22.17, 7.11]
	Behavior by SS N1 Amplitude		Behavior by SS ERN Amplitude	
Accuracy	**-0.017**	**[-.036, -.006]**	**-0.016**	**[-.034. -.004]**
SS Accuracy	-0.007	[-.019, .000]	-0.005	[-.016, .001]
SS Delay	**-36.40**	**[-74.4, -10.5]**	**-23.60**	**[-56.9, -6.59]**
SSRT	**26.60**	**[9.24, 59.4]**	**15.60**	**[4.69, 37.8]**

Note: LD = lexical decision, SS = stop signal, SSRT = stop signal reaction time, C.I. = confidence interval. Text P2 is the peak amplitude all following text stimuli at PZ. SS N1 is the peak amplitude following all SS at FZ. SS P3 is the peak amplitude following all word SS at CZ. Bold values indicate significant mediation.

CHAPTER IV

Discussion

Consistent with the impulsivity and low constraint that are prominent features of impulsive antisociality individuals high in IA showed an impulsive style of responding during the task as reflected by reduced LD and SS inhibition accuracy, shorter SSDs, and longer SSRTs. However, contrary to previous research (Carlson et al., 2008), IA was not significantly related to a reduction in P3 amplitude following the onset of the text. This result is likely due to differences in task demands such as stimulus and task complexity. In the traditional rotated heads task stimuli are simple shapes, not words, and the response requires a spatial determination (the ear is on the left or right) instead of a language based decision. Additionally, the stimuli in the rotated heads task are typically presented for less than 100 ms and the majority of trials do not require a response. Therefore, although the non-words were less frequent that the words (similarly to the targets in the rotated heads task), they were not the sole target stimuli. Words were also targets in that a decision must be made between the two options and a response was required on every trial. Therefore, reductions in P3 amplitude typically seen in externalizing disorders may be more target related, which this task did not test.

The lack of findings related differences in to valence modulation in both FD and IA may also be due to demands within the task. Previous research has shown psychopaths to exhibit ERP modulation for emotional stimuli when instructed to attend to the valence of the stimuli but not when it is irrelevant to the task (Anderson & Stanford, 2012). In this task word valence was not task relevant and may have not been attended to as fully as if participants had been instructed to indicate the valence of the word. Additionally, compared to earlier components like the P1 and P2, the P3 component may be more sensitive to task demands (Kissler et al., 2006) and therefore the effect for word vs. non-word overpowers most of the effect of valence. However, although only P3 following aversive words was significantly greater than following neutral words our results do follow the same pattern as that found by Williamson, Harpur, & Hare, (1991) with P3 following aversive words greater than pleasant, which were in turn greater than neutral indicating that perhaps the valence of the words was not salient enough to produce a significant effect.

Additionally, the findings related to early sensory and attentional components being modulated by word valence and lexical status, although not entirely consistent, do generally follow the results found in previous research. Generally, as we see here, previous research has shown larger ERP amplitudes following emotional versus neutral stimuli (Anderson & Stanford, 2012; Kanske & Kotz, 2007; Kissler et al., 2006; Williamson et al., 1991). This lack of a deficit in processing of the go stimulus is also consistent with the predictions of the RMH which posits only deficits in processing of the peripheral cue.

Therefore, as expected, IA was associated with significantly reduced N1 amplitude following all SS, indicating a failure to fully process this cue. Additionally, the finding that this reduction was not related to the type of preceding text and was not mediated by the reduction in P2 amplitude or behavioral performance suggests a specific deficit related to SS processing in line with the RMH. Also consistent with previous research involving externalizing disorders and error-related brain activity (Hall et al., 2007), those high in IA showed reduced ERN amplitude across correct and incorrect trials, suggesting that IA is associated with reduced outcome monitoring generally as well as reduced error processing in particular.

As expected given the RMH participants' N1 amplitude significantly mediated the relationship between IA and ERN indicating that the deficits in IA related to processing cues that call for behavioral changes explain their deficits in processing errors when they fail to alter their behavior. Specifically, it was the relationship between IA and the unique variance associated with the ERN following SS inhibition errors that was mediated by N1 amplitude. This suggests that, broadly speaking, deficits in the processing of SS inhibition errors can be explained by the extent to which there is a deficit in SS processing.

Additionally, participants' overall level of engagement and LD effort did not explain the relationships between IA and other behavioral measures or ERP amplitudes. Thus, the impulsive response style, deficits in processing of peripheral cues, and deficits in error monitoring seen in IA are independent of their effort. Contrary to Leotti and Wager (2010), we did not find that effort or engagement correlated with any measure of stop signal performance.

As a whole, these results provide direct evidence for response modulation deficits specifically in IA. The finding that participants' N1 amplitude significantly mediated the relationship between IA and behavioral measures as well as IA and ERN also provides information about the temporal sequence of events involved in the stopping process more generally by showing that individuals who do not process the need to change their behavior are less likely to inhibit their response and then fail to fully process subsequent inhibition errors.

The lack of findings related to FD, particularly in relation to reaction time, is somewhat surprising. However, because FD was differentially related to early text processing as indicated by the P1 and P2 components, which were both positively related to RT, it may be the case that any RT benefit gained from increased P1 is offset by a reduction in processes associated with P2 amplitude. As for the RMH predictions for FD, it may be necessary to test a more nuanced form of behavioral adaptation or inhibition that what is measured by the SS task. Other paradigms with direct relevance to defensive processing might be needed to demonstrate RMH-predicted deficits in FD (Benning & Malone, 2010).

Limitations and Future Directions

The self-report assessment of engagement in this study was relatively brief. Future studies may benefit from using more variegated measures of engagement. However, the relationships between engagement, psychopathy, and behavioral measures were generally as expected indicating that this measure provided at least a reasonable assessment of participants' true level of effort.

Additionally, the influence of SS processing on subsequent events should also be assessed while manipulating the frequency of the SS along with the type and difficulty of the dominant task. In particular, the emotional salience of the go stimuli should be increased, perhaps by using requiring participants to respond by indicating the valence of the text. This may allow for individual differences in emotion processing to be more fully expressed and could elicit response modulation deficits in FD as well. Furthermore, in the current task, participants were required to stop following all tones and therefore the possibility of a general reduction in processing auditory stimuli in the midst of a visual task cannot be ruled out. To fully explore this possibility a selective stop signal task in which one two tones are presented, one which signals the need to stop and the other which is to be ignored, should be used. The prediction of the RMH would be that psychopathic individuals would show a selective reduction in processing the stop tone because it is the cue signaling the need to change behavior.

Finally, these findings also bear replication in other disinhibited populations, such as individuals with ADHD and substance abuse to explore the generalizability of response modulation deficits. If such deficits are shown to be generalizable to a variety of populations research may begin to look for ways to increase these individuals ability to process the cues and adapt their behavior accordingly. This may include providing rewards for stopping and using attentional re-training to make these individuals more aware of the cue.

In conclusion, the findings presented here show that deficits in the recognition of stopping errors are preferentially associated with IA and that these deficits are associated with reduced processing of peripheral cues which signal the need to change a behavior. Specifically, as expected based on the RMH, deficits in the processing of peripheral cues signaling the need to change a dominant response mediate deficits in subsequent error processing, rather than deficits in processing stimuli in the dominant task itself.

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Footnotes

[1] Three (Neumann, Malterer, & Newman, 2008) and four (Neumann, Hare, & Newman, 2007; Seibert, Miller, Few, Zeichner, & Lynam, 2011) factor models of psychopathy have also been proposed, although there is still considerable debate regarding the factor structure of various psychopathy measures as well as the construct itself (Hare & Neumann, 2010; Skeem & Cooke, 2010a, 2010b). We have elected to use the FD/IA model of psychopathy in this paper because of the body of research supporting it and its ability to parse the features of psychopathy into independent components.

[2] A similar pattern of results was found with the 12 participants with poor LD or SS accuracy included. Likewise, the pattern of results was essentially identical after controlling for alcohol and drug use symptomatology as assessed by the Alcohol Dependence Scale (Horn & Skinner, 1984) and the Short Drug Abuse Screening Test (Skinner, 1982).