



## Dysfunctional error-related processing in incarcerated youth with elevated psychopathic traits



J. Michael Maurer<sup>a,b,\*</sup>, Vaughn R. Steele<sup>a,b,c</sup>, Lora M. Cope<sup>d</sup>, Gina M. Vincent<sup>e</sup>,  
Julia M. Stephen<sup>a</sup>, Vince D. Calhoun<sup>a,f</sup>, Kent A. Kiehl<sup>a,b,\*</sup>

<sup>a</sup> The Mind Research Network, an affiliate of the Lovelace Biomedical and Environmental Research Institute (LBERI), Albuquerque, NM, United States of America

<sup>b</sup> Department of Psychology; University of New Mexico, Albuquerque, NM, United States of America

<sup>c</sup> Neuroimaging Research Branch, National Institute on Drug Abuse, Intramural Research Program, National Institutes of Health, Baltimore, MD, United States of America

<sup>d</sup> Department of Psychiatry and Addiction Research Center; University of Michigan, Ann Arbor, MI, United States of America

<sup>e</sup> Department of Psychiatry; University of Massachusetts Medical School, Worcester, MA, United States of America

<sup>f</sup> Department of Electrical Engineering; University of New Mexico, Albuquerque NM, United States of America

### ARTICLE INFO

#### Article history:

Received 25 September 2015

Received in revised form 16 February 2016

Accepted 16 February 2016

Available online 22 February 2016

#### Keywords:

Juvenile delinquency

Psychopathy

Event-related potentials

Principal component analysis

Error-related processing

### ABSTRACT

Adult psychopathic offenders show an increased propensity towards violence, impulsivity, and recidivism. A subsample of youth with elevated psychopathic traits represent a particularly severe subgroup characterized by extreme behavioral problems and comparable neurocognitive deficits as their adult counterparts, including perseveration deficits. Here, we investigate response-locked event-related potential (ERP) components (the error-related negativity [ERN/Ne] related to early error-monitoring processing and the error-related positivity [Pe] involved in later error-related processing) in a sample of incarcerated juvenile male offenders ( $n = 100$ ) who performed a response inhibition Go/NoGo task. Psychopathic traits were assessed using the Hare Psychopathy Checklist: Youth Version (PCL:YV). The ERN/Ne and Pe were analyzed with classic windowed ERP components and principal component analysis (PCA). Using linear regression analyses, PCL:YV scores were unrelated to the ERN/Ne, but were negatively related to Pe mean amplitude. Specifically, the PCL:YV Facet 4 subscale reflecting antisocial traits emerged as a significant predictor of reduced amplitude of a subcomponent underlying the Pe identified with PCA. This is the first evidence to suggest a negative relationship between adolescent psychopathy scores and Pe mean amplitude.

© 2016 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

### 1. Introduction

Psychopathy is a multifaceted personality disorder characterized by affective, interpersonal, and behavioral dysfunction. Psychopaths have been classically defined by their overall absence of moral emotions and their impulsive, irresponsible lifestyle (Hare, 1991, 2003). About 15–25% of incarcerated offenders meet the diagnostic criteria for psychopathy, with increased prevalence in higher security levels (Hare, 2003). This disconcerting population has often proven impervious to treatment intervention approaches, as highlighted by their increased propensity towards violent

recidivism (Hemphill et al., 1998; Rice & Harris, 1997). Researchers have recently attempted to delineate the adolescent manifestation of this condition, as personality traits are still in nascent stages of development. Intervention efforts targeted at youth may have a better chance of altering life-course persistent antisocial behavior if started early (Caldwell, 2011; Caldwell et al., 2007).

Youth scoring high on measures of psychopathic traits exhibit similar neurocognitive deficits as adult psychopathic offenders. For example, youth with elevated psychopathic traits exhibit increased behavioral impulsivity (Roussy & Toupin, 2000), reduced sensitivity to punishment cues (Vitale et al., 2005), and passive avoidance learning (Finger et al., 2008) deficits. Furthermore, using both functional and structural neuroimaging, abnormalities have been observed in youth with elevated psychopathic traits consistent with adult psychopathic offenders as young as fourteen years of age (Cope et al., 2014; Ermer et al., 2013; Harenski et al., 2014; Lockwood et al., 2013; Marsh et al., 2008). Reduced hemodynamic

\* Corresponding authors at: Mind Research Network; 1101 Yale Boulevard NE, Albuquerque, NM 87106. Tel.: +505 925 4516.

E-mail addresses: [jmmaurer@unm.edu](mailto:jmmaurer@unm.edu) (J.M. Maurer), [kkiehl@unm.edu](mailto:kkiehl@unm.edu) (K.A. Kiehl).

activity and reduced gray matter have been found in a number of paralimbic regions, including the orbitofrontal cortex (Cope et al., 2014; Ermer et al., 2013), insula (Lockwood et al., 2013), amygdala (Harenski et al., 2014; Marsh et al., 2008), posterior cingulate cortex (PCC) (Ermer et al., 2013), parahippocampal gyrus (Ermer et al., 2013), and anterior cingulate cortex (ACC) (Cope et al., 2014; Ermer et al., 2013; Marsh et al., 2008).

One additional cognitive deficit juveniles with elevated psychopathic traits may experience is the processing of error-related information. Youth with elevated psychopathic traits often perseverate during behavioral inhibition and experimental learning paradigms, failing to adjust their behavior to meet the demands established by external sources (Budhani & Blair, 2005; Finger et al., 2008; Roussy & Toupin, 2000; Vitale et al., 2005). Event-related potentials (ERPs) are commonly used to examine different components of cognitive control including error-related processing. The two most frequently investigated error-related ERPs are the error-related negativity (the ERN or Ne) and the error-related positivity (Pe). Though closely related temporally, the ERN/Ne and Pe reflect distinct stages of error-related processing. The ERN/Ne reflects initial, automatic error-correction and action-monitoring processes (Falkenstein et al., 1991; Gehring et al., 1993; Yeung & Summerfield, 2012). However, the Pe is involved in later, more elaborative error-processing stages, indexing the accumulation of error-related information (Yeung & Summerfield, 2012), including the motivational (Ullsperger et al., 2010) or affective (Overbeek et al., 2005) appraisal of such stimuli. Additionally, the ERN/Ne is said to arise within the cognitive, caudal division of the ACC (cACC), whereas both the caudal and rostral portions (rACC) of the ACC contribute to Pe amplitude (Edwards et al., 2012; van Veen & Carter, 2002). However, recent evidence suggests that the ERN/Ne may be generated by the PCC (Agam et al., 2011), whereas the insula may additionally contribute to the Pe (Schroder et al., 2012; Ullsperger et al., 2010).

In adult psychopathic offenders, several studies have found comparable ERN/Ne amplitudes between adult psychopaths and control groups when using affectively neutral stimuli (Brazil et al., 2009; Brazil et al., 2011; Maurer et al., *in press*; Munro et al., 2007; Steele et al., 2016; von Borries et al., 2010). However, reduced ERN/Ne amplitude has been observed in adult psychopathic offenders when incorporating evocative angry and fearful facial stimuli (Munro et al., 2007).

Compared to the ERN/Ne, disparate findings have been observed regarding Pe amplitude in adult psychopathic offenders. Two previous reports with adult males and females have associated reduced Pe amplitude with increased psychopathy scores (Brazil et al., 2009; Maurer et al., *in press*). However, a recent report associated increased Pe amplitude with higher psychopathy scores in an incarcerated male sample (Steele et al., 2016). Intact ERN/Ne and deficits in Pe amplitude in adult offenders with elevated psychopathic traits suggests that this population can detect that an error has occurred, but exhibit specific dysfunction in regards to post-error processing. Reduced Pe amplitude in adult psychopathic offenders suggests a specific deficit in using information received from errors to improve future behavior (Brazil et al., 2009; Maurer et al., *in press*), which may partly explain this population's increased propensity towards perseveration in experimental learning paradigms (Newman & Kosson, 1986). Importantly, the Pe component has been shown to be malleable, increasing in amplitude through mindfulness meditation intervention (Larson et al., 2013). Thus, the present study sought to examine whether adolescent psychopathy scores were associated with reduced Pe amplitude. If hypotheses are confirmed, the Pe may be a target for future interventions, such as mindfulness, to help ameliorate dysfunctional post-error processing.

Despite interest in the electrophysiological correlates of adult psychopathic offenders, such processes have never been

investigated in youth with elevated psychopathic traits. Here, we address this issue by reporting on error-related electrophysiological indices using ERPs and a response inhibition Go/NoGo paradigm in a sample of incarcerated male adolescents. Psychopathic traits were assessed using the Hare Psychopathy Checklist: Youth Version (PCL:YV) (Forth et al., 2003), a downward extension of the Hare Psychopathy Checklist–Revised (PCL-R) (Hare, 2003) modified for age appropriateness.

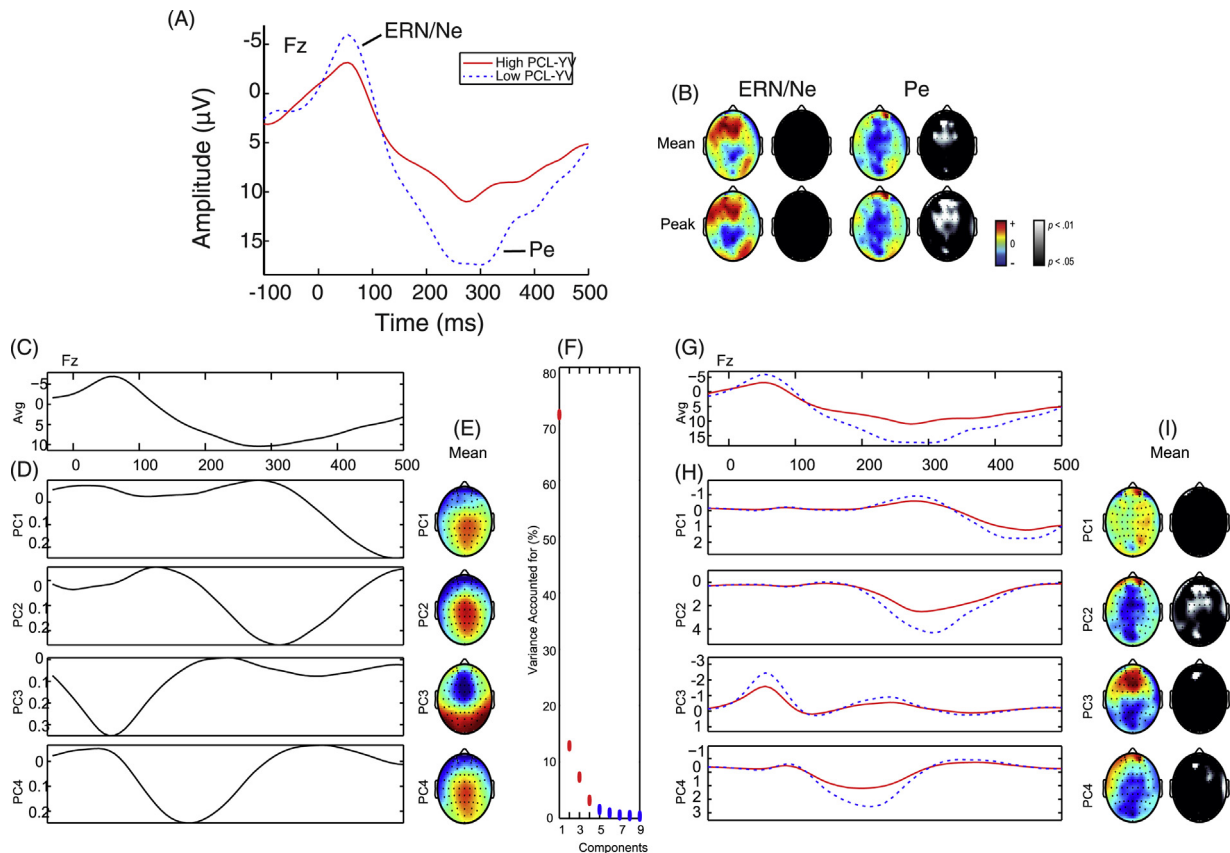
Based on previous error-related ERP studies performed with adult psychopathic offenders (Brazil et al., 2009; Brazil et al., 2011; Maurer et al., *in press*; Munro et al., 2007; Steele et al., 2016; von Borries et al., 2010), we hypothesized adolescent psychopathy scores would be unrelated to early, action-monitoring processes, as indexed by intact ERN/Ne amplitude. In addition, we hypothesized adolescent psychopathy scores would be negatively related to Pe amplitude, consistent with previous studies with adult psychopathic offenders (Brazil et al., 2009; Maurer et al., *in press*), but contrary to a recent report with adult psychopathic male offenders (Steele et al., 2016). An increased Pe amplitude observed with adult psychopathic male offenders may result from a compensatory mechanism, attempting to overcome initial post-error processing deficits experienced as adolescents. In addition to the use of traditional time-domain ERP analyses, we incorporated an approach based on principal component analysis (PCA), which provides a robust decomposition of overlapping variance both between and within ERP components (Bernat et al., 2011; Dien et al., 2007). This approach has been incorporated in a number of reports (Anderson et al., 2015; Maurer et al., *in press*; Steele et al., 2015; Steele et al., 2014; Steele et al., 2016), providing a more sensitive and predictive measure compared to traditional time-domain ERP analyses. In the current report, four principal components were extracted, one reflecting mean ERN/Ne amplitude, and the remaining three reflecting early, middle, and late subcomponents underlying the Pe (see Fig. 1). The three separate subcomponents underlying the Pe appear to reflect unique patterns of cognitive processing and hemodynamic activity in subregions of the ACC (Edwards et al., 2012). In particular, the early Pe subcomponent has been previously associated with both cACC and rACC activity, the middle Pe subcomponent has been associated with cACC activity, and the late Pe subcomponent has been associated with rACC activity (Edwards et al., 2012). In regards to PCA analyses, we hypothesized adolescent psychopathy scores would be negatively related to a middle subcomponent underlying the Pe, which has been shown to be dysfunctional in previous reports (Maurer et al., *in press*; Steele et al., 2016).

## 2. Method

### 2.1. Participants

Participants were 142 incarcerated adolescents at a maximum-security juvenile detention center who participated in a larger study (Southwest Advanced Neuroimaging Cohort–Youth (SWANC–Y)). The sample was predominantly right-handed (7% reported being left-hand dominant). Participants were predominantly Hispanic/Latino (76%), with the remaining self-identifying as Black/African American (12%), White (10%), or more than one category (2%).

Incarcerated adolescents are considered a vulnerable population for research, so extra precautions were taken in order to minimize the potential for coercive influences that could reduce their ability to provide voluntary consent to participate (Edens et al., 2011; Gostin et al., 2007). For example, potential study participants may feel inclined to participate in research in order to relieve boredom and interact with people from outside the prisons (Edens et al., 2011). With the issue of coercion in mind, we did our best



**Fig. 1.** Response-locked event-related potential (ERP) and principal component analysis. (A) Representative ERP waveform plotted at Fz for each group with negative plotted up. Youth with elevated psychopathic traits (PCL:YV Total score > 30,  $n = 21$ ) (red) and youth with low levels of psychopathic traits (PCL:YV Total score < 20,  $n = 22$ ) (dotted blue) are plotted. ERP components of interest (the error-related negativity [ERN/Ne] and error-related positivity [Pe]) are identified. (B) Topographic difference (color) and statistical (black and white) maps are plotted for each component window highlighting youth with elevated psychopathic traits show reduced Pe amplitude. (C) Grand average waveform plotted at Fz. (D) Principal components extracted accounting for 94.97% of the variance. (E) Topographic depiction of the mean spatial distribution for each principal component. (F) Screen plot of singular values which was used to determine a four-component solution. (G) Group average waveform for youth with elevated psychopathic traits (red line) and low levels of psychopathic traits (blue line) are plotted at Fz. PC2 reflects Pe mean amplitude. (H) Principal components plotted by group. (I) Topographic difference (color) and statistical (black and white) maps are plotted for each principal component highlighting youth with elevated psychopathic traits show reduced Pe amplitude.

to ensure that study participants did not feel coerced in any way to participate. Accordingly, our recruitment procedure was as follows: Initial contact was made with potential study participants through announcements made at the detention center by trained research staff (not correctional staff). Meetings were scheduled with interested participants, providing them the opportunity to make an informed choice about participating. Participants 18 years of age or older provided written informed consent and participants younger than 18 years of age provided written informed assent in conjunction with parent/guardian written informed consent. Participants were informed of their right to terminate participation at any point, the lack of direct institutional benefits, and that their participation would not affect their facility status or release. Participants also received remuneration at the hourly labor wage of the facility. The University of New Mexico Health Science Center Human Research Review Committee and the Office of the Human Research Protections approved all procedures.

### 2.1.1. Assessments

Psychopathic traits were assessed by trained research assistants, graduate students, and postdoctoral researchers using the PCL:YV (Forth et al., 2003). The PCL:YV assesses interpersonal, affective, behavioral, and lifestyle features related to psychopathic traits in adolescents. Total scores can range from 0 to 40. There is currently no accepted diagnostic cutoff for youth psychopathy. For identification of specific psychopathic traits associated with

electrophysiological error-related indices, we used a two-factor model of psychopathic traits, with Factor 1 comprising interpersonal and affective traits and Factor 2 consisting of lifestyle and antisocial traits (Harpur et al., 1989). To allow for increased specificity, we also examined the four-facet model with four latent dimensions representing the underlying dimensions of psychopathy: interpersonal, affective, behavioral/lifestyle, and antisocial traits, respectively (Neumann et al., 2006). The mean PCL:YV Total score for this sample was 23.83 ( $SD = 6.46$ ). The mean Factor 1 score was 6.75 ( $SD = 3.19$ ) and the mean Factor 2 score was 12.78 ( $SD = 3.20$ ). PCL:YV Factor 1 and 2 scores were significantly correlated ( $r = .58, p < .001$ ), consistent with previous reports (Harpur et al., 1989). See Table 1 for the remaining correlations.

In addition to psychopathic traits, assessments were administered to assess intelligence quotient (IQ), substance dependence, mental illness, and traumatic brain injury (TBI) by trained research assistants, graduate students, and postdoctoral researchers. Exclusion criteria included: a full-scale IQ less than 70 ( $n = 0$ ), a TBI accompanied with a significant loss of consciousness ( $n = 4$ ), poor behavioral performance or significant movement during data collection ( $n = 16$ ), or personal history of bipolar or psychotic disorders ( $n = 0$ ). Participants were also excluded for mood disorders, including major depression ( $n = 10$ ), and anxiety disorders, including post-traumatic stress disorder (PTSD) ( $n = 3$ ), due to the important role these disorders play for both the ERN/Ne (Chiu & Deldin, 2007; Olivet & Hajcak, 2008) and Pe (Bridwell et al., 2015) amplitude.

**Table 1**  
Correlations among PCL:YV Variables and Covariates.

Variable	PCLYV Total	PCLYV Factor1	PCLYV Factor2	PCLYV Facet 1	PCLYV Facet 2	PCLYV Facet 3	PCLYV Facet 4	Age	IQ	Sub. Use
PCLYV Total	–									
PCLYV Factor 1	0.86**	–								
PCLYV Factor 2	0.90**	0.58**	–							
PCLYV Facet 1	0.66**	0.85**	0.39**	–						
PCLYV Facet 2	0.78**	0.84**	0.60**	0.42**	–					
PCLYV Facet 3	0.80**	0.50**	0.90**	0.34**	0.50**	–				
PCLYV Facet 4	0.78**	0.50**	0.86**	0.30**	0.54**	0.56**	–			
Age	0.08	0.08	0.02	0.15	–0.02	0.05	–0.02	–		
IQ	–0.05	0.07	–0.12	0.19	–0.07	–0.14	–0.08	0.05	–	
Sub. Use	0.33**	0.24**	0.30**	0.15	0.26**	0.32**	0.22**	–0.07	0.02	–

Note. Assessments: PCL:YV Total is the total score derived from the Psychopathy Checklist: Youth Version (PCL:YV); PCL:YV Factor 1 and 2 are Factor 1 and 2 scores derived from the PCL:YV; PCL:YV Facet 1, Facet 2, Facet 3, and Facet 4 scores are Facet 1, 2, 3, and 4 scores derived from the PCL:YV (Forth et al., 2003); Intelligence Quotient (IQ) was calculated from the Wechsler Adult Intelligence Scale–Third Version (WAIS-III) (Wechsler, 1997); Sub. Use is the number of substance dependencies calculated by summing the total number of substances (alcohol and drug) for which participants met lifetime dependence diagnoses from the Kiddie Schedule for Affective Disorders and Schizophrenia (K-SADS) (Kaufman et al., 1997).

\*\**p* < .05; \**p* < .01.

**Table 2**  
Descriptive statistics and independent samples *t*-tests for variables.

Variable	All Participants			PCL:YV Lower Quartile			PCL:YV Highest Quartile			<i>t</i>	df	<i>p</i>
	( <i>N</i> = 100)			( <i>N</i> = 22)			( <i>N</i> = 21)					
	<i>N</i>	Mean	SD	<i>N</i>	Mean	SD	<i>N</i>	Mean	SD			
PCL:YV Total	100	23.82	6.46	22	14.64	3.53	21	32.03	1.47	–20.93	41	< .001
PCL:YV Factor 1	100	6.75	3.19	22	3.45	2.11	21	11.05	1.36	–13.96	41	< .001
PCL:YV Factor 2	100	12.78	3.20	22	8.36	2.74	21	15.86	1.49	–11.08	41	< .001
PCL:YV Facet 1	100	2.24	1.91	22	1.09	1.60	21	4.76	1.14	–8.63	41	< .001
PCL:YV Facet 2	100	4.51	1.87	22	2.36	1.33	21	6.29	1.10	–10.51	41	< .001
PCL:YV Facet 3	100	6.52	2.02	22	3.91	1.54	21	8.19	1.17	–10.24	41	< .001
PCL:YV Facet 4	100	8.18	1.81	22	6.09	2.05	21	9.67	0.66	–7.64	41	< .001
Age	100	17.38	0.86	22	17.36	0.85	21	17.62	0.81	–1.01	41	.317
IQ	91	93.90	10.97	18	95.06	12.98	19	94.63	9.60	0.13	35	.910
Substance Use	100	2.33	1.67	22	1.55	1.14	21	2.67	1.93	–2.33	41	.025
ERN/Ne	100	–3.17	4.39	22	–3.69	4.96	21	–3.08	3.57	–0.46	41	.649
Pe	100	6.25	6.78	22	8.61	7.05	21	4.84	7.37	1.72	41	.093
PC1	100	0.31	0.41	22	0.37	0.48	21	0.30	0.38	0.55	41	.586
PC2	100	0.64	0.50	22	0.87	0.50	21	0.50	0.51	2.40	41	.021
PC3	100	–0.13	0.21	22	–0.17	0.21	21	–0.10	0.17	–1.11	41	.273
PC4	100	0.37	0.42	22	0.52	0.48	21	0.29	0.38	1.67	41	.102

Note. Assessments: PCL:YV Total is the total score derived from the Psychopathy Checklist: Youth Version (PCL:YV); PCL:YV Factor 1 and 2 are Factor 1 and 2 scores derived from the PCL:YV; PCL:YV Facet 1, Facet 2, Facet 3, and Facet 4 scores are Facet 1, 2, 3, and 4 scores derived from the PCL:YV (Forth et al., 2003); Intelligence Quotient (IQ) was calculated from the Wechsler Adult Intelligence Scale–Third Version (WAIS-III) (Wechsler, 1997); Substance Use is the number of substance dependencies calculated by summing the total number of substances (alcohol and drug) for which participants met lifetime dependence diagnoses from the Kiddie Schedule for Affective Disorders and Schizophrenia (K-SADS) (Kaufman et al., 1997); ERN/Ne, Pe, PC1, PC2, PC3, and PC4 refer to the mean amplitude of the time-domain and principal components pertaining to ERN/Ne and Pe amplitude.

Female participants (*n* = 9) were excluded from final analyses, as there were not enough female participants to power gender effects. Additionally, participants (*n* = 0) were excluded for making fewer than four errors. Reliability analyses suggest that the ERN/Ne and Pe can be quantified in as few as four to six trials (Olvet & Hajcak, 2009; Pontifex et al., 2010; Steele et al., in press). This resulted in a final sample of *n* = 100 male participants, ranging from 16 to 20 years of age (*M* = 17.38, *SD* = 0.86) at the time of electroencephalography (EEG) collection (Table 2).

We included the following covariates in addition to psychopathy variables in linear regression analyses: age, IQ, and number of substance dependencies. Full-scale IQ was estimated using the Vocabulary and Matrix Reasoning sub-tests of the Wechsler Adult Intelligence Scale (WAIS-III) (Wechsler, 1997) (*M* = 93.90, *SD* = 10.93); IQ scores were unavailable for *n* = 9 participants. Mental illness and substance dependence were assessed using the Kiddie Schedule for Affective Disorders and Schizophrenia (K-SADS) (Kaufman et al., 1997). Number of substance dependencies were calculated by summing the total number of substances (alcohol and drug) for which participants met lifetime dependence diagnoses (possible range 0–9, *M* = 2.33, *SD* = 1.68), as psychopathic

traits are often comorbid with substance use (Smith & Newman, 1990; Walsh et al., 2007). Complete collection of the full assessment protocol is difficult due to the nature of the prison institutional environment (e.g. unannounced facility transfers, early release, disciplinary actions, etc.).

2.2. Stimuli and task

EEG data were collected in a quiet, dimly lit room, reserved for EEG data collection at the correctional facility, separate from the general population housing. Participants were collected between 8:00 AM to 5:00 PM. After placement of electrodes, participants were seated in a comfortable chair 60 cm away from a computer monitor on which the task stimuli were presented and were instructed to refrain from excessive blinking and movement during data collection. Participants then performed a response inhibition Go/NoGo task (Kiehl et al., 2000) consisting of two experimental runs, each comprising 245 visual stimuli, each about seven minutes in duration. After the first run, participants were afforded the opportunity to take a break to minimize fatigue. Stimuli were presented to participants through the computer-controlled

Neurobehavioral Systems Inc. visual presentation software package, Presentation. Each stimulus appeared for 250 ms in white text within a continuously displayed rectangular fixation box. Participants were instructed to respond as quickly and accurately as possible with their right index finger on a computer keyboard every time the target Go stimulus (a white “X” appeared) and to withhold a response whenever the distracter NoGo stimulus (a white “K”) appeared. The stimuli subtended approximately  $3 \times 5$  visual degrees against a black background. Targets appeared with higher frequency (84%, 412 trials, with 206 on each run) than distracters (16%, 78 trials, with 39 on each run) to establish a strong stimulus-response mapping on Go trials. Two “K’s” were never presented sequentially. The inter-stimulus interval was pseudo-randomly jittered (1–3 s stimulus onset asynchrony [SOA] averaging 1.5 s). The SOA between Go stimuli varied to the constraint that three Go stimuli were presented within each 6 s period. The NoGo stimuli were interspersed among the Go stimuli in a pseudo-random manner subject to two constraints: the minimum SOA between Go and NoGo stimuli was 1000 ms and the SOA between successive NoGo stimuli was in the range 8 to 14 seconds. Hits were defined as successful responses to Go stimuli; False Alarms (FAs) were defined as incorrect responses to NoGo stimuli. Prior to recording, each participant performed a block of ten practice trials to ensure that directions were clearly understood.

### 2.3. EEG recordings

EEG data were collected using two computers and a 64-channel BioSemi amplifier. The first computer used Presentation software to deliver the stimuli, accept responses, and send digital triggers to the EEG acquisition computer when a stimulus or response occurred. The second acquired electroencephalographic data using BioSemi software and amplifiers. All signals collected with the BioSemi software were low-pass filtered using a fifth-order sinc filter with a half-power cutoff of 204.8 Hz, then digitized to 1024 Hz during data collection. EEG activity was recorded using sintered Ag-AgCl active electrodes placed in accordance with the 10–20 International System. The participant’s nose was used as a reference. Six electrodes were placed on the participant’s face to measure electrooculogram, above, below, and lateral to the canthus of each eye. All impedances were kept below 10 k $\Omega$ .

### 2.4. Analytic strategy

Pre-processing included down-sampling to 512 Hz, bad channel detection and replacement, epoching, eye-blink removal, and low-pass filtering to 15 Hz. Bad channels were identified as having activity four standard deviations away from all other non-ocular channels. These channels were replaced using the mean of surrounding electrodes. ERP epochs were defined relative to the response, from 1000 pre- to 2000 ms post-response. An independent component analysis (ICA) eye-blink removal protocol was also performed. The ICA utility in EEGLab software (Delorme & Makeig, 2004) was used to derive components; then, using an in-house template matching algorithm (Jung et al., 2000) blink components were identified and removed from the data.

Classic time-domain response-locked ERP components, relative to a False Alarm were extracted: the ERN/Ne, the mean amplitude of the negative deflection occurring 0–100 ms and the Pe, the mean amplitude of the positive deflection, occurring 94–500 ms. Response-locked components were baseline corrected with a –200 to –50 ms window relative to FAs. Within each trial, individual electrodes with activity exceeding  $\pm 100 \mu\text{V}$  were omitted from analyses. Applying these criteria, 20.72% of response-locked trials were excluded from analyses. An additional data reduction method,

PCA, was also performed. Temporal PCA with varimax rotation was carried out on the covariance matrix from all electrodes to define a four component response-locked component solution for FA stimuli accounting for 94.97% of the variance. A subset of nine electrodes representing maximal time-domain component activation were selected for the ERN/Ne and Pe (AF3, AFz, AF4, F3, Fz, F4, FC3, FCz, and FC4) and used in both time-domain and PCA analyses below. Linear regression analyses were carried out on all  $n = 100$  participants to predict mean time-domain and PCA decompositions reflecting mean ERN/Ne and Pe amplitude using psychopathy variables and three covariate measures: age, IQ, and number of substance dependencies to take full advantage of our large sample size. Effects that did not reach statistical trend ( $p \geq .10$ ) are not reported.

## 3. Results

### 3.1. Behavioral results

Response times (RTs) and frequency for Hits and FA’s were analyzed. As expected, participants responded faster to NoGo stimuli ( $M = 381$  ms,  $SD = 43$  ms) than Go stimuli ( $M = 419$  ms,  $SD = 51$  ms),  $t(99) = 7.74$ ,  $p < .001$ . Participants made significantly more errors (FA’s) to NoGo stimuli ( $M = 23.76$ ,  $SD = 11.85$ , range 4–63) compared to Go (Hits) stimuli ( $M = 12.61$ ,  $SD = 14.65$ ),  $t(99) = 17.89$ ,  $p = .001$ . There was a main effect for post-error slowing (PES) ( $M = 28$  ms,  $SD = 73$  ms), defined as the difference in RT for Go stimuli preceded by a correct response to NoGo stimuli versus an incorrect response to NoGo stimuli; thus, incorrect responses to NoGo stimuli should result in a subsequent slowing to Go stimuli compared to correct responses to NoGo stimuli (Rabbitt, 1981). Participants responded more slowly after error trials ( $M = 384$  ms,  $SD = 84$ ) than after correct trials ( $M = 356$  ms,  $SD = 33$  ms),  $t(99) = 3.86$ ,  $p < .001$ . PES did not correlate with PCL:YV variables (Total, Factor, or Facet scores), covariate measures, time-domain, or PCA measures reflecting ERN/Ne and Pe mean amplitude ( $r$ ’s  $< .15$ ). Psychopathy variables and other covariates were not significantly correlated with response times or error rates ( $r$ ’s  $< .15$ ).

### 3.2. Time-domain ERP linear regression analyses

Separate linear regressions were performed to assess unique contributions to mean ERN/Ne and Pe amplitude measured with traditional classic windowed ERP components and PCA with all  $n = 100$  participants. Each of the six regressions performed had an ERP component as the dependent measure (i.e., in three regressions ERN/Ne mean amplitude was the dependent variable and in the other three regressions Pe mean amplitude was the dependent variable). PCL:YV measures (Regression 1: PCL:YV Total; Regression 2: PCL:YV Facets 1–4 (interpersonal, affective, lifestyle, and antisocial traits, respectively); and Regression 3: PCL:YV Factor 1 (interpersonal and affective traits) and Factor 2 (lifestyle and antisocial traits)); and three covariate measures (age, IQ, and number of substance dependencies) were entered as simultaneous predictor variables. PCL:YV Facet scores were measured before Factor scores, as they provide a more precise measure of specific psychopathic traits (Neumann et al., 2006).

In addition, we implemented a Simes-Hochberg correction to all linear regression analyses (Hochberg, 1988; Simes, 1986) to maintain the family wise error rate at an acceptable rate. This correction is in the class of sequential Bonferroni correction methods, which consists of arranging the obtained  $p$ -values within a family of tests from largest to smallest and excluding tests on a sequential basis on whether they are associated with a  $p$ -value that is less than a previously adjusted alpha level. Therefore, all significant results reflect this correction.

Using the Simes-Hochberg correction, neither PCL:YV scores (Total, Factor, and Facet scores) or covariate measures included in analyses (age, IQ, and number of substance dependencies) were significant predictors of either ERN/Ne or Pe mean amplitude.

### 3.3. PCA ERP linear regression analyses

Linear regression analyses were also performed to assess the amount of variance in four PCA-derived subcomponents (one measuring ERN/Ne mean amplitude [PC3] and three components measuring early, middle, and late subcomponents of the Pe [PC1, PC2, and PC4] explained by PCL:YV variables. Like before, PCL:YV Total, Factor, or Facet scores were the predictor variables of interest in three separate regression models for each ERP subcomponent, along with age, IQ, and number of substance dependencies as covariates.

Using the Simes-Hochberg correction, neither psychopathy variables or the three covariates were significant predictors of PC3 mean amplitude, reflecting the ERN/Ne. Similarly, psychopathy variables and covariate measures were not significant predictors of PC1 or PC4 mean amplitude, reflecting early and late subcomponents underlying the Pe. Elevated psychopathy scores were negatively related to PC2 mean amplitude, reflecting the middle subcomponent underlying the Pe. In separate linear regression analyses, PCL:YV Total ( $p=.037$ ) and Facet 4 (antisocial traits) ( $p=.011$ ) emerged as significant predictors of reduced PC2 mean amplitude (Table 3). PCL:YV Factor 2 scores emerged as a marginally significant predictor of reduced PC2 mean amplitude ( $p=0.039$ ) with the implementation of the Simes-Hochberg correction.

## 4. Discussion

Psychopathy is a serious personality disorder with enormous societal cost. Given the importance of this construct, research has sought to understand the adolescent manifestation of this condition. The prevailing view is that intervention efforts targeted towards youth will have a better chance of altering life-course persistent antisocial behavior if started early (Caldwell, 2011; Caldwell et al., 2007). Here, we examined whether adolescent psychopathy scores were associated with reduced Pe amplitude. Participants provided informed consent, and were not coerced in any way to participate in the current study, which is especially important when collecting data from incarcerated settings (Edens et al., 2011; Gostin et al., 2007).

In the current report, psychopathy scores were not related to ERN/Ne amplitude, consistent with previous reports with adult offenders with elevated psychopathic traits when using affectively neutral stimuli (Brazil et al., 2009; Brazil et al., 2011; Maurer et al., in press; Munro et al., 2007; Steele et al., 2016; von Borries et al., 2010). However, adolescent psychopathy scores were negatively related to Pe amplitude, consistent with two previous reports with adult males and females with elevated psychopathic traits (Brazil et al., 2009; Maurer et al., in press), but inconsistent with a recent report with incarcerated adult males with elevated psychopathic traits (Steele et al., 2016). Taken together, our current results suggest that adolescent psychopathy scores, specifically Facet 4 (antisocial) traits, are not associated with dysfunctional error-correction and action-monitoring processes (Falkenstein et al., 1991; Gehring et al., 1993; Yeung & Summerfield, 2012), but are associated with specific deficits in post-error processing.

Our results were most strongly supported through the use of PCA to separate overlapping variance between and within ERP components. PCA identified three subcomponents underlying the time-domain Pe component: an early, middle, and late subcomponent. Elevated psychopathic scores were negatively related to the middle subcomponent underlying the Pe in Principal Component

2. This subcomponent has a similar temporal distribution as a subcomponent defined in a previous report associated with cACC activity (Edwards et al., 2012). Reduced Pe amplitude has also been suggested as a specific deficit in using information received from errors to improve future behavior (Brazil et al., 2009). This Pe reduction could help explain a variety of deficits youth with elevated psychopathic traits experience, including increased behavioral impulsivity (Roussy & Toupin, 2000), and reduced performance in passive avoidance learning paradigms (Finger et al., 2008).

PCL:YV Facet 4, reflecting antisocial and criminogenic behavioral traits, emerged as a significant predictor of reduced Pe mean amplitude. This antisocial facet includes traits directly tapping into the early onset of psychopathic traits, including early behavioral problems before the age of 12 (Forth et al., 1990; Neumann et al., 2011). The emergence of early antisocial behavior in youth is an important predictor for the development of psychopathy in adulthood (Frick et al., 2003). Some remain apprehensive over the inclusion of this antisocial facet within the superordinate construct of psychopathy, believing criminal and antisocial behavior to be a consequence, rather than a foundation of psychopathic traits (Cooke & Michie, 2001; Skeem & Cooke, 2010). Others argue that eliminating this antisocial facet may result in a considerable narrowing of the psychopathy construct, particularly in regards to the developmental course of psychopathic traits (Hare & Neumann, 2010; Lynam, 1997; Neumann et al., 2011).

Results of the present study indicate Facet 4 traits contribute considerable importance for future research investigating the neurodevelopmental course of psychopathy. A negative association between Facet 4 traits and Pe mean amplitude may enable researchers to identify a subset of youth on a life-course persistent trajectory towards severe antisocial behavior. Specifically, reduced post-error processing of errors may result in an inability for such youth to learn from their mistakes, resulting in an increased propensity towards severe antisocial behavior, incarceration, recidivism, and substance use proclivity (Edens et al., 2007; Gregory et al., 2015).

The examination of the Pe with an at-risk juvenile sample is particularly intriguing within the developmental context of this ERP component. Compared to the ERN/Ne, which increases in amplitude throughout adolescence, the Pe's development is rather invariant, showing comparable amplitudes between youth and adult samples (Davies et al., 2004; Ladouceur et al., 2007; Santesso et al., 2006). Reduced Pe amplitude could suggest a potential biological vulnerability marker for the development of life-course persistent psychopathic traits. Furthermore, a recent report associated increased Pe amplitude with elevated psychopathic traits in an incarcerated adult male sample (Steele et al., 2016). Increased Pe amplitude in adulthood may reflect a compensatory mechanism, attempting to overcome initial post-error processing deficits experienced in adolescence in individuals with elevated psychopathic traits. Additionally, Pe amplitude has been shown to increase through mindfulness meditation training (Larson et al., 2013). These results suggest that the developmental anomaly in reduced Pe amplitude observed in youth with elevated psychopathic traits may be able to increase and stabilize in amplitude through specialized treatment intervention approaches.

### 4.1. Limitations

Psychopathic traits, at least at moderate levels detected early in life, often reduce naturally in a large proportion of youth samples (Frick et al., 2003; Lee et al., 2009; Lynam et al., 2007). The best evidence of continuity from adolescence to adulthood comes from longitudinal research using both self-report and interview-based measures of psychopathic traits, showing moderate stability from age 13 to 23 (Lynam et al., 2007). As such, there exists the

**Table 3**  
Linear regression analyses with psychopathy variables entered with covariates predicting principal component 2 (PC2) mean amplitude.

Predictors	B	SE B	t	$\beta$	Sig.
Regression 1:					
PCL:YV Total	−0.018	0.008	−2.112	−.218	.037
IQ			0.857		.394
Age			−1.643		.104
Sub. Use			−1.263		.210
Regression 2:					
PCL:YV Facet 1			0.687		.494
PCL:YV Facet 2			0.091		.927
PCL:YV Facet 3			−0.183		.855
PCL:YV Facet 4	−0.073	0.028	−2.609	−.267	.011
IQ			0.755		.452
Age			−1.825		.071
Sub. Use			−1.305		.195

Regression 1:  $R^2 = .048$ ,  $R = .218$ ,  $F(1,89) = 4.461$ .

Regression 2:  $R^2 = .071$ ,  $R = .267$ ,  $F(1,89) = 6.806$ .

Note. Assessments: PCL:YV Total is the total score derived from the Psychopathy Checklist: Youth Version (PCL:YV); PCL:YV Factor 1 and 2 are Factor 1 and 2 scores derived from the PCL:YV; PCL:YV Facet 1, Facet 2, Facet 3, and Facet 4 scores are Facet 1, 2, 3, and 4 scores derived from the PCL:YV (Forth et al., 2003); Intelligence; Intelligence Quotient (IQ) was calculated from the Wechsler Adult Intelligence Scale–Third Version (WAIS-III) (Wechsler, 1997); Sub. Use is the number of substance dependencies calculated by summing the total number of substances (alcohol and drug) for which participants met lifetime dependence diagnoses from the Kiddie Schedule for Affective Disorders and Schizophrenia (K-SADS) (Kaufman et al., 1997).

possibility that youth in our current study may not grow up to meet the diagnostic criteria of psychopathy. Longitudinal research is desperately needed to measure whether reduced Pe amplitude in youth samples can serve as a potential biomarker for the development of psychopathic personality.

Additionally, our study recruited participants from a maximum-security detention center. Compared to youth in community samples, youth in incarcerated settings differ on a number of variables, including substance use history, general intelligence, and trait anxiety (Foley, 2001; Wasserman et al., 2002). We note that our sample had PCL:YV Total scores ranging from the low to the extreme range of scores, with means in line with previously published incarcerated youth samples. Thus, our sample should be considered one with clinical levels of psychopathy, which may not extrapolate to samples with lower psychopathy scores. Moreover, there appears to be little agreement between various self-report and interview-based measures of psychopathic traits in adolescent samples (Fink et al., 2012). We recommend that future studies compare samples on identical measures of psychopathic traits; comparison across assessment instruments is not likely to lead to replication.

In addition, the present study reported a negative relationship between adolescent psychopathy scores and Pe mean amplitude within an incarcerated sample with clinical levels of psychopathy. As it is common practice in the psychopathy field, we tested our hypotheses by examining participants with low to high levels of psychopathy within this sample. This allows us to carefully control for potential moderating variables (i.e., substance use, etc.). However, we did not compare our results to a ‘healthy’ population; thus, our results need to be considered in this light. Future research should attempt to replicate and extend our current results incorporated a non-incarcerated control group, carefully attending to critical moderating variables (IQ, substance use, etc.).

## 5. Conclusions

In sum, adolescent psychopathy scores were unrelated to the ERN/Ne mean amplitude, and negatively related to Pe mean amplitude. Results were most strongly supported through the use of PCA, whereby adolescent psychopathy scores were negatively related to a middle subcomponent underlying the Pe. Linear regression analyses associated reduced amplitude of this subcomponent underlying the Pe with PCL:YV Facet 4 (antisocial traits), including early behavioral problems. This is the first evidence to suggest a potential

negative relationship between adolescent psychopathy scores and Pe mean amplitude.

## References

- Agam, Y., Hämäläinen, M.S., Lee, A.K.C., Dyckman, K.A., Friedman, J.S., Isom, M., Manoach, D.S., 2011. Multimodal neuroimaging dissociates hemodynamic and electrophysiological correlates of error processing. *Proc. Natl. Acad. Sci.* 108 (42), 17556–17561.
- Anderson, N.E., Steele, V.R., Maurer, J.M., Bernat, E.M., Kiehl, K.A., 2015. Psychopathy, attention, and oddball target detection: New insights from PCL-R Facet scores. *Psychophysiology* 52 (9), 1194–1204.
- Bernat, E.M., Nelson, L.D., Steele, V.R., Gehring, W.J., Patrick, C.J., 2011. Externalizing psychopathology and gain-loss feedback in a simulated gambling task: Dissociable components of brain response revealed by time-frequency analysis. *J. Abnorm. Psychol.* 120 (2), 352–364.
- Brazil, I.A., de Bruijn, E.R., Bulten, B.H., von Borries, A.K., van Lankveld, J.J., Buitelaar, J.K., Verkes, R.J., 2009. Early and late components of error monitoring in violent offenders with psychopathy. *Biol. Psychiatry* 65 (2), 137–143.
- Brazil, I.A., Mars, R.B., Bulten, B.H., Buitelaar, J.K., Verkes, R.J., De Bruijn, E.R., 2011. A neurophysiological dissociation between monitoring one's own and others' actions in psychopathy. *Biol. Psychiatry* 69 (7), 693–699.
- Bridwell, D.A., Steele, V.R., Maurer, J.M., Kiehl, K.A., Calhoun, V.D., 2015. The relationship between somatic and cognitive-affective depression symptoms and error-related ERPs. *J. Affect. Disord.* 172, 89–95.
- Budhani, S., Blair, R.J., 2005. Response reversal and children with psychopathic tendencies: Success is a function of saliency of contingency change. *J. Child Psychol. Psychiatry* 46 (9), 972–981.
- Caldwell, M.F., 2011. Treatment-related changes in behavioral outcomes of psychopathy facets in adolescent offenders. *Law Hum. Behavior* 35 (4), 275–287.
- Caldwell, M.F., McCormick, D.J., Umstead, D., Van Rybroek, G.J., 2007. Evidence of treatment progress and therapeutic outcomes among adolescents with psychopathic features. *Crim. Justice Behav.* 34 (5), 573–587.
- Chiu, P.H., Deldin, P.J., 2007. Neural evidence for enhanced error detection in major depressive disorder. *Am. J. Psychiatry* 164 (4), 608–616.
- Cooke, D.J., Michie, C., 2001. Refining the construct of psychopathy: Towards a hierarchical model. *Psychol. Assess.* 13 (2), 171–188.
- Cope, L.M., Ermer, E., Nyalakanti, P., Calhoun, V.D., Kiehl, K.A., 2014. Parietal gray matter reductions in incarcerated adolescent females with psychopathic traits. *J. Abnorm. Child Psychol.* 42 (4), 659–668.
- Davies, P.L., Segalowitz, S.J., Gawin, W.J., 2004. Development of response monitoring in 7- to 25-year olds. *Dev. Neuropsychol.* 25 (3), 355–376.
- Delorme, A., Makeig, S., 2004. EEGLab: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *J. Neurosci. Methods* 134 (1), 9–21.
- Dien, J., Khoe, W., Mangun, G.R., 2007. Evaluation of PCA and ICA of simulated ERPs: Promax vs Infomax rotations. *Hum. Brain Mapping* 28 (8), 742–763.
- Edens, J.F., Campbell, J.S., Weir, J.M., 2007. Youth psychopathy and criminal recidivism: A meta-analysis of the psychopathy checklist measures. *Law Hum. Behav.* 31 (1), 53–75.
- Edens, J.F., Epstein, M., Stiles, P.G., Poythress, N.G., 2011. Voluntary consent in correctional settings: Do offenders feel coerced to participate in research? *Behav. Sci. Law* 29 (6), 771–795.
- Edwards, B.G., Calhoun, V.D., Kiehl, K.A., 2012. Joint ICA of ERP and fMRI during error-monitoring. *NeuroImage* 59 (2), 1896–1903.

- Ermer, E., Cope, L.M., Nyalakanti, P.K., Calhoun, V.D., Kiehl, K.A., 2013. Aberrant paralimbic gray matter in incarcerated male adolescents with psychopathic traits. *J. Am. Acad. Child Adolesc. Psychiatry* 52 (1), 94–103.
- Falkenstein, M., Hohnsbein, J., Hoormann, J., Blanke, L., 1991. Effects of crossmodal divided attention on late ERP components: II: Error processing in choice reaction tasks. *Electroencephalogr. Clin. Neurophysiol.* 78 (6), 447–455.
- Finger, E.C., Marsh, A.A., Mitchell, D.G., Reid, M.E., Sims, C., Budhani, S., Blair, R.J.R., 2008. Abnormal ventromedial prefrontal cortex function in children with psychopathic traits during reversal learning. *Arch. Gen. Psychiatry* 65 (5), 586–594.
- Fink, B.C., Tant, A.S., Tremba, K., Kiehl, K.A., 2012. Assessment of psychopathic traits in an incarcerated adolescent sample: A methodological comparison. *J. Abnorm. Child Psychol.* 40 (6), 971–986.
- Foley, R.M., 2001. Academic characteristics of incarcerated youth and correctional educational programs: A literature review. *J. Emot. Behav. Disord.* 9 (4), 248–259.
- Forth, A.E., Hart, S.D., Hare, R.D., 1990. Assessment of psychopathy in male young offenders. *Psychol. Assess.* 2 (3), 342–344.
- Forth, A.E., Kosson, D.S., Hare, R.D., 2003. *The Psychopathy Checklist: Youth Version*. Multi-Health Systems, Toronto, ON, Canada.
- Frick, P.J., Cornell, A.H., Bodin, S.D., Dane, H.E., Barry, C.T., Loney, B.R., 2003. Callous-unemotional traits and developmental pathways to severe conduct problems. *Dev. Psychol.* 39 (2), 246–260.
- Gehring, W.J., Goss, B., Coles, M.G.H., Meyer, D.E., Donchin, E., 1993. A neural system for error detection and compensation. *Psychol. Sci.* 4 (6), 385–390.
- Gostin, L.O., Vanchieri, C., Pope, A., 2007. *Ethical Considerations for Research Involving Prisoners*. National Academies Press, Washington, DC.
- Gregory, S., Blair, R.J., Ffytche, D., Simmons, A., Kumari, V., Hodgins, S., Blackwood, N., 2015. Punishment and psychopathy: A case-control functional MRI investigation of reinforcement learning in violent antisocial personality disordered men. *Lancet Psychiatry* 2 (2), 152–160.
- Hare, R.D., 1991. *The Hare Psychopathy Checklist - Revised Manual*. Multi-Health Systems, Toronto.
- Hare, R.D., 2003. *Manual for the Hare Psychopathy Checklist - Revised, 2nd Ed.* Multi-Health Systems, Toronto, Canada.
- Hare, R.D., Neumann, C.S., 2010. The role of antisociality in the psychopathy construct: Comment on Skeem and Cooke (2010). *Psychol. Assess.* 22 (2), 446–454.
- Harenski, C.L., Harenski, K.A., Kiehl, K.A., 2014. Neural processing of moral violations among incarcerated adolescents with psychopathic traits. *Dev. Cogn. Neurosci.* 10, 181–189.
- Harpur, T.J., Hare, R.D., Hakstian, R., 1989. Two-factor conceptualization of psychopathy: Construct validity and assessment implications. *Psychol. Assess.* 1 (1), 6–17.
- Hemphill, J.F., Hare, R.D., Wong, S., 1998. Psychopathy and recidivism: A review. *Legal Criminol. Psychol.* 3 (1), 139–170.
- Hochberg, Y., 1988. A sharper Bonferroni procedure for multiple tests of significance. *Biometrika* 75 (4), 800–802.
- Jung, T.P., Makeig, S., Westerfield, M., Courchesne, E., Sejnowski, T.J., 2000. Removal of eye activity artifacts from visual event-related potentials in normal and clinical subjects. *Clin. Neurophysiol.* 111 (10), 1745–1758.
- Kaufman, J., Birmaher, B., Brent, D., 1997. Schedule for Affective Disorders and Schizophrenia for School-Aged Children: Present and Lifetime Version (K-SADS-PL): Initial reliability and validity data. *J. Am. Acad. Child Adolesc. Psychiatry* 37 (7), 980–988.
- Kiehl, K.A., Liddle, P.F., Hopfinger, J.B., 2000. Error processing and the rostral anterior cingulate: An event-related fMRI study. *Psychophysiology* 37 (2), 216–223.
- Ladouceur, C.D., Dahl, R.E., Carter, C.S., 2007. Development of action monitoring through adolescence into adulthood: ERP and source localization. *Dev. Sci.* 10 (6), 874–891.
- Larson, M.J., Steffen, B.V., Primosch, M., 2013. The impact of a brief mindfulness meditation intervention on cognitive control and error-related performance monitoring. *Front. Human Neurosci.* 7 (308), 1–12.
- Lee, Z., Klaver, J.R., Hart, S.D., Moretti, M.M., Douglas, K.S., 2009. Short-term stability of psychopathic traits in adolescent offenders. *Journal of Clinical Child and Adolesc. Psychol.* 38 (5), 595–605.
- Lockwood, P.L., Sebastian, C.L., McCrory, E.J., Hyde, Z.H., Gu, X., De Brito, S.A., Viding, E., 2013. Association of callous traits with reduced neural response to others' pain in children with conduct problems. *Curr. Biol.* 23 (10), 901–905.
- Lynam, D.R., 1997. Pursuing the psychopath: Capturing the fledgling psychopathy in a nomological net. *Journal of Abnorm. Psychol.* 106, 425–438.
- Lynam, D.R., Caspi, A., Moffitt, T.E., Loeber, R., Stouthamer-Loeber, M., 2007. Longitudinal evidence that psychopathy scores in early adolescence predict adult psychopathy. *J. Abnorm. Psychol.* 116, 155–165.
- Marsh, A.A., Finger, E.C., Mitchell, D.G.V., Reid, M.E., Sims, C., Kosson, D.S., Blair, R.J.R., 2008. Reduced amygdala response to fearful expressions in children and adolescents with callous-unemotional traits and disruptive behavior disorders. *Am. J. Psychiatry* 165 (6), 712–720.
- Maurer, J.M., Steele, V.R., Edwards, B.G., Bernat, E.M., Calhoun, V.D., & Kiehl, K.A. (in press). Dysfunctional error-related processing in incarcerated female psychopaths. *Soc. Cogn. Affect. Neurosci.*
- Munro, G.E., Dywan, J., Harris, G.T., McKee, S., Unsal, A., Segalowitz, S.J., 2007. ERN varies with degree of psychopathy in an emotion discrimination task. *Biol. Psychol.* 76 (1–2), 31–42.
- Neumann, C.S., Kosson, D.S., Forth, A.E., Hare, R.D., 2006. Factor structure of the Hare Psychopathy Checklist: Youth Version (PCL:YV) in incarcerated adolescents. *Psychol. Assess.* 18 (2), 142–154.
- Neumann, C.S., Wampler, M., Taylor, J., Blonigen, D.M., Iacono, W.G., 2011. Stability and invariance of psychopathic traits from late adolescence to young adulthood. *J. Res. Pers.* 45 (2), 145–152.
- Newman, J.P., Kosson, D.S., 1986. Passive avoidance learning in psychopathic and nonpsychopathic offenders. *J. Abnorm. Psychol.* 95 (3), 252–256.
- Olivet, D.M., Hajcak, G., 2008. The error-related negativity (ERN) and psychopathology: Toward an endophenotype. *Clin. Psychol. Rev.* 28 (8), 1343–1354.
- Olivet, D.M., Hajcak, G., 2009. The stability of error-related brain activity with increasing trials. *Psychophysiology* 46 (5), 957–961.
- Overbeek, T.J.M., Nieuwenhuis, S., Ridderinkhof, K.R., 2005. Dissociable components of error processing. *J. Psychophysiol.* 19 (4), 319–329.
- Pontifex, M.B., Scudder, M.R., Brown, M.L., O'Leary, K.C., Wu, C.T., Themanson, J.R., Hillman, C.H., 2010. On the number of trials necessary for stabilization of error-related brain activity across the life span. *Psychophysiology* 47 (4), 767–773.
- Rabbitt, P.M.A., 1981. Sequential reactions. In: Holding, D. (Ed.), *Human Skills*. Wiley, New York, pp. 153–175.
- Rice, M.E., Harris, G.T., 1997. Cross-validation and extension of the Violence Risk Appraisal Guide for child molesters and rapists. *Law Hum. Behav.* 21 (2), 231–241.
- Roussy, S., Toupin, J., 2000. Behavioral inhibition deficits in juvenile psychopaths. *Aggress. Behav.* 26 (6), 413–424.
- Santesso, D.L., Segalowitz, S.J., Schmidt, L.A., 2006. Error-related electrocortical responses in 10-year old children and young adults. *Dev. Sci.* 22 (2), 433–445.
- Schroder, H.S., Moran, T.P., Moser, J.S., Altmann, E.M., 2012. When the rules are reversed: Action-monitoring consequences of reversing stimulus-response mappings. *Cogn. Affect. Behav. Neurosci.* 12 (4), 629–643.
- Simes, R.J., 1986. An improved Bonferroni procedure for multiple tests of significance. *Biometrika* 73 (3), 751–754.
- Skeem, J.L., Cooke, D.J., 2010. Is criminal behavior a central component of psychopathy? Conceptual directions for resolving the debate. *Psychol. Assess.* 22 (2), 433–445.
- Smith, S.S., Newman, J.P., 1990. Alcohol and drug abuse-dependence disorders in psychopathic and nonpsychopathic criminal offenders. *J. Abnorm. Psychol.* 99 (4), 430–439.
- Steele, V.R., Anderson, N.E., Claus, E.D., Bernat, E.M., Rao, V., Assaf, M., Kiehl, K.A. (in press). Neuroimaging measures of error-processing: Extracting reliable signals from event-related potentials and functional magnetic resonance imaging. *NeuroImage*.
- Steele, V.R., Claus, E.D., Aharoni, E., Vincent, G.M., Calhoun, V.D., Kiehl, K.A., 2015. Multimodal imaging measures predict rearrest. *Front. Hum. Neurosci.* 9 (425), 1–13.
- Steele, V.R., Fink, B.C., Maurer, J.M., Arbabshirani, M.R., Wilber, C.H., Jaffe, A.J., Kiehl, K.A., 2014. Brain potentials measured during a Go/NoGo task predict completion of substance abuse treatment. *Biol. Psychiatry* 76 (1), 75–83.
- Steele, V.R., Maurer, J.M., Bernat, E.M., Calhoun, V.D., Kiehl, K.A., 2016. Error-related processing in adult males with elevated psychopathic traits. *Personality Disord.* 7 (1), 80–90.
- Ullsperger, M., Harsay, H.A., Wessel, J.R., Ridderinkhof, K.R., 2010. Conscious perception of errors and its relation to the anterior insula. *Brain Struct. Funct.* 214 (5–6), 629–643.
- van Veen, V., Carter, C.S., 2002. The timing of action-monitoring processes in the anterior cingulate cortex. *J. Cogn. Neurosci.* 14 (4), 593–602.
- Vitale, J.E., Newman, J.P., Bates, J.E., Goodnight, J., Dodge, K.A., Pettit, G.S., 2005. Deficient behavioral inhibition and anomalous selective attention in a community sample of adolescents with psychopathic traits and low-anxiety traits. *J. Abnorm. Child Psychol.* 33 (4), 461–470.
- von Borries, A.K., Brazil, I.A., Bulten, B.H., Buitelaar, J.K., Verkes, R.J., de Bruijn, E.R., 2010. Neural correlates of error-related learning deficits in individuals with psychopathy. *Psychol. Med.* 40 (9), 1559–1568.
- Walsh, Z., Allen, L.C., Kosson, D.S., 2007. Beyond social deviance: Substance use disorders and the dimensions of psychopathy. *J. Pers. Disord.* 21 (3), 273–288.
- Wasserman, G.A., McReynolds, L.S., Lucas, C.P., Fisher, P., Santos, L., 2002. The Voice DISC-IV with incarcerated male youths: Prevalence of disorder. *J. Am. Acad. Child Adolesc. Psychiatry* 41 (3), 314–321.
- Wechsler, D., 1997. *WAIS-III: Wechsler Adult Intelligence Scale, 3rd Edition*. The Psychological Corporation, San Antonio, TX.
- Yeung, N., Summerfield, C., 2012. Metacognition in human decision-making: Confidence and error monitoring. *Philos. Trans. R. Soc. B* 367, 1310–1321.