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BRIEF REPORT

Alpha Response Reveals Attention Abnormalities in Psychopathy

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Psychopathy is a personality disorder associated with callous, impulsive, and antisocial behaviors. Decades of research indicate that individuals higher on psychopathy exhibit abnormal allocation of attention during goal pursuit. However, the manner in which attention is allocated to goal-relevant information and the downstream neurocognitive consequences of this attention abnormality remain unclear. The present study addresses this gap by examining the relationship between psychopathy and the allocation of attention during an electroencephalogram (EEG)-based continuous performance task in a sample of 61 adolescents and young adults. Results indicate that individuals higher on psychopathy overallocate attention to visual cues during the task (i.e., enhanced parieto-occipital alpha suppression), and this overallocation of attention reduces the neural resources required for motor control (i.e., blunted central alpha activity during NoGo trials). Psychopathy appears related to a unique pattern of attention allocation that prioritizes neural resources for goal-relevant information, resulting in alterations in the neural response for downstream cognitive functions.

Keywords: psychopathy, attention, motor control, EEG, alpha

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Psychopathy is a chronic personality disorder defined by impulsive, antisocial behavior paired with callousness, shallow affect, and an inability to form long-term, meaningful relationships (Hare, 2003). Although there is a continuing debate about the core deficit(s) in psychopathy, extensive prior research demonstrates that individuals higher on psychopathy exhibit abnormal attention allocation (see Baskin-Sommers & Newman, 2013 for review).

Some conceptualizations of the psychopathy-related attention abnormality propose that individuals higher on psychopathy overallocate attention to goal-related stimuli (MacCoon, Wallace, & Newman, 2004; Patterson & Newman, 1993). Across several studies using attention manipulations (e.g., Flanker, attention blink, and Stroop), there is strong evidence that individuals higher on psychopathy preferentially attend to goal-relevant information, resulting in less behavioral interference (Hiatt, Schmitt, & Newman, 2004; Wolf et al., 2012; Zeier, Maxwell, & Newman, 2009). For instance, individuals higher on psychopathy process rapidly presented visual cues more efficiently than other individuals, significantly reducing the duration and intensity of their "attentional blink" (Wolf et al., 2012). Although the behavioral outcomes of preferentially attending to goal-relevant information are well characterized, there is limited research in psychopathy examining the allocation of neural resources to attentional processing of goal-relevant information and the downstream neurocognitive effects of that allocation. To date, only one study using functional MRI demonstrated that psychopathy-related neural abnormalities in the overallocation of attention are related to subsequent performance on executive functioning tasks (Rodman et al., 2016). However, the specific impact of these psychopathy-related neural abnormalities on downstream neural processes (e.g., motor control, response inhibition, etc.) remains unknown.

The present study used a continuous performance Go/NoGo task, in a sample of late adolescents and young adults, to investigate the impact of psychopathy on the allocation of attentional resources to goal-relevant information. The continuous performance task was selected to examine fluctuations in maintaining attention during goal-pursuit (Esterman, Noonan, Rosenberg, & DeGutis, 2013). Electroencephalogram (EEG)-derived alpha band activity was examined as an index of attention allocation during the task because research demonstrated that it is related to both attention allocation and motor control (i.e., inhibiting a response) during Go/NoGo paradigms (Mazaheri, Nieuwenhuis, van Dijk, & Jensen, 2009; O'Connell et al., 2009; Pandey et al., 2016; Sauseng, Klimesch, Gerloff, & Hummel, 2009).

On the one hand, suppression of alpha activity in posterior regions of the cortex (e.g., the parieto-occipital cortex) is thought to index the amount of attentional resources being allocated to process visual cues (i.e., a decrease in alpha represents an increase in the attentional resources allocated; Mazaheri et al., 2009; O'Connell et al., 2009; Rihs, Michel, & Thut, 2007; Sauseng, Klimesch, Stadler, et al., 2005;

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Thut, Nietzel, Brandt, & Pascual-Leone, 2006; Yamagishi, Goda, Callan, Anderson, & Kawato, 2005). On the other hand, increases in central alpha activity (i.e., alpha activity around the motor cortex) represent a neural index of the resources used during motor control to actively suppress automatic or habitual motor responses (e.g., suppression of a response during a NoGo trial; Busch & Herrmann, 2003; Cooper, Croft, Dominey, Burgess, & Gruzelier, 2003; Herrmann, Senkowski, & Röttger, 2004; Hummel, Andres, Altenmüller, Dichgans, & Gerloff, 2002; Jensen, Gelfand, Kounios, & Lisman, 2002; Klimesch, Doppelmayr, Schwaiger, Auinger, & Winkler, 1999; Klimesch, Sauseng, & Hanslmayr, 2007; O'Connell et al., 2009; Sauseng, Gerloff, & Hummel, 2013; Sauseng, Klimesch, W., Doppelmayr, et al., 2005; Sauseng et al., 2009; Schack & Klimesch, 2002; Tzagarakis, West, & Pellizzer, 2015). Accordingly, alpha activity during a Go/NoGo paradigm represents an ideal measure for investigating the relationship between allocation of attention and the effects of that allocation in psychopathy.

Based on prior research examining neural allocation of attention in psychopathy (Rodman et al., 2016), it is hypothesized that higher levels of psychopathy should be associated with enhanced attention to, and processing of, goal-related visual cues (i.e., enhanced suppression of the parieto-occipital alpha). In addition, because enhanced processing of goal-relevant cues should reduce the amount of neural resources needed to provide an appropriate motor response to these cues, higher levels of psychopathy should be associated with a blunted central alpha response during NoGo trials. Finally, if the overallocation of attention to goal-relevant cues establishes the processing of, and reaction to, information, then enhanced suppression of the parieto-occipital alpha should mediate the relationship between psychopathy and central alpha activity.

Method

Participants

Participants were 44 male and 17 female individuals between the ages of 14 and 24 ($M = 19.52$, $SD = 3.05$; see Table S1 in the online supplemental materials) recruited from the New Haven community.[1] The majority of participants were African American (72.1%), whereas the remaining participants self-identified as mixed race (14.8%), White (11.5%), or American Indian (1.6%); 14.8% of participants self-identified as Hispanic. The sample is "at-risk" for higher rates of antisocial behavior related to psychopathic traits based on being recruited from urban, high-crime regions (Baskin-Sommers, Baskin, Sommers, & Newman, 2013; Raine, 2013). All participants were assessed for psychopathy using the Youth Psychopathic Traits Inventory (YPI; Andershed, Kerr, Stattin, & Levander, 2002). The study was approved by the Human Research Protection Program at Yale University (see Methods in the online supplemental materials for more details about the sample, recruitment, and psychopathy assessment).

Experimental Task

Participants completed a gradual continuous performance Go/NoGo task (Esterman et al., 2013) while undergoing EEG recording (see Methods in the online supplemental materials for details regarding EEG recording). During the task, participants were shown visual scenes of cities (90% of trials) and mountains (10% of trials). Images gradually transitioned from one scene to the next over the course of 800 ms (see Figures S1 and S2 in the online supplemental materials). Participants were instructed to respond via button press to city scenes (Go trials) and not respond to mountain scenes (NoGo trials).

Psychophysiological Analysis

Following preprocessing (see Methods in the online supplemental materials for details about preprocessing), time frequency analyses focused on alpha (8–13Hz) across parieto-occipital sites. Parieto-occipital sites analyzed included the following channels: E56, E63, E68, E73, E81, E88, E94, E99, E107, E64, E69, E74, E82, E89, E95, E50, E58, E65, E70, E75, E83, E90, E96, E101, E59, E66, E71, E76, E84, E97, E52, E60, E67, E72, E77, E85, E92, E61, and E78. Changes in spectral power, as measured by event-related spectral perturbation (ERSP), were extracted using the EEGLab "newtimef" function (Delorme & Makeig, 2004). Epoch length was set at 800 ms. Epochs were convolved using morlet wavelets to yield the initial time frequency findings for each channel. These initial time frequency data were averaged across all parieto-occipital channels, and a Time × Frequency spectrograph was generated for each experimental condition (Figure S2 in the online supplemental materials). This process was then repeated for all central sites including the following: E49, E44, E39, E45, E40, E46, E35, E41, E47, E29, E36, E42, E53, E6, E13, E30, E37, E54, E79, E87, E105, E112, E113, E114, E115, E108, E109, E102, E110, E103, E98, E111, E104, E93, E86, E7, E106, and E31. Following visual inspection of the spectrograph, mean ERSPs were extracted from the precomputed matrices between 210 and 350 ms for the alpha frequency band at all parieto-occipital sites. Mean ERSPs were extracted from the precomputed matrices between 500 and 590 ms for the alpha frequency band at all central sites.

Data Analysis

Individual differences in the alpha response were analyzed using repeated measures general linear models with trial type (Go, NoGo) as a within-subjects categorical factor and YPI total score (z-scored) as a between-subjects continuous factor, for parieto-occipital alpha suppression and central alpha activity, respectively (see Results in the online supplemental materials for models with behavioral performance). Mediation analyses were performed using the SPSS macro "PROCESS", Model 4 (Hayes, 2013). We used a nonparametric resampling procedure (bootstrapping) with 5,000 samples to estimate the indirect effect. The primary mediation model specified YPI total score as the independent variable, parieto-occipital alpha suppression as a mediator, and central alpha activity during NoGo trials as the dependent variable. A secondary mediation model also was run, which specified the YPI total score as the independent variable, parieto-occipital alpha suppression as a mediator, and central alpha activity during Go trials as the dependent variable.

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[1] Sample size was determined via an a priori power analysis using G*Power (Faul, Erdfelder, Buchner, & Lang, 2009), estimating a moderate effect size for the YPI × Alpha response interactions. The analysis indicated that an $n = 56$ would be needed to achieve power of 0.8.

Results

For parieto-occipital alpha suppression, there was a significant main effect of YPI total score, $F(1, 59) = 4.53$, $p = .038$, $\eta_p^2 = .071$, 90% confidence interval (CI) [.002, .191], such that individuals higher on psychopathy displayed more parieto-occipital alpha suppression (Figure 1A). The trial type by YPI total score interaction was not significant, $F(1, 59) = .998$, $p = .322$, $\eta_p^2 = .017$, 90% CI [.000, .102].

For central alpha activity, the main effect of YPI total score was not significant, $F(1, 59) = .225$, $p = .637$, $\eta_p^2 = .004$, 90% CI [.000, .065]. However, there was a significant trial type by YPI total score interaction, $F(1, 59) = 4.77$, $p = .033$, $\eta_p^2 = .075$, 90% CI [.003, .196], (Figure 1B), suggesting that individuals higher on psychopathy displayed less central alpha during NoGo trials, $\beta = -.112$, $p = .156$, $\eta_p^2 = .034$, 90% CI [.000, .135], but more central alpha during Go trials, $\beta = .071$, $p = .041$, $\eta_p^2 = .069$, 90% CI [.001, .187].

Parieto-occipital alpha suppression mediated the relationship between psychopathy and central alpha activity during NoGo trials. The indirect effect of YPI total score on NoGo central alpha activity through parieto-occipital alpha suppression was significant, $\beta = .070$, $SE = .040$, 95% CI [0.010, .172].[2] However, parieto-occipital alpha suppression did not significantly mediate the relationship between psychopathy and central alpha activity during Go trials (indirect effect: $\beta = .010$, $SE = .039$, 95% CI [$-.059$, .107]).

Discussion

The present study used time-frequency analysis of EEG data from a continuous performance Go/NoGo task to examine the relationship between psychopathy and neural measures of attention allocation. Consistent with prior research examining allocation of neural attentional resources in psychopathy (Rodman et al., 2016), the current results suggest that individuals higher on psychopathy overallocate attentional resources to visual cues, as evidenced by greater parieto-occipital alpha suppression to both Go and NoGo cues. Moreover, this allocation of attentional resources mitigates, at least in part, the need to allocate neural resources toward motor control in individuals higher on psychopathy. These findings not only provide additional evidence that individuals with psychopathy overallocate attentional resources to cues during goal pursuit (Rodman et al., 2016; Tillem & Baskin-Sommers, 2018) but also highlight how this attention abnormality may impact other neurocognitive processes, such as motor control.

The current findings add to the growing body of research examining the downstream neurocognitive consequences of psychopathy-related abnormalities in the allocation of selective attention (Hiatt et al., 2004; Rodman et al., 2016; Wolf et al., 2012; Zeier et al., 2009). Specifically, these results demonstrate that although individuals higher on psychopathy show an enhanced allocation of attention to visual cues during a Go/NoGo task, they fail to exhibit the normative spike in central alpha activity when they inhibit their prepotent motor response on NoGo trials (Hummel et al., 2002; Klimesch et al., 2007; Mazaheri et al., 2009; O’Connell et al., 2009; Sauseng et al., 2013; Sauseng, Klimesch, W., Doppelmayr, et al., 2005; Sauseng et al., 2009; Tzagarakis et al., 2015). While speculative, the current findings suggest that the psychopathy-related overallocation of attentional resources to NoGo (and Go) cues may increase their awareness of these cues, thereby reducing the resources required for motor control on NoGo trials (reflected by a diminished central alpha response), but not Go trials.

Interestingly, however, individuals higher on psychopathy also showed increased central alpha activity during Go trials. Although this psychopathy-related increase in central alpha activity during Go trials is unexpected, it is not inconsistent with prior research on motor alpha activity more broadly. Generally, when individuals initially learn a motor response, they exhibit central alpha suppression as the motor cortex activates during action planning and execution (Mazaheri et al., 2009; O’Connell et al., 2009; Zhuang et al., 1997). However, over time, as the motor response is acquired, the role of the motor cortex in action execution is reduced as subcortical structures become more engaged (Pascual-Leone et al., 1998). Thus, as a motor response is learned, central alpha suppression diminishes until it is completely extinguished. Moreover, given enough time to practice, a motor response can be “over-learnt,” resulting in increased central alpha activity during action execution (Zhuang et al., 1997). Applying these findings to the present study, this overlearning may underlie the heightened Go-trial central alpha response in individuals higher on psychopathy. As these individuals overattend to Go cues, they may learn the motor response more rapidly than individuals lower in psychopathy, or even “over-learn” the response, leading to increased central alpha during Go trials.

These findings provide evidence for psychopathy-related abnormalities in the allocation of attention; however, they must be considered in light of several specific limitations. First, the timing of the task limited our ability to assess low-frequency wavebands that are also implicated in attention allocation (e.g., theta; Clayton, Yeung, & Cohen Kadosh, 2015; Missonnier et al., 2006; Sauseng, Hoppe, Klimesch, Gerloff, & Hummel, 2007). Low-frequency wavebands require more data points per trial to assess than higher frequency wavebands (e.g., alpha; Delorme & Makeig, 2004). The current analysis was limited to 800 data points per trial (1,000 Hz sampling rate/800 ms trial = 800 points per trial), which was insufficient to evaluate the low-frequency response. Therefore, future research should more fully explore the range of neural measures tapping attention and the consequences of specific patterns of attention allocation. Second, the current sample used a relatively small sample size, particularly for research examining the neural underpinnings of personality disorders (Abram & DeYoung, 2017; Tackett et al., 2017), which could potentially limit the replicability of the current findings. However, in line with best-research practices (Abram & DeYoung, 2017; Tackett et al., 2017), the current sample size was based upon an a priori power analysis, which indicated that this study was sufficiently powered to detect the predicted interactions. Third, the relatively small effect size for the mediation results could limit the replicability of the current results. However, it is vital to acknowledge that the findings are a conceptual replication and extension of a larger body of research examining psychopathy and the impact of atypical allocation of attention (see Baskin-Sommers & Newman, 2013 for

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[2] Including sex (contrast-coded), race (White versus other; contrast-coded), age, IQ, handedness (contrast-coded), or task accuracy as a covariate in the mediation model did not meaningfully alter this finding.

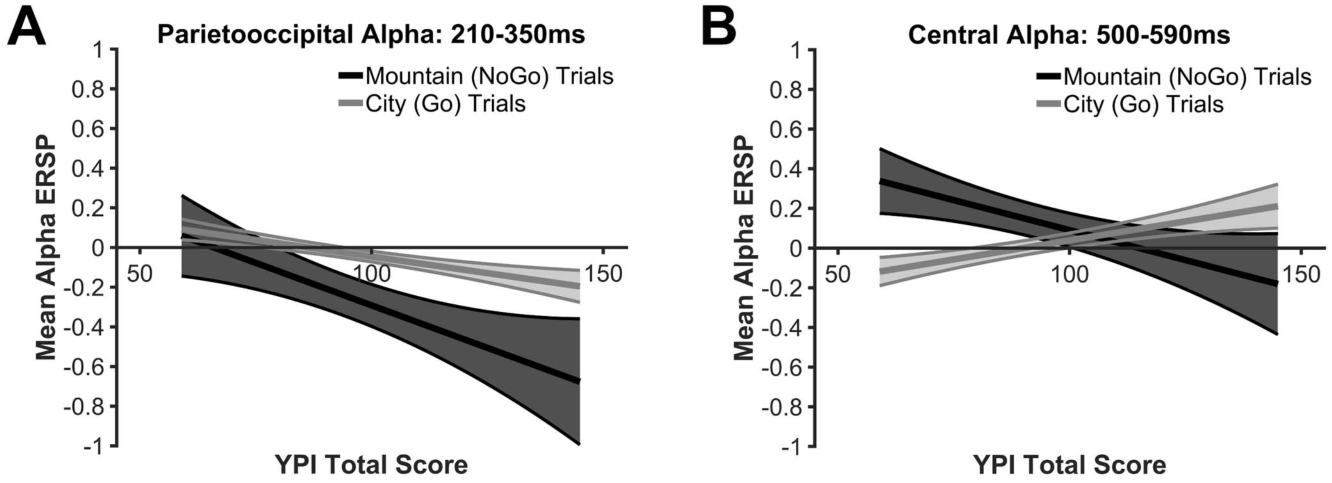

Figure 1. Alpha response as a function of psychopathy. Results for parieto-occipital alpha suppression (A) show that as Youth Psychopathic Traits Inventory total score increases, parieto-occipital alpha suppression to visual cues also increases (i.e., alpha activity decreases) during both Go and NoGo trials. In contrast, results for central alpha activity (B) show that, as Youth Psychopathic Traits Inventory total score increases, central alpha activity decreases during NoGo trials and increases during Go trials. Error bands are set at 1 *SE*.

review; Rodman et al., 2016). Although future replications of the current findings are still essential, the consistency of these findings with both prior theoretical models and recent research examining the neurocognitive underpinnings of psychopathy is a notable strength (Abram & DeYoung, 2017; Tackett et al., 2017).

These findings provide novel neural evidence supporting aberrations in attention allocation among individuals higher on psychopathy in an at-risk community sample. They show the first evidence that these attention differences affect the recruitment of other, downstream neurocognitive processes during goal pursuit and may provide a clue into how individuals with psychopathy engage in an unwavering pursuit of their self-serving goals. The interconnectedness of these neural abnormalities in psychopathy highlights the need for future research into the neural underpinnings of psychopathy to not only identify which neurocognitive processes are disrupted in psychopathy but also examine how different neural disruptions in psychopathy might relate to one another. Clarifying how psychopathy-related attention abnormalities impact behavior, and how they change downstream information processing more broadly, will be critical to advancing our understanding of the neurocognitive underpinnings of psychopathy.

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