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# Endogenous attention modulates early selective attention in psychopathy: An ERP investigation

**Elizabeth A. Krusemark**[1,2] · **Kent A. Kiehl**[2,3] · **Joseph P. Newman**[1]

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**Abstract** Psychopathic individuals are prone to act on urges without adequate consideration of future consequences or the rights of other individuals. One interpretation of this behavior is that it reflects abnormal selective attention (i.e., a failure to process information that is incongruent with their primary focus of attention; Hiatt, Schmitt, & Newman, *Neuropsychology*, 18, 50-59, 2004). Unfortunately, it is unclear whether this selective attention abnormality reflects top-down endogenous influences, such as the strength or specificity of attention focus (i.e., top-down set) apart from other, more exogenous (bottom-up), effects on attention. To explore this question, we used an early visual event-related potential (N2pc) in combination with a modified visual search task designed to assess the effect of early endogenous (i.e., top-down) attention on the processing of set-congruent information. The task was administered to a sample of 70 incarcerated adult males, who were assigned to high, intermediate, and low psychopathy groups using Hare's Psychopathy Checklist-Revised (Hare, 2003). Based on the assumption that their failure to process set-incongruent information reflects the exaggerated effects of endogenous attention, we predicted that participants with high psychopathy scores would show an exaggerated N2pc response to set-congruent information. The results supported the hypothesis and provide novel electrophysiological evidence that psychopathy is associated with exaggerated endogenous attention effects during early stages of processing. Further research is needed to examine the implications of this finding for the well-established failure of psychopathic individuals to process set-incongruent information and inhibit inappropriate responses.

**Keywords** Psychopathy · Selective attention · ERP · N2pc

✉ Elizabeth A. Krusemark
ekrusemark@wisc.edu

[1] Department of Psychology, University of Wisconsin-Madison, Madison, WI 53706, USA

[2] Mind Research Network, an affiliate of Lovelace Biomedical and Environmental Research Institute, Albuquerque, NM, USA

[3] Departments of Psychology, Neuroscience and Law, University of New Mexico, Albuquerque, NM, USA

Psychopathic individuals display a unique combination of callous, manipulative, impulsive, and criminal behaviors and are prone to act on immediate urges without regard for future consequences. In contrast to typical criminals who often display significant impairments in intelligence and executive functioning, psychopathic offenders display little or no impairment in these domains (Blair et al., 2006; Morgan & Lilienfeld, 2000). Nevertheless, psychopathic individuals are responsible for a disproportionate amount of crime and criminal recidivism (Walters, 2003; Hemphill, Hare & Wong, 1998). Given the high societal cost of their persistent criminal offending and recidivism, it is imperative to understand the specific mechanisms responsible for psychopathic behavior.

While it is generally agreed that psychopathic individuals enact inappropriate antisocial behavior without regard for the affective, legal, interpersonal, and personal consequences of their actions, there is less agreement regarding the dysfunction underlying their disinhibited behavior. According to emotion-deficit models, psychopathic individuals are less sensitive to fear and other emotions (e.g., sadness of others) that motivate non-psychopathic individuals to inhibit actions that have negative consequences for themselves and others (Blair, 2005; Fowles, 1980; Lykken 1957, 1995). Conversely, attention-based models attribute the inappropriate behavior of psychopathic individuals to an abnormality in selective attention that precludes the processing of information that is incongruent with their primary focus of attention and, thus, undermines the evaluation and appropriate modulation of behavior (MacCoon, Wallace & Newman, 2004; Moul, Kilcross, & Dadds, 2012; Patterson & Newman, 1993).

In support of attention-based models, there is growing evidence that core deficits in psychopathy are modulated by focus of attention (Newman, Curtin, Bertsch, & Baskin-Sommers, 2010; Newman & Kosson, 1986). For example, psychopathic individuals have difficulty learning to withhold approach responses in the presence of punishment cues when they are focused on earning rewards, but they use the same punishment cues as well as controls when task conditions make avoiding punishment their central focus (Newman & Kosson, 1986). Attentional focus also moderates psychopathy-related differences in physiological reactions (e.g., startle response, skin conductance) to aversive threat cues (Newman et al., 2010; Arnett, Smith, & Newman, 1997). When anticipating electric shocks, psychopathic individuals display significantly less fear potentiated startle than controls under conditions that focus attention on threat-irrelevant information. However, their startle responses are as large or larger than those of controls under conditions that focus attention on the stimuli that predict delivery of electric shocks. Notably, the attention abnormalities observed in psychopathy are not specific to conditions involving affective information. During modified Stroop and Flanker tasks, psychopathic individuals are relatively insensitive to set-incongruent information that slows the responses of non-psychopathic controls. Yet, they display comparable sensitivity to the same information when it is congruent with their attentional set (Hiatt, Schmitt, & Newman, 2004; Zeier, Maxwell, & Newman, 2009). Such findings indicate that the emotion deficits associated with psychopathic individuals are not absolute but may be moderated by attentional focus and that their obliviousness to set-incongruent information is not specific to emotion cues. Moreover, these findings appear to show that attentional set (i.e., focus of attention or processing priority) is a crucial factor determining the quality of information processing in psychopathic individuals.

Given the apparent importance of attentional focus in moderating psychopathy-related processing deficits, it is important to understand the effects that an attentional set has on information processing in psychopathy. In general, models of selective attention involve two distinct processes: a bottom-up, stimulus-driven process and a top-down, goal-driven process (Desimone & Duncan, 1995). More specifically, bottom-up (i.e., exogenous) attention is captured by stimuli in the environment that entail salient perceptual features (such as a bright light, color or motion), while top-down (i.e., endogenous) attention involves an internally-guided focus toward stimuli that are relevant to an individuals' current goal or focus (Müller & Rabbitt, 1989; Jonides, 1981). Although exogenous and endogenous attention reflect distinct operations, it is generally accepted that they interact with one another to guide selective attention. For example, endogenous, top-down attention guides our search for a friend wearing a blue hat in a crowd, but this attention set also moderates exogenous attention (e.g., by increasing the likelihood of noticing someone else carrying a blue umbrella; Corbetta, Patel & Shulman, 2008). The moderating effect of endogenous attention on exogenous attention aligns with the theory that attention is not simply captured by salient exogenous cues, but is dependent upon whether such cues match a person's goal set (Corbetta et al., 2008; Folk et al., 1992; Gibson & Kelsey, 1998). The majority of research on psychopathy has focused on the failure of psychopathic individuals to process salient exogenous stimuli such as threat cues (Moul et al. 2012; Blair & Mitchell, 2009), leading to the widely accepted view that psychopathy involves impaired exogenous attention. However, considering the dynamic influence that endogenous attention (by way of an attentional set) exerts in moderating exogenous attention processing, the current study sought to evaluate the alternative hypothesis that the influence of endogenous attention is exaggerated in psychopathic individuals. Based on the assumption that an attentional set facilitates processing of set-congruent information, another goal of the current study was to evaluate whether endogenous attention would differentially enhance the processing of set-congruent information in psychopathic individuals. Although researchers have considered the possibility that psychopathic individuals are characterized by an exaggerated focus on task-relevant goals (Hiatt et al., 2004; Patterson & Newman, 1993; Kosson & Newman, 1986), experimental investigation has yet to provide direct support for this possibility. However, to date, such studies have been limited by their reliance on behavioral performance and the use of tasks that were not specifically designed to assess the influence of top-down attention. Because behavioral performance reflects a downstream accumulation of diverse cognitive processes, behavioral measures may not be sensitive enough to yield evidence of exaggerated processing of set-congruent information in psychopathic individuals.

In contrast to behavioral assessments of top-down attention, psychophysiological measures such as event-related potentials (ERPs), which involve greater temporal precision, may yield more precise evidence regarding early stages of attention (Luck & Hillyard, 1994; Mangun, Hillyard, & Luck, 1993). However, investigators have yet to exploit these methods to evaluate the influence of top-down endogenous attention in psychopathic individuals. Assessing N100 responses to task-irrelevant auditory stimuli, Jutai and Hare (1983) reported abnormalities in selective attention, but the reduced N100 responses of psychopathic offenders documented the bottom-up costs of selective attention rather than the influence of top-down focus. Recent studies utilizing oddball paradigms provide compelling evidence of early response enhancement and later discrimination for target stimuli that match a task-related attentional set (including the N1, N2, P3 and late ERP negative waves; see Anderson, Steele, Maurer, Bernat, & Kiehl, 2015; Brazil et al., 2012; Kiehl et al., 2006; Kiehl, Hare, Liddle, & McDonald, 1999), but the inconsistent findings in this area preclude concise interpretations of such attention-based effects. Moreover, because oddball tasks compare ERP responses to stimuli with different physical features and response requirements, such ERPs are likely to reflect a combination of bottom-up (e.g., stimulus discrimination) and top-down (e.g., task-relevant) attentional processes. In contrast to previous psychophysiological studies, the present study used an ERP assessment and experimental task that were designed explicitly to examine the contribution of top-down (i.e., endogenous) influences on attention at an early stage of processing.

A propos to the assessment of top-down attention, previous work illustrates that early perceptual processing is modulated by endogenous attention (Eimer & Kiss, 2008). Specifically, this work demonstrates that an early visual ERP associated with attentional selection, the N2pc component, is enhanced in response to set-congruent information. The N2pc component is an index of spatial selective attention (Luck & Hillyard, 1994), characterized by an enhanced negative voltage at posterior sites contralateral to a target object embedded among distractors in visual space. The N2pc typically emerges between 200–300 ms following the onset of an object array during visual search tasks. To investigate the contribution of endogenous attention during early selective attention, researchers have examined the N2pc in conjunction with a modified visual search task that presents set-congruent, but spatially uninformative, cues prior to target search arrays (Eimer & Kiss, 2008; Folk et al., 1992). The pre-target cues are set-congruent because they share features with target stimuli (e.g., color), and they are spatially uninformative because their location is unrelated to the ultimate location of the subsequent target on the majority of trials (Fig. 1a). Thus, although the cues elicit reliable attention responses, as indexed by the N2pc response, their attentional salience is a function of endogenous influences (i.e., set-relevance). Consistent with this interpretation, Eimer and Kiss (2008) found a significant N2pc response to set-congruent pre-target cues (i.e., their Color task) that was essentially non-existent during an alternative visual search task that employed physically identical, set-incongruent cues (i.e., their Size task). Although both tasks present salient red pre-target stimuli that may be expected to elicit strong bottom-up responses (Fig. 1a & b), it is only when the pre-target cues resemble target stimuli (i.e., are set-relevant) that they elicit a significant N2pc response. In contrast to the Size task, the use of task-irrelevant, but set-congruent cues during the Color task makes it possible to measure of the effect of the attentional set on early perceptual processing. Additionally, behavioral results presented by Eimer and Kiss (2008) showed that spatial cueing effects were only apparent during the Color task; providing further evidence that set-congruent information facilitated early selective attention.

Importantly, the attentional mechanism characterized by Eimer and Kiss (2008) appears to reflect the same attentional process proposed to be operating in psychopathy. Thus, based on the assumption that enhanced selective attention exhibited by psychopathic individuals reflects the exaggerated contribution of endogenous attention, we predicted that participants with high psychopathy scores would exhibit an exaggerated N2pc relative to nonpsychopathic participants in response to set-congruent cues during the Color task. Furthermore, we expected to replicate the task-related (i.e., Color versus Size task) cueing effects on behavior reported by Eimer and Kiss (2008), but we did not predict behavioral differences between our psychopathy groups because the putative abnormality in early attention is likely to be moderated by downstream effects that mitigate its effects on behavioral performance.

## Method and materials

### Participants

Eighty-four European American men from a medium security prison in Southern Wisconsin were invited to participate [Mean(SD)Age = 32(8.47)]. Individuals were invited to participate if they were 18 to 55 years old, had no history of psychosis or bipolar disorder, were not currently taking psychotropic medication, had normal or corrected to normal vision, had no history of head injury, were right handed, and scored ≥70 on the Wechsler Adult Intelligence Scale-Revised (WAIS-R: Wechsler, 1997). PCL-R interview assessments and file reviews, WAIS-R assessments, and experimental tasks were all completed during separate sessions. Participants with extreme behavioral data (response time and accuracy) beyond ±2 SD from the group mean during valid and invalid conditions in each task were excluded from further analyses (e.g., accuracy (n = 11) or response time (n = 3)), leaving a final sample of 70 inmates. Participants provided informed consent to take part in the study, which was approved by the University of Wisconsin Institutional Review Board. Participants were paid $10 per hour for their participation. During consent, inmates were informed that their decision to participate in the interview and experiment sessions would have no impact on their status in the correctional institution.

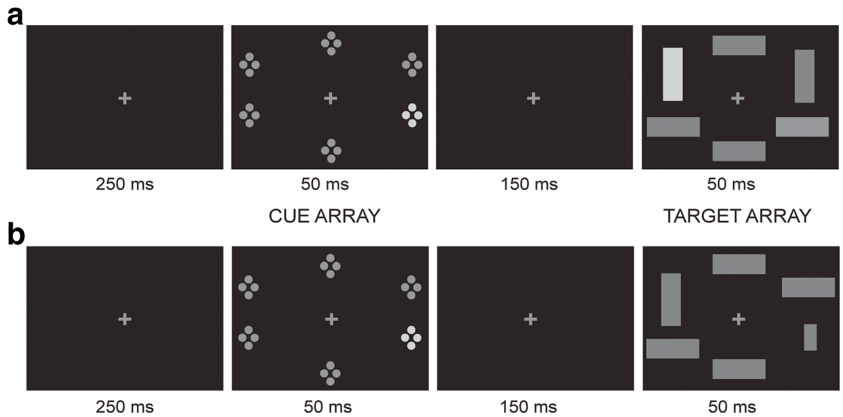


**Fig. 1** Visual search tasks. (**a**) Color task. (**b**) Size task. Trials began with central fixation (250 ms), followed by cue arrays (50 ms). Cues were presented in valid locations (matching target locations) for 25 % of trials. Following an interstimulus interval with fixation for 150 ms, target arrays appeared for 50 ms. During both tasks, participants were instructed to respond to indicate the orientation of the target bar. Intertrial interval was 1500 ms

### Psychopathy assessment

Psychopathy was assessed using a semi-structured interview and information from prison files. The Psychopathy Checklist Revised (PCL-R: Hare, 2003) contains 20 items that rate the degree to which a characteristic is present (2 = significantly, 1 = moderately, 0 = not at all). In the present sample, total scores ranged from 10 to 34 [M(SD) = 23.16(5.91)]. Clinical interviews were conducted by 12 research assistants who received extensive training and supervision from a highly experienced clinical interviewer (the third author). Interrater reliability was evaluated for six participants in this sample, and the intraclass correlation was .96. To evaluate our hypotheses, we classified participants into low (PCL-R total score ≤ 20, n = 23), intermediate (PCL-R = 21-26, n = 23), and high psychopathy groups (PCL-R ≥ 27, n = 24).

Table 1 presents sample characteristics and intercorrelations. To rule out confounds that may influence psychophysiological or behavioral performance, we examined whether groups differed on age, intelligence, or substance use history. Analyses confirmed that groups did not differ on these variables ($p$'s > .13).

### Visual search tasks

Participants completed two visual search tasks adapted from Eimer and Kiss (2008). Participants were seated in a dimly lit room during the task, approximately 120 cm from a CRT monitor. Task presentation and recording were controlled by the Psychtoolbox 3.0.11 extension (Brainard, 1997; Pelli, 1997; Kleiner et al., 2007) as implemented in Matlab 2012b (Mathworks, Inc., Natick, MA).

Figure 1a illustrates the timing and stimulus presentation for the Color task. Trials began with a central fixation cross (250 ms), followed by a cue array containing six sets of dots (each set subtending a visual angle of 0.8° × 0.8°). Red and gray stimuli were isoluminant (4 cd/m$^2$) and presented against a black background on a 16-inch monitor. Cues appeared at one of four lateral locations for 50 ms. Following an interstimulus interval with fixation (150 ms), a target array containing six bars appeared (each bar subtended 1.3° × 0.5°) for 50 ms. Red target bars appeared at one of four lateral locations, and participants were instructed to indicate the orientation of the target on a button pad (horizontal or vertical). The blank intertrial interval was for a fixed duration of 1500 ms.

**Table 1** Sample Characteristics

| $N$ = 70 | *M(SD)* *Range* | Bivariate Correlations | | | Psychopathy Group | | |
|---|---|---|---|---|---|---|---|
| | | WAIS | PCL-R | ASI *(n = 58)* | Low *(n = 23)* | Intermediate *(n = 23)* | High *(n = 24)* |
| Age | 32.20(8.44) 20-55 | -.07 | -.21† | .33* | 35.09(10.07) 22-55 | 31.26(8.54) 20-48 | 30.33(5.86) 22-41 |
| WAIS | 98.45(12.24) 74-126 | . - | .09 | -.07 | 95.79(12.08) 74-120 | 98.63(11.63) 77-120 | 100.72(12.96) 80-126 |
| PCL-R | 23.16(5.91) 10-34 | - | - | .18 | 16.12(2.40) 10-20 | 23.50(1.62) 21-26 | 29.57(2.06) 27-34 |
| ASI *(n = 58)* | 21.62(17.39) 0-89 | - | - | - | 21.25(19.61) 0-65 | 18.78(19.93) 0-89 | 24.35(13.13) 3-58 |

Scores based on final sample $N$ = 70. Mean (standard deviation) and ranges included for WAIS: Wechsler Adult Intelligence Scale (Wechsler 1997); PCL-R: Psychopathy Checklist-Revised (Hare, 2003); ASI: Addiction Severity Index (McLellan et al., 1992) in entire sample and by psychopathy group. ** $p$ < .01, * $p$ < .05, † $p$ < .10

Figure 1b illustrates the timing and stimuli in the Size task. In contrast to the Color task, target arrays in the size task contained six gray bars, and targets were smaller than the remaining stimuli (targets subtended 0.9° × 0.2°).

Participants initially practiced an abbreviated version of each task in order to become familiar with the timing and response requirements. Each task consisted of 384 trials, with 96 valid trials and 288 invalid trials. During valid trials, cues and targets appeared at congruent locations, whereas cues and targets appeared at different locations during invalid trials. Similar to the task parameters employed by Eimer and Kiss (2008), preceding cues were spatially uninformative (cues were only presented at spatially congruent locations during 25 % of trials). Cues and targets were presented randomly and with equal probability at each of the four lateral locations (trial types were counterbalanced throughout the task). Task order was counterbalanced between participants. Each of the two tasks included six blocks of 64 trials.

### Psychophysiological recording

EEG was recorded at 2500-Hz with a filter bandpass of 0.05-500 Hz from Ag-AgCl electrodes mounted on an elastic cap (Electro Cap International, Eaton, OH) at four midline positions (Fz, FCz, Cz, and Pz) and six lateral positions (O1, O2, P3, P4, F3, and F4) utilizing Neuroscan Synamps2 amplifiers and acquisition software (Compumedics, Charlotte, NC). Recording was referenced to the right mastoid. Electrooculogram (EOG) was recorded above and below the left eye (VEOG) aligned with the pupil. Research assistants showed participants eye movement artifacts in the data following cap placement, and stressed the importance of maintaining central fixation throughout the task. HEOG was monitored throughout the task, and if horizontal eye movements were detected, participants were reminded to maintain fixation. Impedance was kept below 10 KΩ using light scalp abrasion in conjunction with conductive gel at each site.

Offline processing included re-referencing to average mastoid locations, low-pass filtering (2nd order, 30 Hz Butterworth low-pass filter), epoching (−300 to 600 ms locked to cue onset), baseline correction, and artifact rejection (trials with voltages beyond ±75 μV) were discarded from further analyses. Offline analyses indicated that at least 95 % of trials remained following artifact rejection, with an average of 370 trials remaining from each task. ERPs were averaged relative to the 300 ms precue baseline for each task (Color vs. Size), trial type (valid vs. invalid), and cue position (left vs. right hemifield) across the four possible target locations. We examined the N2pc ERP component as an index of attentional selection (Luck & Hillyard, 1994; Eimer & Kiss, 2008). The N2pc component triggered by cue onset began to emerge at 180 ms at lateral posterior sites P3 and P4. Mean amplitudes for the N2pc were quantified by measuring the mean amplitude at sites P3 and P4 contralateral and ipsilateral to the cue from 180–265 ms.

### Data analysis

Our analytical strategy addressed two goals: 1) confirm that task-related effects for the Color and Size tasks replicated previous behavioral and ERP results; 2) evaluate the hypothesis that psychopathic individuals exhibit exaggerated endogenous attention effects, as indicated by larger N2pc responses during the Color task. We examined task-related effects on reaction time (RT) and accuracy using two-way repeated measures analyses of variance (ANOVA) with Task (Color vs. Size) and Validity (e.g., cue-target position: same vs. different) as within-subject factors. To examine task-related effects on mean ERP amplitudes (N2pc), we used a two-way repeated measures ANOVA with Task (Color and Size) and Laterality (hemisphere contralateral or ipsilateral to cue location from sites P3/P4) as within-subjects factors. To test our hypothesis regarding N2pc, we analyzed mean ERP amplitude from the Color task, using a two-way mixed-model ANOVA with Laterality (contralateral vs ipsilateral to cue location) as the within-subjects variable and Group (low, intermediate, and high psychopathy groups) as the between-subjects variable.

## Results

### Task-related effects

**RT and accuracy** Analyses revealed a significant main effect of task [$F(1,69) = 76.27$, $p < .001$, $\eta_p^2 = .53$] illustrating that the task providing set-congruent cues (e.g., Color task) elicited faster response times [$M(SE) = 549.67(9.16)$] than the Size task [$M(SE) = 612.14(11.96)$]. There was also a significant main effect of validity on RT [$F(1,69) = 200.59$, $p < .001$, $\eta_p^2 = .74$] illustrating that participants responded faster during valid trials overall. The main effect of validity was qualified by an expected task by validity interaction on RT, [$F(1, 69) = 124.95$, $p < .001$, $\eta_p^2 = .64$]. Further examination of this interaction revealed the expected spatial cueing effect (faster RT on valid trials) in the Color task [$F(1,69) = 309.59$, $p < .001$, $\eta_p^2 = .82$] but not the Size task ($p = .15$) (Fig. 2a). Analyses also revealed a significant main effect of task on accuracy [$F(1,69) = 8.44$, $p = .005$, $\eta_p^2 = .11$], indicating that participants were more accurate during the Color task [$M(SE) = 0.96(.002)$] than the Size task [$M(SE) = 0.96(.001)$]. There was also a significant main effect of validity on accuracy [$F(1,69) = 37.99$, $p < .001$, $\eta_p^2 = .36$], illustrating that participants were more accurate during valid [$M(SE) = 0.97(.002)$] than invalid trials [$M(SE) = 0.95(.001)$]. The expected significant task by validity interaction on

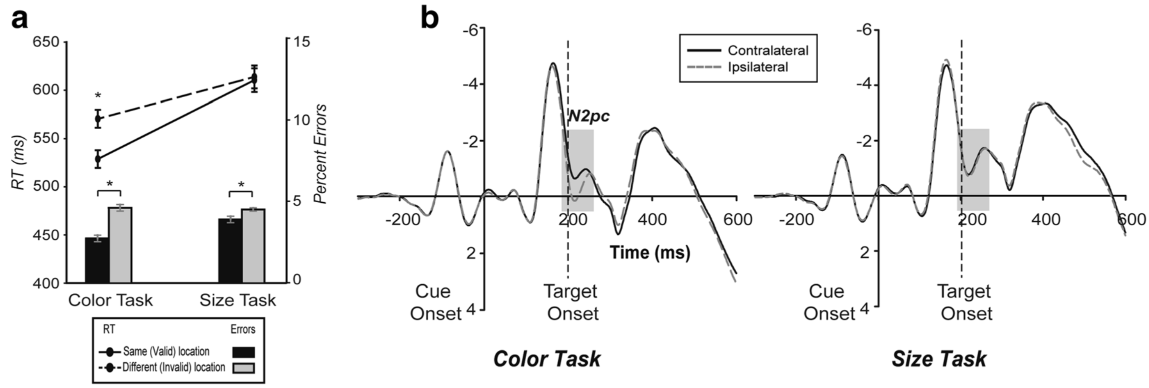


**Fig. 2** Task effects. (**a**) Response time (line graph) and accuracy (bar graph) for the Color and Size tasks during valid and invalid trials. (**b**) ERP grand averages for the −300 to 600 ms interval around cue onset for the Color and Size tasks. Gray boxes indicate N2pc interval between 180 and 265 ms post cue onset. Solid lines correspond to sites (P03/P04) contralateral to cue presentation and dashed lines correspond to ipsilateral sites

accuracy [$F(1,69) = 10.58$, $p = .002$, $\eta_p^2 = .13$] revealed a stronger validity effect for the Color [$F(1,69) = 52.03$, $p < .001$, $\eta_p^2 = .43$] versus the Size task [$F(1,69) = 4.92$, $p < .05$, $\eta_p^2 = .07$].

**Event-related potentials** Consistent with previous work, analyses revealed significant main effects for task and laterality as well as a significant task by laterality interaction on mean amplitude. The significant main effect of task revealed that the mean amplitude between 180–265 ms was more negative during the Color task than during the Size task across contralateral and ipsilateral conditions [$F(1, 69) = 29.90$, $p < .001$, $\eta_p^2 = .30$]. The significant main effect of laterality [$F(1,69) = 34.11$, $p < .001$, $\eta_p^2 = .33$] illustrated that ERPs in the contralateral condition were more negative than in the ipsilateral condition across both tasks (Table 2). Finally, as expected, the significant task by laterality interaction [$F(1,69) = 44.66$, $p < .001$, $\eta_p^2 = .39$] revealed a significant N2pc (e.g., as indexed by a significant difference between contralateral and ipsilateral conditions) in the Color task [$F(1,69) = 48.96$, $p < .001$, $\eta_p^2 = .42$], but not in the Size task ($p = .64$) (Fig. 2b).

### Primary analyses: psychopathy

**RT and accuracy** There were no significant main effects or interactions involving psychopathy for RT or accuracy ($p$'s > .13 and .36, respectively), indicating that all three groups performed at a similar level in the Color and Size tasks.

**Event-related potentials** The main effect of psychopathy on mean amplitude during the Color task approached significance ($p = .07$), but was qualified by the significant psychopathy by laterality interaction [$F(2,67) = 3.52$, $p < .04$, $\eta_p^2 = .10$]. Because the N2pc reflects the difference between the contralateral and ipsilateral conditions, we next analyzed the difference scores for the low, intermediate and high psychopathy groups using a one-way analysis of variance with planned difference contrasts (comparing the low and intermediate vs. high psychopathy group and low vs. intermediate groups). As predicted, planned contrasts revealed that the N2pc difference was significantly larger for high [$M(SD) = 0.71(.52)\mu V$] than low [$0.38(.55)\mu V$] and intermediate participants [$0.32(.58)\ \mu V$; $p = .01$], whereas the N2pc for low and intermediate participants did not differ ($p = .72$) (Table 2; Figs. 3 & 4).[1]

## Conclusions

Using a task explicitly designed to assess the influence of endogenous attention on early perceptual processes, we tested the hypothesis that psychopathic individuals demonstrate an exaggerated response to set-congruent information (i.e., a stronger effect of endogenous attention). Consistent with this hypothesis, an electrophysiological marker of selective attention, the cue-induced N2pc, was significantly larger for participants with high PCL-R scores than for participants with low or intermediate PCL-R scores. Highlighting the dynamic influence of endogenous attention in moderating sensitivity to set-congruent information, the N2pc for high PCL-R

[1] Although we did not expect to find group differences for the N2pc during the Size task, we conducted a supplemental analysis of the Size task ERP effects. Analyses revealed a significant group by contralaterality interaction, [$F(2, 67) = 4.31$, $p = .02$, $\eta_p^2 = .11$]. Follow up difference contrasts on the ipsilateral-contralateral difference between psychopathy groups revealed that the significant interaction was driven by a significant difference between the low [$M(SD) = -.09(.18)\mu V$] and intermediate psychopathy groups [$M(SD) = .15(.43)\mu V$; $p = .005$], whereas the difference between the high psychopathy group and the other groups was not significant ($p = .76$). Importantly, the significant effect observed in the low psychopathy group (marked by a more positive amplitude in the contralateral than the ipsilateral condition) replicated previous findings in the Size task (Eimer & Kiss, 2008).

**Table 2** Mean ERP amplitude during the N2pc window (180–265 ms) for contralateral (CL) and ipsilateral (IL) conditions

| | *Color Task CL M(SD)* | *Color Task IL* | *Size Task CL* | *Size Task IL* |
|---|---|---|---|---|
| *N* = 70 | −1.27 (1.96) | −0.79 (1.97) | −1.71 (1.84) | −1.69 (1.84) |
| Low Psychopathy (*n* = 23) | −0.91 (1.83) | −0.53 (1.89) | −1.39 (1.95) | −1.49 (1.97) |
| Intermediate Psychopathy (*n* = 23) | −0.73 (1.42) | −0.41 (1.62) | −1.28 (1.24) | −1.13 (1.21) |
| High Psychopathy (*n* = 24) | −2.12 (2.27) | −1.41 (2.27) | −2.42 (2.06) | −2.42 (2.04) |

participants was exaggerated during the Color task, which established an endogenous attentional set. Moreover, the magnitude of the N2pc response in the Color task for the intermediate and low psychopathy groups did not differ. Thus, in contrast to previous investigations which relied entirely on performance-based assessments of endogenous attention, our study provides compelling evidence that psychopathy is associated with an exaggerated effect of endogenous attention to set-congruent information during early stages of perception and attention.

Paralleling the results from the Eimer and Kiss (2008) study, we found that the pre-target cues elicited a significant N2pc response in the Color task (i.e., when they were set-congruent) in contrast to the Size task (i.e., when they were not set-congruent). The fact that the N2pc was present in the Color task in comparison to the Size task despite using identical pre-target cues in both paradigms provides good support for the assumption that the N2pc reflects the specific influence of top-down processes (i.e., endogenous processes) rather than bottom-up attentional capture alone. Importantly, the N2pc in response to pre-target cues during the Color task reflects the influence of endogenous attention in moderating sensitivity to task-irrelevant information that matched the features of the established attentional set. Moreover, the finding indicates that the cue-induced N2pc response in the Color task provides a valid method for evaluating our hypothesis that the effects of endogenous attention are exaggerated in psychopathic individuals. Consequently, the fact that psychopathic participants displayed significantly larger N2pc responses than other participants in the Color task demonstrates that endogenous attention exerts a significantly stronger influence on early perceptual processing in psychopathic individuals than in other participants. While it is important to note that the exaggerated effect of endogenous attention is not operating in isolation, but rather moderating exogenous responses to set-congruent information, the exaggerated effects of endogenous attention observed in this study offer a potential mechanism underlying the attention abnormality in psychopathic individuals. To our knowledge, this is the first study to demonstrate exaggerated endogenous attention effects in psychopathic individuals.

Notably, results from our investigation replicated previous behavioral findings for the Color and Size tasks (Eimer & Kiss, 2008) in addition to the task-related ERP effects. Specifically, we found significantly faster response time and greater accuracy on valid trials during the Color task, indicating significant behavioral spatial cueing effects across all participants. Overall, these findings indicate that our incarcerated participants performed the task much like non-incarcerated individuals and showed essentially the same task effects that were used to support the claim that early attention processing is modulated by top-down focus of attention.

After we completed this investigation, Hoppenbrouwers, Van der Stigchel, Slotboom, Dalmaijger, & Theeuwes (2015) published a study using an attention manipulation in combination with visual search tasks to examine the effects of top-down attention in moderating bottom-up processing. Contrary to our conclusions, the authors found psychopathy-

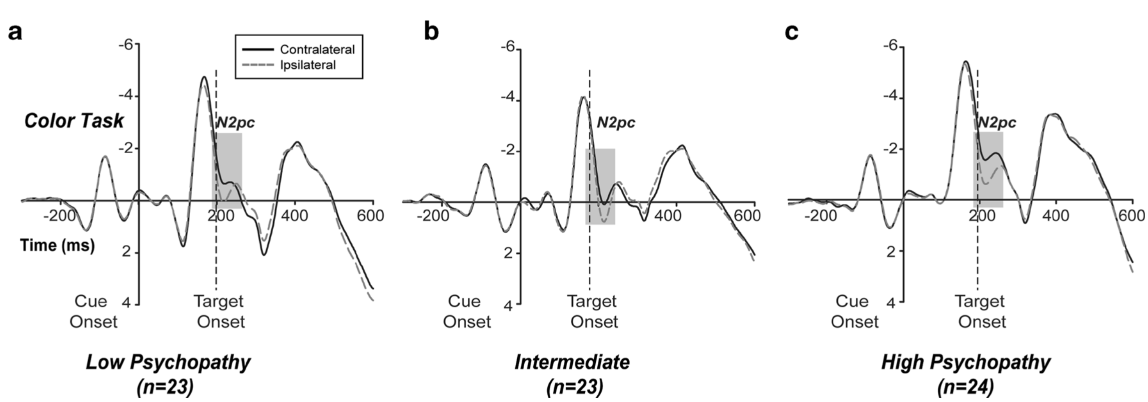


**Fig. 3** Color task ERP grand averages for the low group (**a**), intermediate group (**b**), and high psychopathy group (**c**)

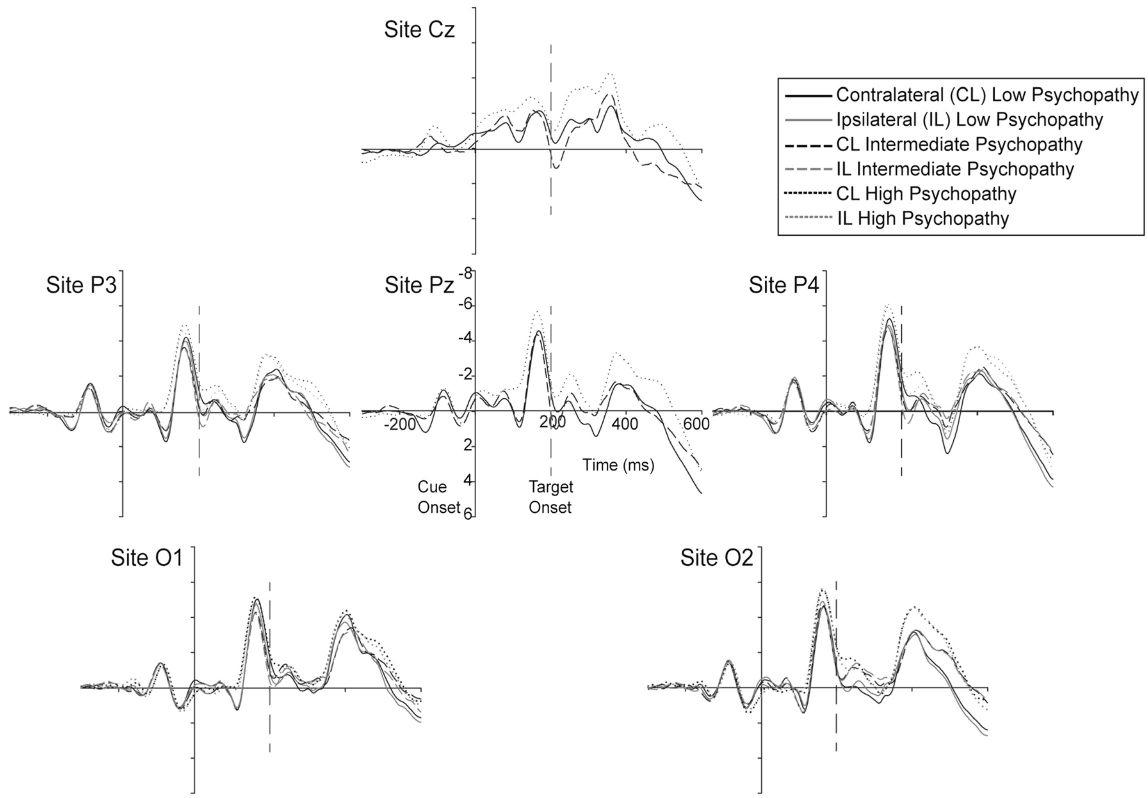


**Fig. 4** Color task ERP average waveforms for the low, intermediate and high psychopathy groups at lateral sites O1, O2, P3, and P4 and midline sites Pz and Cz for ipsilateral and contralateral conditions

related performance deficits in processing top-down cues, concluding that psychopathic individuals have difficulty "using contextual information to aid top-down visual search, even when the use of this information could be highly beneficial". In light of our different conclusions, it is important to examine methodological differences that might account for the differences. In contrast to the present study, Hoppenbrouwers and colleagues (2015) relied on behavioral performance, used a top-down manipulation involving trial-by-trial verbal instructions to focus on a particular color, and measured the speed with which participants correctly identified a target within set-relevant stimuli. Of note, the authors recognized the potential importance of the attentional demand associated with re-focusing attention on each trial and suggested the effects of top-down set on the performance of psychopathic individuals might have been stronger, if they used a blocked (i.e., more consistent) manipulation of top-down set. In other words, demands associated with processing instructions, maintaining an attentional focus on color, and discriminating other stimulus features (e.g., line orientation) on each trial required multiple attention sets and may have been particularly difficult for psychopathic participants. The current results, obtained with a less effortful and more consistent focusing manipulation, align with their speculation, though our use of psychophysiological measures of early attention may also be crucial. Notably, both studies indicate that selective attention processing in psychopathic individuals reflects the influence of top-down attention.

In light of the current ERP findings documenting an exaggerated effect of endogenous attention in high PCL-R participants, it should be possible to observe superior selective attention at the behavioral level. To date, however, there is little to no evidence that psychopathic individuals respond more quickly or accurately to set-congruent information (Zeier et al., 2009; Kosson, 1998, but see Dargis, Mattern, & Newman, manuscript submitted for publication). Such evidence for superior selective attention in psychopathic individuals has been limited to reduced processing of secondary cues (e.g., interference) under experimental conditions that cue a specific attentional set (Zeier et al. 2009, Zeier and Newman 2013; Hiatt et al., 2004; Jutai & Hare, 1983). Thus, one possibility is that the exaggerated effect of endogenous attention displayed by high PCL-R participants in the current study reflects the selectivity or specificity of information processing, rather than amount of attention allocated to the primary task. More specifically, the selective attention of individuals with high psychopathy may involve restricting attention to events of primary interest rather than allocating more attentional capacity to such events (which would be expected to enhance performance). This possibility is consistent with Kosson and Newman's (1986) proposal that psychopathic individuals allocate more attentional resources than non-psychopathic individuals to the concurrent task of managing their attentional focus. In other words, the discrepant findings for ERP and behavioral measures may reflect a tradeoff whereby the efficiency of selective attention of psychopathic individuals (i.e., maintaining a set-congruent focus of attention) is achieved at the expense of attention available to perform their primary task.

One interpretation of exaggerated attention response in psychopathy in the present study is that the N2pc reflects greater contributions from neural circuitry supporting top-down attention. Previous research using simultaneous ERP and event-related magnetic field recordings confirms that N2pc emanates from posterior parietal and occipito-temporal cortex (Hopf et al., 2000). Thus, one speculative, but plausible, interpretation of the exaggerated N2pc displayed by psychopathic individuals is that it reflects enhanced posterior parietal and occipito-temporal activity and an associated increase in early endogenous processing of set-congruent information. This early cue-elicited activity is likely reflecting increased activity supporting a feature-based control setting in the Color task (Ansorge, Kiss, Worschech, & Eimer, 2011). Consistent with this possibility, psychopathic individuals exhibit enhanced fronto-centrally distributed N2 responses to target stimuli (Kiehl et al., 2006) and show typical fronto-central and parietal P3 discrimination between novel and target stimuli (Brazil et al., 2012) during visual and auditory oddball tasks. These findings align with the notion that later aspects of set-relevant information processing may be augmented by frontal and parietal activity independent of sensory modality. Given that these regions exert top-down influence on occipito-temporal regions during visual attention in general (Bressler et al., 2008), it is also possible that the enhanced N2pc exhibited by high PCL-R individuals reflects exaggerated top-down influence from the dorsal attention network (i.e., including dorsal frontal and parietal circuitry; see Corbetta, Patel, & Shulman, 2008) on early visual attention.

Given the current findings, it is also important to consider why enhanced endogenous attention does not lead to more adaptive behavior in psychopathic individuals. One possibility is that despite exaggerated effects of top-down attention during early stages of perception, there are important neurocognitive operations that break down during subsequent stages of processing to culminate in disinhibited, antisocial behavior. Another possibility relates to impaired exogenous attention in psychopathy. There is substantial evidence that psychopathy is associated with deficient bottom-up responses to a variety of salient cues (e.g., cues for emotion, punishment, and conflict), signaling a need to evaluate and adapt behavior (Moul et al., 2012; Aharoni et al., 2013; Blair & Mitchell, 2009). To the extent that psychopathy involves such a deficiency, it is possible that a strong top-down focus of attention on set-congruent information would contribute to maladaptive behavior by creating an imbalance between top-down and bottom-up attention processing (Patterson & Newman, 1993). As described by MacCoon and colleagues (2004), an imbalance of this type undermines self-regulation and results in the poorly modulated expression of goal-directed behavior.

Before concluding, there are limitations to consider in the current study. First, although the low and intermediate psychopathy groups provided two incarcerated control groups, there was no neurotypical control group in the study. Second, although groups were matched on important variables that may confound ERP and behavioral effects (such as age and substance use), the high psychopathy group was slightly younger. Additionally, the task employed fixed stimulus durations that likely resulted in artifact in the ERP baseline, so future studies that manipulate the timing of visual attention tasks or use of other analytical methods such as independent component analyses may further clarify early selective attention processes. Future studies contrasting psychopathic individuals to healthy non-incarcerated individuals and those employing more diverse groups with regard to race, ethnicity and gender could further clarify the specific contributions of other variables to early selective attention processes.

Psychopathy is associated with an array of antisocial behaviors and callous, manipulative traits. Attention-based models contend that the problematic behaviors of psychopathic individuals reflect an inability to balance two important functions involved in selective attention: that of top-down attentional focus on goal-relevant information and that of bottom-up attentional capture by salient exogenous information. Using an experimental task and psychophysiological assessment designed to evaluate selective attention during early stages of perception, the current findings provide powerful new evidence for exaggerated endogenous attention effects in psychopathy and offer fresh insight regarding attention-based explanations for psychopathic behavior.

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## References

Aharoni, E., Vincent, G. M., Harenski, C. L., Calhoun, V. D., Sinnott-Armstrong, W., Gazzaniga, M. S., & Kiehl, K. A. (2013). Neuroprediction of future arrest. *Proceedings of the National Academy of Science 110,* 6223–6228.

Anderson, N. E., Steele, V. R., Maurer, M., Bernat, E. M., Kiehl, K. A. (2015): Psychopathy, attention and oddball target detection: New insights from PCL-R facet scores. *Psychophysiology.*

Ansorge, U., Kiss, M., Worschech, F., & Eimer, M. (2011). The initial stage of visual selection is controlled by top-down task set: New ERP evidence. *Attention, Perception and psychophysiology, 73,* 113–122.

Arnett, P. A., Smith, S. S., & Newman, J. P. (1997). Approach and avoidance motivation in incarcerated psychopaths during passive avoidance. *Journal of Personality and Social Psychology, 72,* 1413–1428.

Blair, R. J. R. (2005). Applying a cognitive neuroscience perspective to the disorder of psychopathy. *Development and Psychopathology, 17,* 865–891.

Blair, K. S., & Mitchell, D. G. V. (2009). Psychopathy, attention and emotion. *Psychological Medicine, 39,* 543–555.

Blair, K. S., Newman, C., Mitchell, D. G. V., Richell, R. A., Leonard, A., Morton, J., & Blair, R. J. R. (2006). Differentiating among prefrontal substrates in psychopathy: Neuropsychological test findings. *Neuropsychology, 20,* 153–165.

Brainard, D. H. (1997). The psychophysics toolbox. *Spatial Vision, 10,* 433–436.

Brazil, I. A., Jan Verkes, R., Brouns, B. H. J., Buitelaar, J. K., Bulten, B. H., & de Briujn, E. R. A. (2012). Differentiating psychopathy from general antisociality using the P3 as a psychophysiological correlate of attentional allocation. *Plos One, 7,* 1–8.

Bressler, S. L., Tang, W., Sylvester, C. M., Shulman, G. L., & Corbetta, M. (2008). Top-down control of human visual cortex by frontal and parietal cortex in anticipatory visual spatial attention. *Journal of Neuroscience, 28,* 10056–10061.

Corbetta, M., Patel, G., & Shulman, G. L. (2008). The reorienting system of the human brain: From environment to theory of mind. *Neuron, 58,* 306–324.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual review of neuroscience, 18*(1), 193–222.

Eimer, M., & Kiss, M. (2008). Involuntary attentional capture is determined by task set: Evidence from event-related brain potentials. *Journal of Cognitive Neuroscience, 20,* 14231433.

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 1030–1044.

Fowles, D. C. (1980). The three arousal model: implications of gray's two factor learning theory for heart rate, electrodermal activity, and psychopathy. *Psychophysiology, 17,* 87–104.

Gibson, B. S., & Kelsey, E. M. (1998). Stimulus-driven attentional capture is contingent on attentional set for displaywide visual features. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 699–706.

Hare, R. D. (2003). *Manual for the Hare Psychopathy Checklist-Revised* (2nd ed.). Toronto, Ontario, Canada: Multi-Health Systems.

Hemphill, J. F., Hare, R. D., & Wong, S. (1998). Psychopathy and recidivism: a review. *Legal and Criminological Psychology, 3,* 139–170.

Hiatt, K. D., Schmitt, W. A., & Newman, J. P. (2004). Stroop Tasks Reveal Abnormal Selective Attention Among Psychopathic Offenders. *Neuropsychology, 18,* 50–59.

Hopf, J., Luck, S. J., Girelli, M., Hagner, T., Mangun, G. R., Scheich, H., & Heinze, H. (2000). Neural sources of focused attention in visual search. *Cerebral Cortex, 10,* 1233–1241.

Hoppenbrouwers, S. S., Van der Stigchel, S., Slotboom, J., Dalmaijger, E. S., & Theeuwes, J. (2015). Disentangling attentional deficits in psychopathy using visual search: Failures in the use of contextual information. *Personality and Individual Differences, 86,* 132–138.

Jonides, J. (1981). Voluntary versus automatic control over the mind's eye's movement. *Attention and Performance. IX, 9,* 187–203.

Jutai, J. W., & Hare, R. D. (1983). Psychopathy and selective attention during performance of a complex perceptual-motor task. *Psychophysiology, 20,* 146–151.

Kiehl, K. A., Hare, R. D., Liddle, P. F., & McDonald, J. J. (1999). Reduced P300 responses in criminal psychopaths during a visual oddball task. *Biological Psychiatry, 45,* 1498–1507.

Kiehl, K. A., Bates, A. T., Laurens, K. R., Hare, R. D., & Liddle, P. F. (2006). Brain potentials implicate temporal lobe abnormalities in criminal psychopaths. *Journal of Abnormal Psychology, 115,* 443–453.

Kleiner, M., Brainard, D., Pelli, D., Ingling, A., Murray, R., & Broussard, C. (2007). What's new in psychtoolbox-3? *Perception, 36,* 1–1.

Kosson, D. S. (1998). Divided visual attention in psychopathic and nonpsychopathic offenders. *Personality and Individual Differences, 24,* 373–391.

Kosson, D. S., & Newman, J. P. (1986). Psychopathy and allocation of attention in a divided attention situation. *Journal of Abnormal Psychology, 95,* 252–256.

Luck, S. J., & Hillyard, S. A. (1994). Spatial filtering during visual search: Evidence from human electrophysiology. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1000–1014.

Lykken, D. T. (1957). A study of anxiety in the sociopathic personality. *Journal of Abnormal and Social Psychology, 55,* 6–10.

Lykken, D. T. (1995). *The antisocial personalities*. Hilldale, NJ: Erlbaum.

MacCoon, D. G., Wallace, J. F., & Newman, J. P. (2004). Self-regulation: The context-appropriate allocation of attentional capacity to dominant and non-dominant cues. In R. F. Baumeister & K. D. Vohs (Eds.), *Handbook of self-regulation: research, theory, and applications* (pp. 422–446). New York: Guilford Press.

Mangun, G. R., Hillyard, S. A., & Luck, S. J. (1993). Electrocortical substrates of visual selective attention. In D. Meyer & S. Kornblum (Eds.), *Attention and performance* (Vol. 14, pp. 219–243). Cambridge, MA: MIT Press.

McLellan, A. T., Kushner, H., Metzger, D., Peters, R., Smith, I., Grissom, G., & Argeriou, M. (1992). The fifth edition of the Addiction Severity Index. *Journal of Substance Abuse Treatment, 9,* 199–213.

Morgan, A. B., & Lilienfeld, S. O. (2000). A metaanalytic review of the relation between antisocial behavior and neuropsychological measures of executive function. *Clinical Psychology Review, 20,* 113–136.

Moul, C., Killcross, S., & Dadds, M. R. (2012). A model of differential amygdala activation in psychopathy. *Psychological Review, 119,* 789–806.

Müller, H. J., & Rabbitt, P. M. (1989). Reflexive and voluntary orienting of visual attention: time course of activation and resistance to interruption. *Journal of Experimental psychology: Human perception and performance, 15*(2), 315.

Newman, J.P., & Kosson, D.S. (1986). Passive avoidance learning in psychopathic and nonpsychopathic offenders. *Journal of Abnormal Psychology*, 257–263.

Newman, J. P., Curtin, J. J., Bertsch, J. D., & Baskin-Sommers, A. R. (2010). Attention moderates the fearlessness of psychopathic offenders. *Biological Psychiatry, 67,* 66–70.

Patterson, C. M., & Newman, J. P. (1993). Reflectivity and learning from aversive events: Toward a psychological mechanism for the syndromes of disinhibition. *Psychological Review, 100,* 716–736.

Pelli, D. G. (1997). The VideoToolbox software for visual psychophysics: Transforming numbers into movies. *Spatial Vision, 10,* 437–442.

Walters, G. D. (2003). Predicting institutional adjustment and recidivism with the psychopathy checklist factor scores: a meta-analysis. *Law and Human Behavior, 27,* 541–558.

Wechsler, D. (1997). *Wechsler Adult Intelligence Scale*. New York: Psychological Corporation.

Zeier, J. D., Maxwell, J. S., & Newman, J. P. (2009). Attention moderates the processing of inhibitory information in primary psychopathy. *Journal of Abnormal Psychology, 118,* 554–563.

Zeier, J. D., & Newman, J. P. (2013). Feature-based attention and conflict-monitoring in psychopathic offenders: Interactive relations of psychopathy with anxiety and externalizing. *Journal of Abnormal Psychology, 122,* 797–806.