Searching *"Inaffectively"*: A Behavioral, Psychometric, and Electroencephalographic Investigation of Psychopathic Personality and Visual-Spatial Attention

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Abstract

Psychopathic personality's characterization by abnormal visual-spatial attention and emotional response during visual search was evaluated in 3 related empirical investigations. Study 1 examined whether psychopathy impacts event-related potential (ERP) measures of stimulus salience (Ppc), target selection (N2pc), distractor suppression (Pd), and working memory (CDA). Psychopathic impulsivity traits were positively correlated with heightened visual-cortex salience calculations for distractor stimuli, requiring subsequent spatial suppression of those items. However, psychopathy was unassociated with target selection ability. Study 2 assessed whether psychopathy alters ERP measures of emotional face target salience (Ppc), selection (N2pc), and working memory representation (CDA). Similar to the results observed with low-level feature targets in study 1, even when targets were defined by complex emotional categories psychopathy remained unassociated with selection. Instead, the condition was negatively correlated with the strength of emotional face representations in working memory. Finally, study 3 tested whether individual differences in psychopathy explain longstanding discrepancies in a behavioral measure of efficiency during search for emotional faces (search slope). Detection of emotional targets was inefficient for all participants, and this effect was not moderated by the presence of psychopathic traits.

These results clarify several mechanisms underlying the attention and affect irregularities proposed in theoretical models of psychopathic personality. Rather than failure to detect information outside immediate focus, study 1 suggests external stimuli are hyper salient during pre-attentive scans, but are reflexively hyper suppressed. Studies 2 and 3 demonstrate emotional expression detection is unimpaired, but affective abnormalities occur later during evaluation. Notably, across all participants the emotional status of stimuli was best reflected at evaluative stages, not spatial reorienting stages. This is in line with guided search attention models, which posit that only select low-level stimulus features have the capacity to direct visual-spatial focus, and psychological construction affect models, which argue that perception of discrete emotional states occurs during conceptual evaluation of ostensibly emotional objects.

Keywords: Psychopathic Personality; Attention; Affect; Cognitive Neuroscience; Event-Related Potentials; Ppc; N2pc; Pd; CDA

To Etta, my friend, soulmate, and partner in crime.

And to my grannies. Two indomitable women and immigrants. I wish I could have given you this before you had to leave.

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Preface

This dissertation integrates two broad research areas: psychopathic personality, and event-related potential (ERP) visual-spatial attention. Psychopathic personality, or psychopathy, is characterized by deficits in emotional and empathic response, as well as impulsive behavior, and difficulties with inhibitory control. In extreme cases psychopathy is associated with instrumental criminal violence, but extreme presentations are rare. It is the view of many researchers and clinicians that psychopathic personality represents a conflux of normally distributed traits. Most measures, including the Psychopathic Personality Inventory-Revised self-report scale (PPI-R) – the primary tool used to assess psychopathy in this project – cluster these traits under factors or facets that broadly capture blunted emotionality, egocentricity, impulsivity/instability, and coldness/callousness.

Visual search is an everyday task that highlights several fundamental visual-spatial control mechanisms. Consider searching a baggage carousel after a long flight. You obviously do not have to inspect every single bag to discriminate yours from the others. Instead, you will like depend on your bag's distinctiveness along low-level feature dimensions such as color and size to guide your search. When you detect a salient item you can "select" or focus on its location to resolve its identity. But if that salient item is a distractor, you can instead suppress its location while focusing elsewhere. And in some situations – for example, once you've confirmed that your bag is not yet on the carousel, and will be arriving at the baggage chute – rather than searching, you may simply need to vigilantly constrain spatial focus to an invariant location. These operations can be indexed by ERPs in laboratory tasks by presenting salient (visually distinctive) items at lateral screen location. Due to the brain's cross lateralization, these salient items will be represented within the contralateral occipital cortex, and reflected in several scalp ERPs over those locations:

- **Ppc: salience computation.** Regardless of its target or distractor status, a singleton item will evoke an increased positivity at contralateral scalp approximately 100 ms following stimulus presentation. This Ppc, has been argued index a singleton's relative salience prior to spatial reorientation.

- **N2pc: singleton spatial selection.** When a salient target singleton is spatially selected for subsequent evaluation, the process is indexed by the N2pc component, an increased contralateral negativity that peaks between 170 – 300 ms after stimulus presentation.
- **CDA: visual working memory activity.** When an item is retained, manipulated, or recalled in visual working memory the N2pc is followed by a contralateral delay activity (CDA). The CDA is a sustained negative voltage enhancement at similar electrodes as the N2pc, but beginning approximately 300 ms after stimulus presentation.
- **Pd: singleton spatial suppression.** Finally, when a salient item's location is suppressed, a distractor positivity (Pd) occurs at occipital scalp locations during a similar time window as the N2pc. However, the Pd component is a singleton contralateral positivity.

There are several reasons to anticipate an association between psychopathic personality and these visual search processes. Attention-based models of the condition, such as the response modulation theory have proposed that it is characterized by hyper focused attention. Individuals high in psychopathic traits are argued to attend solely to the task at hand, while ignoring potentially important peripheral information. This information may include the distress cues of others, or knowledge of punishments. Furthermore, a large body of research has found that individuals high in psychopathy show small but reliable deficits in the ability to detect and identify the emotional expressions of others. As such, their ability to locate and retain targets defined by affective or emotional salience might be further altered.

The following manuscript consists of three chapters describing essentially independents studies with similar methodologies (participant selection, psychometric tools, stimuli and apparatuses), and a final chapter summarizing key themes that emerged across the entire project. Where relevant, chapters will refer back to others. Ultimately, the central objective of this project was the assessment of how psychopathic personality impacts visual-spatial attention control and emotional responsiveness during visual search. The first study examined whether psychopathic personality is associated with event-related potential measures of stimulus salience (Ppc), selection (N2pc), suppression (Pd), or visual working memory representation. Results suggested that psychopathy is characterized by heightened cortical salience for distracting stimuli, and that these items are subsequently prevented from entering working memory through spatial suppression. However, psychopathic traits were not associated with the detection

or intentional selection of targets. The second study tested whether psychopathy was associated with event-related potential measures of salience (Ppc), selection (N2pc), or working memory representation (CDA) for emotional faces during visual search. Similar to the first study, psychopathy was unassociated with target selection even when targets were defined by complex emotional categories, rather than simple low-level features. However, it did appear to be associated with diminished representation of target faces once they were localized. The third study tested whether psychopathy impacts behavioral measures of search efficiency when detecting emotional faces. Results showed inefficient detection of emotional targets, and that this effect was unassociated with psychopathic personality. In the final fourth chapter, results from all three studies are integrated in terms of two key themes that arise throughout the manuscript: 1) nature of visual-spatial attention in psychopathy and how this interacts with emotional expression recognition, and 2) The broader relationship of affective value and visual-spatial attention orienting.

Chapter 1.

Electroencephalographic evidence of increased distractor salience AND suppression in psychopathic personality (but target detection is unaffected)

1.1. Abstract

Selective attention models of psychopathy attribute the condition's interpersonal and affective impairments to a more general failure to process environmental information that is incongruent with one's attention-set. The current study used event-related potentials (ERPs) to examine whether this theoretical account extends to visual-spatial attention mechanisms responsible for pre-attentive salience mapping (target and distractor Ppc), goal-directed item selection (target N2pc), suppression of task-irrelevant information (distractor Pd), and working memory evaluation (CDA). Eighty undergraduate students completed the Psychopathic Personality Inventory-Revised (PPI-R; Lilienfeld & Widows, 2005) self-report measure, and performed a pair of cognitive tasks in which a search display containing a lateralized singleton was presented surrounding a fixation point that varied in luminance from trial-to-trial. During visual search for the singleton, reaction time and N2pc fractional-latency were strongly correlated, but neither measure correlated with scores on the PPI-R or its subscales. Regression analyses indicated that psychopathy did not moderate the association between N2pc latency and reaction time, and was unassociated with any target related ERP component amplitudes. In contrast, when responding to fixation point luminance and ignoring the search display, PPI-R scores correlated positively with amplitudes of the distractor singleton Ppc, as well as a sustained positive voltage component in the CDA time window. Furthermore, mediation analyses indicated that the increase in distractor salience indexed by Ppc amplitude accounted for the subsequent sustained CDA positivity, which was proposed to index a spatial suppression mechanism similar to

the standard Pd. This pattern of findings suggests that psychopathy does not impair one's ability to simply direct spatial attention to salient objects (N2pc). However, during focused attention, psychopathic impulsivity is characterized by a widened "pre-attentive window," increasing initial salience calculations (Ppc) and subsequent suppression (Pd) for task-irrelevant items.

1.2. Introduction

1.2.1. Visual-spatial attention, in the context of visual search

The term *attention* broadly encompasses a suite of nervous system processes that collectively focus sensation, perception, and cognition into high-resolution representations of select mental or environmental phenomena, while simultaneously encoding low-resolution representations of ambient stimuli. This coupling maximizes signal processing efficacy for central-events, while still allowing peripheral-events some limited access to the 'mind's eye' lest they become relevant. Even when restricted to the visual modality attention is not a unitary concept. Rather, it emerges from the interaction many sensory and cognitive functions (Wolfe & Horowitz, 2004). Within the context of *visual search* – locating a target within a group of distractors – the critical processes under consideration include enhancing representations of visual-spatial locations occupied by targets in order to facilitate their identification, suppressing visual-spatial locations occupied by competing items to limit their access to higher-order cognition, and biasing visual cortex sensitivity toward task relevant stimulus characteristics such as shape and color so as to prime the ongoing sensory sweeps that guide these visual-spatial actions.

Visual-spatial attention shifts are either overt, when accompanied by a saccade, or covert, when an observer mentally focuses on or suppresses an object's location without performing an actual eye movement (Luck & Kappenman, 2012). These visual-spatial shifts are guided by the relative *salience* of available items (Wolfe & Horowitz, 2004), which can be quantified as their degree of difference in some dimensional space, for example chromaticity in the case of color salience (Gaspar & McDonald, 2014). *Highly salient* stimuli are those whose degree of difference from others on a particular feature dimension substantially exceeds the threshold required to simply discriminate them. Salient items are considered *singletons* when presented within sets of largely identical items, as is typical in highly controlled laboratory investigations of visual search. In many situations visual-spatial attention deployment is a reflexive process (exogenous or “bottom-up”) driven toward the most salient item in the environment (Eimer & Kiss, 2008). The “inherent” salience of an object will vary based on observer characteristics, history, genetic inheritance, and current context. But all things being equal, item that are distinctly different on one of a limited number of critical “guiding feature dimensions” including onset, motion, orientation, size, color, luminance, and shape, can effectively capture visual-spatial attention, triggering shifts of focus to it location to enable its evaluation (Wolfe & Horowitz, 2004). Alternatively, visual-spatial attention can be directed intentionally (endogenous or “top-down”) in order to achieve internally generated goals. In such instances, the observer focuses on the location of a task relevant *target* object to evaluate or identify it. This endogenous search is most efficient when the target is highly salient on a guiding feature (its “signal” is strong), and there is little to no variation amongst the accompanying non-target items, hereafter referred to as *fillers* (their “noise” is low). Search may be impeded by the presentence of additional salient non-target singletons, hereafter referred to as *distractors*. However as explained below, visual-spatial attention can still be directed to a target efficiently even if it is not the most salient singleton in a display (Gaspar & McDonald, 2014; Jannati, Gaspar, & McDonald, 2013).

Despite this distinction between endogenous and exogenous visual-spatial shifts, these processes are also interactive. For example, when targets are defined by a particular dimension such as color, exogenous shifts to any singletons salient on that dimension become more likely due to its task-contingent enhancement. This can result in *contingent capture* of attention by irrelevant items beyond the capacity predicted by their inherent salience (Eimer & Kiss, 2008; Hopfinger & Ries, 2005). As an explanation of these interactive mechanisms, Jannati, Gaspar, and McDonald (2013) have proposed a model in which ongoing visual scans of the environment continually update contextualized *salience maps.* In turn, the “pre-attentive stage” salience maps guide reflexive (exogenous) orienting to stimuli at the subsequent “attentive stage.” Executive processes can also direct visual-spatial focus at the attentive stage to or from object-locations coded within that salience map in order to perform goal related identification (endogenous attention in the most classic sense). Additionally, endogenous realignment of feature dimension weights used for salience map calculations can increase or decrease the relative salience of objects, and by extension their capacity to guide reflexive and intentional attention shifts in real-time. Once oriented to, an object can then be subject to higher-order identification or discrimination. The following section outlines some of the electrophysiological correlates of these various attention processes.

Event-related potential indices of visual-spatial attention mechanisms

The cross-lateralized structure of the human visual system has facilitated the discovery of several electroencephalographic (EEG) event-related potential (ERP) components indexing specific visual-spatial operations. As noted above, typical ERP visual search investigations employ stimulus arrays containing many identical or largely identical non-target fillers, as well as salient lateralized singletons that may be distractors or targets depending on task demands. This approach is particularly powerful and dramatically reduces measurement error because singleton specific activity can be isolated both within-subject and within-trial (Luck, 2014). This is achieved by subtracting stimulus-locked ERP activity of electrodes at scalp locations ipsilateral to (on the same side as) the visual hemifield containing the singleton from ERP activity of electrodes contralateral to (on the opposite side as) the singleton.[1] Quantitatively, this difference in electrical activity can be tested in an analysis of variance framework by treating contralateral and ipsilateral sites as two-levels of a within-subjects factor. Alternatively, component amplitudes and latencies can be extracted from contralateral-minus-ipsilateral difference waveforms and used as outcome variables in linear regression analyses.

The most widely studied lateralized visual-spatial attention ERP component is the posterior contralateral N2 (N2pc) to targets. The N2pc occurs 175 – 300 ms after the

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[1] Note: Unless otherwise stated, for the remainder of this chapter the term “contralateral” refers to electrodes/scalp sites contralateral to the visual hemifield containing the singleton, whereas “ipsilateral” refers to electrodes/scalp sites ipsilateral to the visual hemifield containing the singleton (rather than being contralateral or ipsilateral to some other reference point, such as another electrode).

presentation of a multi-item visual search display containing a salient lateralized singleton. It is observed as a greater negativity at occipital scalp-sites contralateral to the singleton than scalp-sites ipsilateral to the singleton. For the component to occur there must be some competition between the singleton and surrounding fillers, leading to the early conclusion that it reflects spatial filtering (Luck & Hillyard, 1994b). Target enhancement, distractor filtering, or a combined process, ultimately guided by stimulus-driven capture or endogenous selection have all been proposed to underlie the component, but most researchers agree that the N2pc indexes the selection of an item from a group of neighboring items for further processing (McDonald, Green, Jannati, & Di Lollo, 2013). Strength, timing, and reliability of this selection mechanism, as well as the completion of preceding supplemental mechanisms can be assessed by examining the component's amplitude or latency (Luck, 2014). In simple visual search tasks for salient targets, N2pc latency often correlates with reaction time because the target must be localized before responses can be made. Variability of the delay between target localization and responding may indicate differences in cognitive evaluation or response selection processes. Although an N2pc elicited by a target likely reflects intentional orienting, one elicited by a distractor may indicate exogenous attention capture (Eimer & Kiss, 2008; Hickey, Di Lollo, & McDonald, 2009; McDonald et al., 2013).

In many visual search studies, a target N2pc is followed by the contralateral delay activity (CDA), a lateralized ERP component thought to index stimulus representation in visual short-term memory (Jolicœur, Brisson, & Robitaille, 2008; Vogel & Machizawa, 2004). The CDA is a negative voltage enhancement at similar singleton-contralateral versus ipsilateral electrodes as the N2pc. It was first observed by Vogel and Machizawa (2004) in a study of visual working memory during the retention intervals that occurred between presentations of memory and test arrays. The component was correlated with memory load, as well as individual differences in visual working memory capacity for simple visual stimuli (shapes). Further research has found that CDA amplitude also indexes the load and capacity of maintaining representations of faces in working memory (Towler, Kelly, & Eimer, 2015).

Functionally, the underlying neural activity reflected at scalp level as the CDA achieves more than the simple maintenance of information over brief time intervals. This sustained electrical signal also indexes processing and manipulation of information in visual working memory. Mazza, Turatto, Umiltà, and Eimer (2007) briefly displayed search arrays (150 ms) containing a lateralized luminance-salient singleton that participants were either required to simply locate by indicating the visual hemifield in which it appeared, or discriminate by identifying its shape (a non-singleton feature that was unrelated to the search). Although the singleton elicited an N2pc regardless of the task demands, this was followed by a CDA only when participants performed the *compound search* required in the discrimination condition. This finding indicates that whereas the N2pc relates to a spatial localization mechanism, the CDA is involved in higher-order object evaluation following selection. Although much research on the CDA has examined the component under circumstances in which visual stimuli are no longer available to participants, it is also observed in compound search tasks in which stimuli persist on screen until after a response has been made (Gaspar & McDonald, 2014; Jannati et al., 2013). Additionally, when participants are cued to recall features of a salient singleton from a lateral location within a *previously* presented search display, a similar negative amplitude ERP component has been observed across posterior singleton-contralateral scalp (Fortier-Gauthier, Moffat, Dell'Acqua, McDonald, & Jolicœur, 2012). Thus, the visual working memory processes indexed by the CDA and related components likely depend on – or perhaps even directly represent – preservation and reactivation of the same spatiotopic external-space mapping that is continually being performed by the brain during sensation and perception.

In addition to spatial selection and object discrimination, visual-spatial ERPs can be used to index suppression of a salient but task irrelevant distractor lateralized within a search array. The distractor positivity (Pd) occurs at occipital scalp locations during a similar time window as the N2pc. However, the Pd component is a positivity at singleton-contralateral versus singleton-ipsilateral sites (Gaspar & McDonald, 2014). Measurement of the Pd can be conflated by simultaneous measurement of the target N2pc, but by presenting targets on the vertical midline of search arrays and distractors at lateral locations, researchers have been able to isolate distractor specific activity (Hickey et al., 2009). Studies employing this approach have shown that the Pd is inversely associated with behavioral indices of distractor interference. When searching for a target in a display containing a salient distractor, fast response trials are characterized by strong Pd amplitude, whereas slow response trials are characterized by weak Pd amplitude and a subsequent increase in distractor CDA amplitude, indicating its inadvertent representation in visual working memory (Gaspar & McDonald, 2014; Gaspar, Christie, Prime, Jolicœur, & McDonald, 2016; Sawaki, Geng, & Luck, 2012). Gaspar and McDonald (2014) demonstrated that Pd reflects a spatial filtering mechanism that suppresses an ignored item's location, rather than a feature dimension mechanism that minimizes attention capture by the item. This suppression helps resolve competition when the distractor is more salient than the target on the task relevant dimension (within-dimension competition) or salient on a different dimension than the target entirely (e.g. a shape distractor presented with a color target; cross-dimension competition). However, if a distractor is less salient than the target within the critical feature dimension no Pd is observed, presumably because spatial filtering is not required to select the target (Gaspar & McDonald, 2014). Intriguingly, in the previously described study examining ERP responses during cued recall of a search display (Fortier-Gauthier et al., 2012), if the cue indicated that the lateral singleton was a distractor instead of a target, the CDA-like component it elicited appeared to have a positive amplitude rather than a negative amplitude. Given the interpretation that the neural activity underlying visual short-term memory mirrors that of sensation and perception, this raises the possibility these later positive amplitude components that occur across occipital-temporal scalp reflect some canonical spatial suppression mechanism employed across numerous cognitive stages. Taken together in the context of visual search, Pd amplitude and latency reflect the degree and timing of endogenous spatial suppression of distractors. Relative increases in Pd strength between participants or conditions may indicate more effective control of spatial attention, or more need to engage in such a process.

The N2pc and Pd may also be preceded by a lateralized component overlapping the time ranges of the visual P1 and N1. Salient singletons elicit a posterior positivity at contralateral occipital scalp sites (Ppc) during this early sensory processing stage, regardless of their status as targets or distractors (Luck & Hillyard, 1994a). Thus, whereas a singleton must be both salient and task relevant to elicit the N2pc, salience alone can be sufficient for a stimulus to elicit the Ppc. The component likely reflects refractory activity of visual cortex neuron populations. Almost by definition, singletons occur less frequently than fillers in a visual search task. Because of this, neurons with receptive fields tuned to the particular regions of feature dimension-space that define singletons are stimulated less frequently than those tuned to filler item feature dimension-space (Luck & Hillyard, 1994a). By extension the aggregated visual cortex sensory responses elicited by singletons should be greater than those elicited by fillers. Because of this, enhanced contralateral P1 (i.e. Ppc) during visual search was initial interpreted as low-level sensory confound, as opposed to the higher level cognitive processing indexed by enhanced N2pc (Luck & Hillyard, 1994a). Nevertheless, this sensory component likely plays an important role in guiding attention.

Within the salience map framework proposed by Jannati and colleagues (2013), the Ppc has been argued to index the strength of a singleton's pre-attentive stage (i.e. prior to visual-spatial reorienting) "attend-to-me" signal, which subsequently guides spatial selection (N2pc) *or* suppression (Pd) of its location at the later attentive stage (i.e. spatial reorienting). Strength of this response can be increased by prior spatial enhancement of a singleton's location due to voluntary shifts or preceding presentation of a valid spatial cue (Hopfinger & Ries, 2005; Livingstone, Christie, Wright, & McDonald, 2017). Enhanced Ppc amplitude has also been observed to color singleton targets presented within an array composed *entirely* of color singletons (Christie, Livingstone, & McDonald, 2015), and to the prior location of salient-singleton targets and distractor during visual working memory recall of a search array (Fortier-Gauthier et al., 2012). This would indicate that Ppc effects are greatest for items that have the highest activity on the salience map or otherwise have priority due to task relevance.

Together, the Ppc, N2pc, Pd, and CDA provide a set of ERP indices for the most fundamental visual-spatial attention controls. Item salience calculation is measured by the Ppc, suppression by the Pd, selection by the N2pc, and evaluation by the CDA. By manipulating task conditions and stimulus parameters researchers can test how these controls respond to various environmental demands. Additionally, by testing the covariance of these components with pathology symptoms or personality traits, researchers can better understand the neural mechanisms that mediate psychological experience. This latter approach is used in the current study to clarify whether visual-spatial attention is dysregulated in psychopathic personality, a condition notable for its distinctive executive control profile.

1.2.2. Psychopathic personality: dysfunctions of attention and emotion, or maybe just attention?

Psychopathic personality is characterized by core deficits in emotional and empathic capacity, as well as impulsive disinhibited behavior (Lilienfeld & Widows, 2005). In its most extreme presentations, psychopathy has a notable association with social deviance, particularly instrumental, goal directed criminal violence. However, extreme presentations are rare and psychopathic personality is thought to be a conflux of traits that are normally distributed throughout both community and correctional populations (Benning, Patrick, Hicks, Blonigen, & Krueger, 2003). Most clinical conceptualizations and measurement tools of psychopathy identify fearlessness, shallow emotionality, glib or superficial interpersonal charm, failure to take responsibility/parasitic lifestyle, narcissism, and lack of inhibition among its core symptoms or traits. Several assessments and self-report measures such as the widely used Psychopathic Personality Inventory-Revised (PPI-R; Lilienfeld & Widows, 2005), cluster these traits under facets/factors that broadly capture blunted emotionality, egocentricity, impulsivity/instability, and coldness/callousness.

Psychometrically, psychopathic personality is associated with a complex nomological web (Kastner, Sellbom, & Lilienfeld, 2012; Ray, Weir, Poythress, & Rickelm, 2011; Uzieblo, Verschuere, Van den Bussche, & Crombez, 2010), though its various facets may independently or even differentially predict scores on affect, impulsivity, empathic, drive, and inhibition measures (Lilienfeld & Widows, 2005). Behaviorally, psychopathy is associated with modest impairments in the ability to identify emotions conveyed within facial expressions (Wilson, Juodis, & Porter, 2011), vocalizations (Blair et al., 2002; Stevens, Charman, & Blair, 2001), and body language (Muñoz, 2009). Biological measurements have demonstrated reduced electrodermal response to distress cues (Blair, Jones, Clark, & Smith, 1997), and reduced startle potentiation in response to threat stimuli (Patrick, 1994) in individuals with high levels of psychopathic traits. Abnormalities in ERP indices of language processing (Kiehl, Hare, McDonald, &

Brink, 1999; Williamson, Harpur, & Hare, 1991), error feedback processing (Pasion, Cruz, & Barbosa, 2016), and response to positive and negative affective stimuli (Carolan, Jaspers-Fayer, Asmaro, Douglas, & Liotti, 2014) seem to characterize the condition. Although there is little disagreement that psychopathy involves a range of emotional and executive impairments, the exact functional mechanisms that account for these impairments and the etiological pathways that lead to them are somewhat more disputed.

Attention-based models of psychopathic personality such as the response modulation theory hold that frontal lobe abnormalities result in selective attention dysfunctions, which cause a downstream impairment in a high-trait individual's capacity to engage in inhibitory control (Glass & Newman, 2006). Evidence in support of this comes from a study that assessed color-word Stroop effects in offenders classified as psychopathic or non-psychopathic using a clinical assessment measure (Hiatt, Schmitt, & Newman, 2004). Typical Stroop interference was observed across all participants when naming the ink colors of incongruent color words (e.g. slower reaction time for the word “Red” than a letter “X” string when response to blue ink). However, when color and semantic information were spatially separated by presenting colored squares containing incongruent color words written in white ink, inmates rated as psychopathic showed marginally less interference than those rated as non-psychopathic. The study's authors concluded that failure to incorporate external information in psychopathy is not attributable to a simple failure to interrupt ongoing responses, detect mismatches, or accommodate task irrelevant features. Instead, they attributed this characteristic to spatial “over selection” that ignores information irrelevant to immediate goals when it falls outside of immediate focus. Building on this notion, Zeier, Maxwell, and Newman (2009) found that inmates rated high in psychopathy showed less distractor interference than non-psychopathic inmates during a flanker task, but only if prior presentation of a cue was used to direct visual-spatial attention to the target's location. Thus, the response modulation theory ultimately holds that although capacity for inhibitory control is not impaired in psychopathic personality per say, the information needed to activate inhibitory control mechanisms (e.g. expressions of distress, knowledge of punishment costs) is simply not attended to if it falls outside of immediate orientation.

Such theories of psychopathy posit that emotional recognition and conditioning deficits result from this more general inability to implicitly integrate events occurring outside immediate focus. By extension, proponents of this model have argued that if emotional information is congruent with the current attention set of an individual high in trait psychopathy — that is to say a specific emotion is task relevant — the emotional deficits otherwise thought to be so characteristic of psychopathy will disappear (Glass & Newman, 2006). These effects are hypothesized to stem from diminished activity in Orbital and Ventrolateral Frontal Cortex, the regions shown to be most integral to aggression management in lesion studies, though imaging evidence for specific deficits in these regions in psychopathic personality is limited (Blair, 2005). However, this theory is supported by numerous studies in which core psychopathic deficits including startle conditioning, resistance to Stroop effects, affective responding, and error feedback processing are alleviated by manipulations that make external information congruent with task attention set (Krusemark, Kiehl, & Newman, 2016; Newman, Curtin, Bertsch, & Baskin-Sommers, 2010). Thus, it would seem that attention moderates at least some aspects of psychopathic emotionality and learning.

Recent neurological evidence of attention dysfunction in psychopathy comes from an application of the lateralized visual-spatial ERP approach. Krusemark and colleagues (2016) examined contingent capture in incarcerated criminals rated low, moderate, or high on a clinical psychopathy assessment by having them perform a task in which they identified the orientations of salient singleton targets presented within a visual search display. For half of the task blocks, the target was made a salient singleton by increasing its size, whereas for the other half by altering its color. Additionally, for all trials (both size and color singleton blocks) the search display was preceded by a task-irrelevant array containing a spatially uninformative but color-salient cue. Contingent capture occurred in the form of an N2pc to this cue during color singleton blocks but not shape singleton blocks, and the effect was strongest in inmates who were highest in psychopathy. The authors concluded that this reflected top-down hyper selection of the target feature dimension. Their explanation was based on the assumption that this contingent capture was determined by an endogenously held attention set, which triggered more dramatic shifts to task irrelevant but target congruent stimuli. Krusemark and colleagues (2016) did note that this interpretation breaks from the classic response modulation theory, which has suggested that diminished peripheral stimulus processing is due to hyper focus on attended location rather than an inherently feature-based mechanism.

1.2.3. The current study

Krusemark and colleagues (2016) concluded that psychopathy is characterized by excessive endogenous attention-set that over values target congruent stimuli. In contrast, studies investigating psychopathic attention deficits for external stimuli have traditionally attributed this effect to visual-spatial over selection, not a feature-based mechanism (Glass & Newman, 2006; Hiatt et al., 2004; Zeier et al., 2009). Therefore, current ERP findings paint an unclear picture. Additionally, the establishment of visual-spatial ERP components beyond just the N2pc has advanced our understanding of how the visual system selects and inhibits information. Although "directing spatial attention" *sometimes* involves a purely selective process it *sometimes* also involves suppression of competing information. Thus, the current study tested whether psychopathic personality impacts the functioning of four visual-spatial attention processes indexed by well-established ERP components evoked in response to search arrays containing lateralized salient singletons: salience mapping (Ppc), selection (N2pc), suppression (Pd), and evaluation (CDA). These effects should vary predictably with task demands that change the singleton's status as a target or distractor. Therefore, their covariance with a measure of psychopathic traits should provide a more nuanced explanation of how the condition alters visual-spatial attention.

Two visual-spatial attention tasks with identical search array stimuli but differing response requirements were employed in this study (described in *1.3.2 Cognitive Tasks*). In task 1, participants performed a feature guided compound-search for a singleton target. Because rapid target identification could be achieved by up weighing the target feature dimension (shape), the singleton was expected to be salient and to elicit significant Ppc, N2pc, and CDA effects between contralateral and ipsilateral scalp sites across the full sample. A positive associated between psychopathy and the strengths[2] of these components for targets would support the overactive endogenous attention-set account proposed by Krusemark (2016). For the Ppc this would reflect greater endogenous up weighing of the target feature during salience calculation, akin to the mechanism that drives contingent capture (Eimer & Kiss, 2008; Hopfinger & Ries, 2005; Livingstone et al., 2017). For the N2pc and CDA this would reflect efficiency of goal-directed spatial selection using salience information, and subsequent discrimination respectively. If, as posited in the classic response modulation theory (Glass & Newman, 2006; Hiatt et al., 2004; Zeier et al., 2009), heighted spatial selection drives attention abnormalities, a positive association between psychopathy and N2pc or CDA strength, or moderation of the correlation of N2pc latency and reaction time by psychopathy would be observed. However, if spatial attention abnormalities are actually due to suppression of salient distractor information, then no such effect would be expected. In either case, no association of psychopathy with target Ppc is predicted by this account given its emphasis on target spatial location rather than features.

In the second task, participants responded to luminance changes of a central fixation point while ignoring the surrounding search array, including the singleton. Because the fixation target was spatially-invariant, there was no need to attend to potential singleton locations on the periphery in this task. Additionally the singleton's defining feature dimension was always task irrelevant. Thus across the full sample the singleton was anticipated to show minimal salience map priority (Ppc), little evidence of spatial selection or suppression (N2pc and Pd respectively), and negligible representation in working memory (CDA). Krusemark and colleague's (2016) account would predict either a negative correlation, no association at all or between psychopathic traits and the strengths of these components for distractors. Overactive endogenous attention-set should be directed exclusively towards the characteristics of the fixation

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[2] Visual search ERP component "strength" as used here is essentially a proxy term for the component's absolute amplitude value (i.e. value in mV or µV irrespective of sign). Large positive values for Ppc and Pd amplitude reflect strong responses, and large negative values for N2pc amplitude reflect strong responses. Statistically, a positive association with a positive amplitude component is indicated by a positive correlation, but a positive association with a negative amplitude component is indicated by a negative correlation. Note that component polarity alone rarely indicates a particular underlying cellular action. See Luck (2014, p.42) for a discussion of how cellular mechanisms, cortical structure, and recording methodologies interact to determine component polarity observed at the scalp.

target and ascribe little salience to distractor features. Two response profiles could be predicted from the classic response modulation theory. It could be that spatial over selection of the fixation target simply results in a general failure to register peripheral distractors, in which case psychopathy would correlate negatively with strength of all visual-spatial components investigated here. Alternatively, if phenotypic over selection is actually achieved by suppression of peripheral information following their registration, psychopathy should be positively correlated with the strength of the Pd.

As will be explained in the following sections, data from task 1 of the current study showed no association of psychopathy with any of these components during search for target singletons. Therefore, failure to incorporate external information cannot be explained by superior selective attention for target spatial locations or features. Instead, data from task 2 indicated that psychopathic traits were associated with increased response to distractors. This initially took the form of enhanced Ppc amplitude, implying that distractors were attributed greater pre-attentive priority. This was followed by a subsequent positive amplitude effect that began during the time range of the Pd and became significant in the time range of the CDA, suggesting that these items were subsequently suppressed to eliminate their continued representation within visual working memory.

1.3. Methods

Prior to data collection, this study was reviewed by the Simon Fraser University Office of Research Ethics and received a minimal risk designation.

1.3.1. Participants and procedure

Power analyses conducted prior to data collection and statistical tests determined that to achieve adequate power (.80) for tests of *r* at α = .05 (two-tailed), a sample size of 84 or 28 would be needed to detect significant effects of medium (*r* = .30) or large (*r* = .50) size, respectively (Cohen, Cohen, West & Aiken, 2003). Based on these considerations, a sample of 80 undergraduate students (age *M* (*s*) = 21.08 (3.60); 64 female and 16 male, 3 left-handed, none colorblind, 48 English first-language speakers) completed a demographics and medical questionnaire (Appendix A), a battery of personality and temperament measures (described in Appendix B) that included the Psychopathic Personality-Revised (PPI-R; Lilienfeld & Windows, 2005), and two cognitive tasks accompanied by EEG data recording. Sessions were approximately 2-hours, for which participants received course credit through the Department of Psychology's Research Participation System. Of these participants, 13 reported having had a head injury resulting in loss of consciousness or a concussion, and 6 reported a history of migraines. An additional nine participants reported a previous diagnosis of depression, anxiety disorder, bipolar disorder, and/or obsessive compulsive disorder (one of these participants also reported migraines); one reported diagnoses of borderline personality disorder and anorexia, as well as a previous concussion; one reported diagnosis of autism spectrum disorder; and three reported diagnosis of dyslexia or another learning disability.

Participant exclusions and attrition

Three participants were unable to perform task 1 due to time constraints during their recording sessions. Task 1 data for 2 participants were excluded due to poor EEG quality, resulting in a final sample of 75 participants for target search behavioral and ERP amplitude analyses, and 1 additional participant was excluded from N2pc latency analyses due to the absence of a negative trough in the component window (median number of trials in task 1 individual ERP averages = 507, minimum = 178). Task 2 data for 2 participants were excluded due to poor EEG quality, resulting in a final sample of 78 participants for distractor related analyses (median number of trials in task 2 individual ERP averages = 502, minimum = 167). Any analyses comparing behavioral and ERP effects between tasks were restricted to the 73 participants whose data were retained for both.

1.3.2. Cognitive Tasks

Both tasks were built and run in E-Prime 2.0.8 on a Windows PC. Participants were seated with their face 60 cm from a 19-inch LCD monitor (1024 x 786 resolution, 60 Hz refresh rate). Responses were made with the right hand using a Logitech gamepad. Order of the tasks was counterbalanced across participants.

Task 1: Feature guided search for a peripheral target

Stimuli in this task were presented on a black background, and consisted of a circular array of eight bright green unfilled-shapes (red = 0, green = 255, blue =0) distributed evenly around a central light grey (E-Prime color attribute setting = “silver”) fixation cross. Within the arrays, seven shapes were circles (4 cm diameter), and one singleton was a diamond (4.5 cm^2). A 0.2 cm x 2.5 cm horizontal or vertical silver bar was centered within each shape. Shapes were placed with their centers 10 cm from the center of the screen, at angles of 22.5°, 67.5°, 112.5°, 157.5°, 202.5°, 247.5°, 292.5°, and 337.5°, leaving 5.8 cm between the center points of neighboring shapes (see Figure 1-1). On each trial, the singleton’s location was randomly selected with equal probability for all locations, and the fixation cross luminance became brighter (“white”) or darker (“grey”). Participants were instructed to identify the orientation of the line within the singleton as quickly and accurately as possible while not moving their eyes from the fixation cross. Stimulus arrays offset 100 ms after response and were followed by a jittered interstimulus interval (800 to 1300 ms) before the onset of the next array. Participants performed 18 blocks of 30 trials, with 15 second breaks between blocks. Trials were rejected from analyses if participant reaction time (RT) was too fast or too slow (150 ms < RT < 2500 ms).

Task 2: Peripheral distractor inhibition during response to a spatially-invariant fixation target

The apparatus, stimuli, and presentation parameters in this task were identical to the visual search task, however rather than responding to the singleton, on each trial participants identified whether the fixation cross had become brighter or darker. Participants were instructed to ignore the surrounding array, making the singleton a task irrelevant distractor.

1.3.3. EEG recording and processing

EEG activity was recorded using an electrode cap with sintered Ag/AgCl active electrodes at 64 standard Modified Combinatorial Nomenclature sites (Biosemi Active Two amplifier, Amsterdam). Additional bilateral active electrode pairs were placed over mastoids, external canthi (for horizontal eye movements), and infraorbital locations (for vertical eye movements and blinks). Voltages were recorded against a common mode sense (CMS) active electrode. Data were sampled at a rate of 512 Hz.

All offline EEG data processing and extraction was conducted in MATLAB (R2016a) using the Field Trip Toolbox (version 2016.05.10; Oostenveld, Fries, Maris, & Schoffelen, 2011). For each participant, segments of EEG time-locked to stimulus onset were sampled from continuous EEG (correct response trials only), demeaned, and re-referenced to average mastoid. Independent component analysis (ICA) decomposed the data to 20 unique spatial-temporal signals, from which up to 4 representing ocular artifacts (vertical and lateral saccades, blink propagation, or electromyographic activity) were identified and removed on the basis of visual inspection.[3] Recomposed data was digitally high-pass filtered (0.05 Hz, 4th order, Butterworth) and aligned to a -200 to 0 ms baseline. Any trials remaining contaminated by blinks, saccades, or skeletal muscle movement were identified and removed through visual inspection aided by a semiautomatic artifact detection procedure.

Time-locked ERP averages were computed for each subject for each task, collapsed across fixation-cross luminance and singleton-bar orientation for the various array configurations. ERPs for three pairs of bilateral occipito-parietal electrode sites (O1/O2, PO7/PO8, and P7/P8) were collapsed across left and right electrodes, and left and right visual hemifields to produce waveforms ipsilateral and contralateral to the singleton and eliminate brain-hemisphere specific effects. Contralateral-minus-ipsilateral ERP difference waveforms were computed to isolate singleton-related lateralized activity. Subjects with fewer than 30 artifact-free trials for either task were rejected from further analyses. Finally, before export for statistical analyses or grand average visualizations, subject averages were digitally low-pass filtered with a 28 Hz cut-off for mean amplitude values or a 10 Hz cut-off for latency values (both 4th order Butterworth). These differing low-pass filter settings for amplitude versus latency were chosen to optimize data quality and limit data distortion within each type of analysis, based on recommendations by Luck (2014, p. 245 – 246, p. 300).

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[3] Visual inspection identified components with temporal characteristics and topographical distributions similar to ocular artifacts described by (Jung et al., 1998; Jung et al., 1998).

Latency of the N2pc was defined as the 50% fractional negative area of the PO7/PO8 contralateral-minus-ipsilateral difference wave over a 175 to 400 ms post-stimulus interval (as recommended by Luck, 2014), and was extracted only for task 1. Because fractional area operations are not included in the standard Fieldtrip toolbox, values were derived using customized Matlab scripts (available on request) built with the functions *trapz( ), max(y,0),* and *min(y,0)*. For both tasks, mean amplitudes of the Ppc, N2pc, Pd, and CDA components were extracted from bilateral electrode pairs (contralateral and ipsilateral to the singleton) selected on the basis of previous literature, across time windows centered on appropriate peaks or troughs of grand average contralateral-minus-ipsilateral difference waveforms. Ppc mean amplitude was calculated at occipital sites O1/O2 (Jannati et al., 2013) from 75 to 125 ms. Mean amplitudes of the N2pc and Pd were calculated at occipito-parietal sites PO7/PO8 (Gaspar & McDonald, 2014); Luck, 2012, 2014) from 250 to 310 ms. Negative component amplitude would be taken as evidence of an N2pc, whereas positive component amplitude would be taken as evidence of a Pd. Finally, CDA mean amplitude was calculated at the same occipito-parietal sites as the N2pc over two potential time windows, 350 to 410 ms and 450 to 510 ms (Gaspar & McDonald, 2014; Jannati et al., 2013; Jolicœur et al., 2008; Mazza et al., 2007).

1.3.4. Data reduction and analyses

All statistical analyses were conducted in SPSS Statistics (version 19.0.0; IBM, 2010). Those incorporating PPI-R values treated total and factor scores as continuous interval variables (unit-weighted composites; see measure description in Appendix B), though percentile scores were used to separate participants into low- (≤ 33rd), medium- (34th to 66th), and high-trait (≥ 67th) groupings for graphical depictions. Behavioral performance between tasks was assessed using a paired samples *t*-test on mean accuracy (within-subjects comparison of search versus fixation), and a repeated measures analysis of variance (rANOVA) on correct response median RT using within-subject factors of *task* (search or fixation), *singleton lateralization* (left or right visual hemifield), and *singleton location* (four levels corresponding to the positions within each hemifield). Significant interactions and effects were probed with follow-up paired samples *t*-tests or rANOVAs that controlled for family-wise error using Bonferroni corrections.

To assess the impact of target localization on search efficiency during task 1, N2pc latency was correlated with median RT. Moderation of this association by psychopathic personality was tested though multiple linear regressions incorporating PPI-R total or factor scores and component latency by scale interaction terms (as described by Baron & Kenny, 1986; Cohen et al., 2003). Mean amplitudes of the Ppc and N2pc/Pd time windows were assessed for both tasks via rANOVA using a single within-subject factor of *electrode site* (contralateral or ipsilateral to the singleton) in order to confirm the presence of significant lateralized ERP components at the group level. CDA rANOVAs incorporated an additional within-subjects factor of *epoch* (mean amplitudes during the 350 – 410 ms and 450 – 510 ms time windows) and were followed by paired samples *t*-tests to assess significant interactions.

Further analyses tested whether psychopathic personality moderated component mean amplitudes by incorporating PPI-R total or factor scores as covariates in repeated measures analyses of covariance (rANCOVAs) using the same within-subjects factor(s). For rANCOVAs revealing significant moderation of a component by psychopathy, contralateral-minus-ipsilateral electrode mean amplitude differences were correlated with the relevant measure to better quantify the direction of the relationship. Convergent validity was assessed by correlating component mean amplitude difference with relevant external measures, including the Triarchic Psychopathy Measure (TriPM) total and subscale scores, Behavioral Activation System/Behavioral Inhibition System (BAS/BIS), Barratt Impulsiveness Scale-Version 11a (BI-11a), and State Trait Anxiety Inventory (STAI-I/II), all of which are discussed in Appendix B.

1.4. Results

A covariance matrix of PPI-R total, factor, and subscale scores computed across all 80 participants can be found in Table 1-1. Means and standard deviations for the remaining test battery questionnaires can be found in Table 1-2. ERP outcome variable scores can be found in Table 1-3. ERP electrode plots for both tasks are presented in Figure 1-2.

1.4.1. Behavioral data and manipulation checks across the sample

Analysis of behavioral performance during visual search in task 1 and response to fixation in task 2 indicated that they were of comparable difficulty. Mean accuracy was high for both and did not differ significantly between them (task 1: M = .962, s = .0345; task 2: M = .966, s = .0338; $t_{task1\text{-}task2}(72) = -.985$, p = .328; r = .300, p = .010).

Slower responses in task 1 than task 2 confirmed that an initial search was required before participants could respond to peripheral targets. This was further supported by differences in RT based on the singleton's location in task 1, but not task 2. Specifically, RT was substantially slower for the search task (715.5 ms) than the fixation task (608.5 ms), and there were significant interactions of *task* by *laterality* and *task* by *location* ($F_{task}(1,72) = 152.158$, $p < .001$, $\eta_p^2 = .679$; $F_{task*laterality}(1,72) = 11.321$, $p = .001$, $\eta_p^2 = .136$; $F_{task*location}(3,216) = 6.561$, $p < .001$, $\eta_p^2 = .084$). A follow-up rANOVA restricted to the fixation task indicated that the main-effects and interactions of *location* and *laterality* were negligible, with RT ranging from 605.3 ms to 612.9 ms depending on singleton location. In contrast, the rANOVA and *t*-tests within the search task indicated that responses were significantly faster when singletons were presented in the right visual hemifield than the left (a difference of 12.8 ms; $F_{laterality}(1,72) = 11.342$, $p = .001$, $\eta_p^2 = .136$), and closer to the horizontal meridian than the vertical meridian (differences ranged from 8.2 to 19.7 ms; $F_{location}(3,216) = 5.615$, $p = .001$, $\eta_p^2 = .072$). However, the *laterality* by *location* interaction was non-significant ($F_{laterality*location}(3,216) = 0.240$, $p = .869$, $\eta_p^2 = .003$). So although RT data did indicate that visual search speed differed as a function of target placement, the small sizes of these effects and absence of an interaction between singleton hemifield and location supported the decision to collapse trials within each task for ERP analyses.

1.4.2. Task 1 target search ERP data

Analysis of visual search task data indicated that salient singleton targets elicited the anticipated ERP effects across the full sample. Median RT and N2pc fractional-latency (M = 288.9 ms, s = 24.88) were strongly correlated, demonstrating a clear relationship between target selection time and observed behavioral response speed (r = .342, p = .003). This association was not moderated by psychopathic personality, as evidenced by small, non-significant regression coefficients for main-effects and interactions of PPI-R total and factor scores as predictors of RT (for all, $|b^*| \leq .086$, $p \geq .451$). Additionally, these measures were uncorrelated with N2pc latency or RT, indicating little evidence of enhanced target selection speed in psychopathy (for all, $|r| \leq .069$, $p \geq .558$).

Mean amplitude analyses confirmed that target singletons evoked significant Ppc, N2pc, early CDA, and late CDA components across the full sample (see Table 1-3, and Figure 1-2 upper panel), but as with latency and RT analyses these tests provided no evidence of enhanced selective attention in psychopathy. Significant contralateral minus ipsilateral electrode voltage differences in the appropriate directions were observed across the sample for the Ppc (0.1121 μV; $F_{site}(1,74) = 12.994$, $p = .001$, $\eta_p^2 = .149$) and the N2pc (-1.5778 μV; $F_{site}(1,74) = 101.230$, $p < .001$, $\eta_p^2 = .579$). As was anticipated, there was no evidence of target singleton suppression during the N2pc window. The rANOVA assessing the CDA returned significant main effects of *electrode site* and *epoch*, and a significant interaction of these factors ($F_{site}(1,74) = 11.611$, $p = .001$, $\eta_p^2 = .136$; $F_{epoch}(1,74) = 21.780$, $p < .001$, $\eta_p^2 = .227$; $F_{site*epoch}(1,74) = 6.387$, $p = .014$, $\eta_p^2 = .079$). Follow-up *t*-tests indicated significant negative contralateral minus ipsilateral mean amplitude differences during both the early CDA (-0.212 μV; $t_{contra\text{-}ipsi}(74) = -2.330$, $p = .023$) and late CDA (-0.39 μV; $t_{contra\text{-}ipsi}(74) = -3.937$, $p < .001$), and that this difference became significantly stronger over time (i.e. the amplitude difference became increasingly more negative; $t_{early\text{-}late}(74) = -2.527$, $p = .014$). Despite these significant effects at the group level, moderation analyses incorporating PPI-R total or factor scores as rANCOVA covariates found no significant interactions of psychopathy with the differences between contralateral and ipsilateral electrode sites during any component window (for all Ppc interactions, $F(1,73) \leq 2.854$, $p \geq .096$, $\eta_p^2 \leq .038$; for all N2pc interactions $F(1,73) \leq 2.079$, $p \geq .096$, $\eta_p^2 \leq .038$; and for all early and late CDA interactions $F(1,73) \leq .852$, $p \geq .359$, $\eta_p^2 \leq .012$). Taken together, task 1 yielded no evidence that psychopathic personality traits are associated with enhanced pre-attentive salience calculation, visual-spatial selection, or subsequent evaluation of targets. This calls into question Krusemark and colleagues' (2016) interpretation that enhanced target feature selection drove stronger N2pc contingent capture effects among inmates higher in psychopathy. This also indicates that enhanced target spatial selection may not account for failure to incorporate external information, as argued by the classic response modulation theory (Hiatt et al., 2004).

1.4.3. Task 2 fixation target, peripheral distractor ERP data

ERP grand average waveforms for task 2 data across the full sample (Figure 1-2 second panel from the top) indicated that when participants focused on the spatially-invariant fixation cross, the peripheral singleton distractor was still ascribed pre-attentive salience. These waveforms also suggested that participants suppressed the distractor at later cognitive stages, possibly to limit competition with the target in visual working memory. The singleton elicited a significant Ppc mean amplitude difference between contralateral and ipsilateral electrodes (0.0897 μV; $F_{site}(1,77) = 9.062$, $p = .004$, $\eta_p^2 = .105$). Despite the appearance of greater positive mean amplitude at contralateral than ipsilateral electrodes during the Pd window of the grand average waveform, this difference failed to reach significance (.0989 μV; $F_{site}(1,77) = 3.551$, $p = .063$, $\eta_p^2 = .044$). An exploratory rANCOVA controlling for participant RT found no interaction of Pd amplitude and response speed. The rANCOVA on mean amplitudes during the CDA windows found significant main effects of *electrode site* and *epoch* but absolutely no interaction of the two factors ($F_{site}(1,77) = 9.082$, $p = .003$, $\eta_p^2 = .106$; $F_{epoch}(1,77) = 19.524$, $p < .001$, $\eta_p^2 = .202$; $F_{site*epoch}(1,77) < 0.001$, $p = .991$, $\eta_p^2 < .001$). Curiously, follow-up *t*-tests indicated significant positive rather than negative mean amplitude differences for contralateral minus ipsilateral electrodes during both the early (0.1720 μV; $t_{contra-ipsi}(77) = 3.341$, $p = .001$) and late (0.1717 μV; $t_{contra-ipsi}(77) = 2.528$, $p = .014$) windows. Given that CDA mean amplitude to a salient item is typically negative, this finding was somewhat unexpected. However, a Pd-like component has previously been reported during visual working memory recall of search arrays containing a salient lateralized distractor (Fortier-Gauthier et al., 2012). Authors of that study posited that this visual working memory distractor related positivity, the standard Pd, and other positive amplitude occipital components that follow pre-attentive salience mapping (which itself is indexed by the P1, N1, and Ppc), may reflect a generalized suppression mechanism that facilitates multiple stages of visual-spatial attention. Thus, this positive amplitude component in the CDA time range may have reflected activity of a similar spatial suppression mechanism to that underlying the Pd. Partially supporting this interpretation, there was a small negative correlation between RT and amplitude of the earlier CDA window, but the effect failed to reach significance (r = -.201, p = .077). Of note, an exploratory rANOVA and follow-up *t*-tests compared contralateral-minus-ipsilateral mean amplitude differences of the Ppc, N2pc/Pd, early CDA, and late CDA between tasks 1 and 2. Results of this analysis indicated that Ppc component amplitude did not differ significantly for targets and distractors ($t_{task1\text{-}task2}(72) = 1.066$, p = .290). However, there were strong significant differences between component amplitudes of the N2pc/Pd ($t_{task1\text{-}task2}(72) = -11.223$, $p < .001$) and both CDA time windows (early: $t_{task1\text{-}task2}(72) = 3.634$, p = .001; late: $t_{task1\text{-}task2}(72) = 4.381$, $p < .001$).

Although no relationship was found between psychopathy and target selection in task 1, moderation analyses for task 2 revealed a substantive impact of psychopathy on lateralized ERP responses to distractors (see Figure 1-2 lower panels). The pattern that emerged when accounting for PPI-R total and Self-centred Impulsivity (SCI) factor scores indicated that individuals highest in these traits drove the significant Ppc and positive CDA contralateral-minus-ipsilateral electrode mean amplitude differences observed in the grand averaged data. In lower trait individuals, electrode mean amplitudes were only minimally differentiated for these components. First, Ppc rANCOVAs produced significant interactions between *electrode site* and both the SCI and PPI-R covariates ($F_{site*SCI}(1,77) = 4.638$, p = .034, η_p^2 = .058; $F_{site*PPIR}(1,77) = 5.598$, p = .021, η_p^2 = .069). A follow-up correlation indicated that Ppc amplitude became stronger as scores increased on SCI (r = .240, p = .034) and PPI-R (r = .262, p = .021). That is to say, psychopathic impulsivity and total score were positively associated with distractor singleton salience attribution. Second, CDA rANCOVAs found significant interactions of *electrode site* with SCI and PPI-R scores ($F_{site*SCI}(1,77) = 13.937$, $p < .001$, η_p^2 = .155; $F_{site*PPIR}(1,77) = 4.701$, p = .033, η_p^2 = .058). Given that no interactions were observed with the CDA *epoch* factor, follow-up correlations were assessed on contralateral-minus-ipsilateral electrode amplitude differences averaged across the two windows. These tests indicated that the component became more positive as SCI (r = .394, p < .001) and PPI-R (r = .241, p = .027) scores increased. Third, some convergent validity of these effects was demonstrated by similar positive correlations between the TriPM Disinhibition subscale and CDA mean amplitude difference (r = .250, p = .033, n = 73). However this measure was uncorrelated with Ppc amplitude (r = .080, p = .502), and no significant correlations were found between distractor components amplitudes and TriPM total score (for all, $|r| \leq .188$, $p \geq .112$, n = 73). Unlike PPI-R total score and SCI, the Fearless Dominance (FD) factor did not moderate ERPs during distractor suppression (for all FD interactions with component mean amplitudes, $F(1,77) \leq .1.929$, $p \geq .169$, $\eta_p^2 \leq .025$). As with the visual search task, median RT was uncorrelated with PPI-R total or factor scores (for all, $|r| \leq .092$, $p \geq .423$). Linear regressions indicated that the association of RT and Pd amplitude was not moderated by SCI or PPI-R total score.

Finally, a mediation analysis was conducted following the procedure outlined by Baron and Kenny (1986)[4] to clarify the relationship of PPI-R total score with the distractor Ppc and CDA components seen in task 2. The possibility that Ppc mean amplitude difference (indexing subjective distractor salience) mediated the relationship between the PPI-R as a predictor of positive CDA mean amplitude difference (potentially indicative of distractor suppression) was tested through a series of linear regressions. As noted above, PPI-R score significantly predicted the CDA outcome variable and the Ppc mediator. Ppc amplitude also significantly predicted CDA amplitude (r = .517, p < .001). And it turn, the multiple linear regression of CDA amplitude on both PPI-R score and Ppc amplitude found that the relationship between PPI-R and CDA became non-significant (b^* = .114, p = .267) in the presence of the strong significant Ppc mediator (b^* = .488, p <

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[4] As described by (Baron & Kenny, 1986), this method involves performing a set of three regressions to determine whether an observed significant relationship between a predictor variable (*A*) and an outcome variable (*B*) is accounted for by a classic “third variable” (*C*). First, a significant regression coefficient (correlation) must be found for A as a predictor of C. Second, a significant regression coefficient must be found for C as a predictor of B. Third, mediation of the A-B relationship by C is indicated by a multiple linear regression with A and C as predictors of B if the coefficient of A as a predictor of B (i.e. the initial relationship in question) is non-significant in the presence of a significant coefficient of B as a predictor of C.

.001). Therefore it is reasonable to conclude that the increased pre-attentive salience of distractor singletons to individuals higher in psychopathic traits accounted for their enhanced positive amplitude response at subsequent evaluative stages. If this positive CDA reflects a generalized visual-spatial suppression mechanism, this finding supports the conclusion that resistance to task irrelevant peripheral information is driven by reactive distractor suppression, and not enhanced selective attention for targets.

1.5. Discussion

As anticipated, this investigation of the covariance between self-reported psychopathic traits and ERP indices of item salience, selection, suppression, and working memory in undergraduate students revealed neurological evidence of abnormal visual-spatial attention to external distractor stimuli. This extends the findings of previous behavioral research, which has shown that individuals rated high in psychopathy are resistant to peripherally presented non-target information (Hiatt et al., 2004; Zeier et al., 2009). Beyond simply providing physiological evidence of this behavioral tendency, patterns observed in the current study shed light on the cognitive and perceptual mechanism that actually drive these attention dysfunctions. Results both supported and contradicted predictions derived from the response modulation theory (Glass & Newman, 2006; Hiatt et al., 2004; Zeier et al., 2009), and conclusions drawn in a recent ERP study of contingent capture in psychopathy (Krusemark et al., 2016). Resistance to peripheral information in psychopathy has traditionally been attributed to enhance selective attention for target-relevant features or spatial locations. However the ERP data here indicated that psychopathic attention abnormalities are better characterized as a perceptual hyper-responsiveness to distractor information, which may be mitigated at later cognitive stages by reactive suppression.

In task 1 of the present study participants performed visual searches for conspicuous target singletons. Across the sample, typical Ppc, N2pc, and CDA component amplitudes were evoked by target singletons. There was a robust correlation between RT and latency of the N2pc component, indicating that the task functioned well. However, scores on the PPI-R self-report measure were unassociated with the value of target-relevant features during pre-attentive salience mapping (target Ppc amplitude).

Therefore, contrary to the conclusions of Krusemark and colleagues (2016) endogenously held attention-set (selective attention for features) was no stronger in individuals high in psychopathy than those low in psychopathy. PPI-R scores were unassociated with the intentional visual-spatial selection of targets during search (N2pc amplitude and latency), or the evaluation of targets in visual working memory following their selection (CDA amplitude, and the correlation of N2pc latency and RT). Thus, there was also no indication that psychopathy involves enhanced spatial selective attention ability.

Instead, psychopathic impulsivity had a substantive impact on neural indices of distractor salience and visual working memory representation when participants focused on a central fixation point and ignored peripheral singletons during task 2. Under these conditions, grand average data for the full sample showed that singletons elicited a pre-attentive salience response (significant Ppc amplitude), and may have been suppressed at later cognitive stages (significant positive component amplitude during the time windows of the typically negative amplitude CDA). Amplitudes of these components were positively correlated with PPI-R total and SCI factor scores, indicating enhancement of pre-attentive and working memory visual-spatial mechanisms for distracting information by psychopathic and impulsivity traits. Similar correlations between Ppc amplitude and an external psychopathic disinhibition measure provided some convergent support for this interpretation. Contralateral-minus-ipsilateral electrode difference waveforms calculated across low, moderate, and high PPI-R score participant groupings (Figure 1-2) clearly showed that lateralized ERP effects to the distractor were driven by greater responses in higher-trait individuals.

Intriguingly, mediation analyses indicated that the PPI-R’s correlation with increased distractor Ppc amplitude accounted for its correlation with increased distractor CDA positive amplitude. Positive amplitude of a CDA-like component at working memory stages has previously been proposed to index a generalized visual-spatial suppression mechanism that also underlies the Pd component; a mechanism that inhibits the representation of salient non-target information within visual working memory in order to resolve competition with task-relevant information (Fortier-Gauthier et al., 2012). If this is indeed the case, individuals higher in psychopathic traits may have engaged in more suppression of distractors because it was *necessitated* by their great attribution of salience to those items at the preceding perceptual stage. In light of these findings, it is worth reconsidering the functional mechanisms underlying attention abnormalities in psychopathic personality.

1.5.1. Is visual-spatial attention abnormally strong or weak in psychopathy? Yes!

As described earlier, the response modulation theory attributes psychopathic inhibitory control deficits to a more general failure to incorporate information that it is incongruent with current attention-set (Glass & Newman, 2006). In real world terms, when a person high in psychopathy engages in goal-directed violent or antisocial behavior, ‘incongruent information’ might be a victim’s emotional expressions of distress, or a cue indicating that a punishment will follow the action. Supporting this theory, behavioral data from flanker and Stroop studies suggests that irrelevant distractors cause less interference (RT slowing) for inmates who are high in psychopathy than those who are low in psychopathy (Hiatt et al., 2004; Zeier et al., 2009). However, distractor resistance has been dependent on spatial separation of semantic and feature information for the color-word Stroop task, and cueing of target location in the flanker task. Thus over selection of target-relevant spatial locations has been proposed as the attention ‘dysfunction’ underlying insensitivity to external stimuli within the model (Hiatt et al., 2004). When performing visual search during task 1, were spatial selection mechanisms excessively enhanced in psychopathy, participants’ PPI-R scores should have correlated positively with absolute value of target N2pc amplitude (i.e. the strength of component) or moderated the correlation of RT with N2pc latency. Additionally, although Krusemark and colleagues' (2016) ERP study of contingent capture found increased N2pc for irrelevant cues in inmates high in psychopathy, they did not report results for the target-locked N2pc. Therefore, there is currently no ERP evidence in support of improved spatial selection in psychopathy.

But this is not to say that visual-spatial attention abnormalities are absent in psychopathic personality. On the contrary, when responding to the spatially invariant fixation point in task 2, PPI-R and SCI scores (which capture psychopathic impulsivity) were correlated with greater positive amplitude to distractors during the time window of the CDA. Previous visual search studies with salient distractors have found that greater Pd amplitude is associated with faster responses and increased working memory capacity (Gaspar & McDonald, 2014; Gaspar et al., 2016; Sawaki et al., 2012). If the positive CDA seen here reflects a similar mechanism to the Pd, one might be tempted to conclude that psychopathy is characterized by improved cognitive control. This would be misguided for a number of reasons. First, although studies have reported associations of psychopathic fearlessness with several positive outcomes, psychopathic impulsivity is generally correlated with negative outcomes, externalizing, poor behavioral controls, and negative affect (Edens & McDermott, 2010; Kastner et al., 2012; Marcus, Fulton, & Edens, 2013). Second, unlike the Pd in the studies described above, the positive CDA observed in data from task 2 was uncorrelated with RT. Thus, its enhancement here was not a necessary condition of effective task performance. Third, significantly greater Ppc amplitude to salient distractors was also observed in participants with higher PPI-R and SCI scores. This component reflects low-level sensory or pre-attentive response to stimulus salience (Jannati et al., 2013; Luck & Hillyard, 1994a). Low- and moderate-trait participants showed only limited lateralized Ppc activity to distractors, and therefore seemed to employ some sustained control approach. There was never a reason to orient to the periphery in task 2, and so the most efficient attention strategy was to restrict focus to the location of the fixation cross. This proactive mechanism has been referred to as the attention zoom-lens, and is thought to be form of voluntary control that can preclude attention capture to distractors (Theeuwes, 1991). Higher-trait individuals may have been less effective at constricting spatial attention, resulting in continuous salience mapping over a wide spatial window that included distractor singletons. Alternatively, they may have been less effective at down weighting the relevance of non-target features, and thus ascribed pre-attentive salience to shape singletons despite their task irrelevance. Regardless, the conclusion that can be drawn from increased Ppc amplitude here is that psychopathic traits predicted more processing of irrelevant distractors during pre-attentive salience calculation. Moreover, Ppc amplitude mediated the correlation of PPI-R total score with CDA positive amplitude, therefore if that correlation indicated more goal-directed distractor suppression in high psychopathy this was a down-stream requirement necessitated by earlier reactivity

This interpretation still accounts for the well-established finding that the external information needed to engage inhibitory control mechanisms is excluded from active awareness in high psychopathy. However, this seems to arise from the interplay of weak pre-attentive control and abnormally strong (reactive) suppression, rather than unequivocally strong spatial selection. This has potential to explain real world behavior of individuals with clinically relevant levels of psychopathy. In everyday situations, such individuals would likely find *everything* in their physical and mental environments captivating, but habitually suppress those stimuli to maintain an essentially normal behavioral presentation. But, it is conceivable that when external objects or internal impulses are more compelling than a simple diamond shape presented among a group of circles, the inhibitory capacity of this nearly reflexive control might be exceeded, resulting in the explosive antisocial-impulsivity thought so characteristic of clinical psychopathy. Future empirical investigation of this possibility seems warranted.

1.5.2. Spatial versus feature-based attention abnormalities

The possibility that greater Ppc to irrelevant distractors in task 2 reflected a general inability to down-weight the relevance of non-target features dovetails into a discussion of whether psychopathic attention abnormalities involve a spatial or feature-based mechanism. Some studies have found that when external information is made relevant to the task (i.e. when it is congruent with attention-set) attention in psychopathy can be normalized. Newman and colleagues (2010) found diminished startle conditioned response in inmates high in psychopathy if they were asked to report basic features of letter conditioned stimuli (upper versus lower case), but normal startle if they were asked to report the punishment contingencies of those letters (threat versus no-threat). Although Zeier and colleagues (2009) behavioral flanker study of psychopathy (described earlier) found spatial attention abnormalities, Zeier and Newman (2013) found what appeared to be enhanced feature-based attention in a follow-up investigation with similar methodology. In this second study, a centrally presented arrow that onset with the flanker items denoted which one was the target. However, on 50% of the trials, a centrally presented cue preceded the flanker stimuli, and indicated what color the target item would be. Inmates who were high psychopathy showed less flanker distractor interference on color-cued trials than inmates who were low or moderate psychopathy.

Zeier and Newman (2013) took this as evidence that hyper selection in psychopathic attention extends to target features. However, it is important to note that the target and distractor items in this task were still spatially separate. Although feature-based mechanisms seem to have influenced performance, this may have been because the additional target relevant information was used to guide spatial selection of the target's location or suppression of the distractor's location, as per the guided search framework (Jannati et al., 2013; Wolfe & Horowitz, 2004). The latter option seems particularly plausible, given that the spatial suppression process indexed by the Pd help resolve competition from distractors (Gaspar & McDonald, 2014), and that the positive amplitude CDA observed in the current study may reflect that same process (Fortier-Gauthier et al., 2012).

On the basis of enhanced N2pc amplitude for task irrelevant but target congruent cues in inmates higher in psychopathy, Krusemark and colleagues (2016) also concluded that psychopathic attention is characterized by stronger endogenously held attention-set for target features. However, this interpretation is at odds with the absence of an association between PPI-R scores and target identification RT, Ppc amplitude, or N2pc amplitude and latency in task 1 of the current study. As noted above, those authors did not report ERP effects time-locked specifically to targets, so only limited conclusion can be drawn regarding the functional significance of their cue N2pc. However, consideration of their findings in conjunction with the pattern of results observed in task 2 may better explain this process. Guided search models of attention (Jannati et al., 2013; Wolfe & Horowitz, 2004) hold that the salience of perceptual features during cursory scans of the environment (pre-attentive) are coded within a visual-cortex map. These salience signals guide selection and suppression of visual-spatial locations during directed attention. Results from task 2 indicate that high psychopathy is associated with an over generalized salience map, such that items beyond the task relevant spatial location have inappropriately high pre-attentive priority. If an individual who tends to compute over generalized maps is required to restrict their focus to a particular location in order to respond – as was the case in task 2 – they would need to employ some Pd-like suppression mechanism in order to prevent distraction. However, if that individual is only required to passively view a task irrelevant stimulus and a particular feature happens to have features of the task target – as was the case in congruent trials of Krusemark (2016) – then the spatial selection mechanism indexed by the N2pc might occur instead. Ultimately, future studies employing more deliberate control of spatial versus feature-based attention will be needed to explain the exact nature of their interaction with psychopathy. However, for now it seems that a spatial suppression account is better able to describe the pattern of results seen in ERP investigations of psychopathy. Furthermore, there is currently no unequivocal support for the claim that psychopathic personality involves superior attention control.

1.5.3. Implications for broader theories of attention

In addition to providing evidence that distractor salience and suppression, but not target selection are dysregulated in psychopathic personality, results have broader implications for general theories of visual-spatial attention. In particular, the current study furthers theories regarding the Ppc's role in Jannati colleagues' (2013) guided search ERP framework by providing an empirical demonstration of predictions made by the model. Sawaki and Luck (2010) have proposed that a distractor contralateral positivity preceding the N2pc could be an early Pd suppression effect. However, Jannati and colleagues (2013) found that if an array contains both a distractor and a target singleton, the most salient item elicits a contralateral positivity preceding the N2pc regardless of whether it is the target or distractor. They concluded that the Ppc does indeed reflect a general response to item salience that guides subsequent attention deployments, and not an early suppression mechanism. Given additional existing evidence that Ppc amplitude is enhanced for singletons appearing at previously cued locations (Hopfinger & Ries, 2005; Livingstone et al., 2017), and for color singleton targets presented within an array composed entirely of color singletons (Christie et al., 2015), it is becoming increasingly clear that the component plays a critical role in visual-spatial attention.

The results of the current study support Jannati and colleagues (2013) interpretation. In both tasks 1 and 2, salient singletons elicited a positive mean amplitude increase at contralateral scalp. Component amplitude was correlated with individual scores on the PPI-R and SCI during the fixation task, but not the search task.[5] This confirms that this low-level physiological response can be moderated by individual differences in some pre-attentive control mechanism, such as feature-weighting or spatial focus constriction. This distractor Ppc amplitude also significantly predicted a subsequent positive amplitude component in the CDA time range, and mediated the relationship of that later component with psychopathy. Although the exact functional role of this later positivity is somewhat less clear, it may reflect a Pd-like suppression mechanism. If so, this statistical pattern is congruent with the notion that initial cursory sweeps compute salience maps, which then guide selective enhancement and suppression of locations occupied by salient items. Those individuals with the greatest Ppc response to distractors also had the greatest response to those items at later discriminative stages. Of note, supplemental analyses for task 1 data found no correlation between target Ppc amplitude and N2pc amplitude ($r = .080$, $p = .495$, $n = 75$) or latency ($r = .028$, $p = .811$, $n = 74$). Presumably, this reflects the fact that regardless of salience computations, covert N2pc section *must occur* in order to perform a visual search. In contrast, if this positive amplitude CDA indexes a Pd-like covert suppression mechanism, this should only occur if necessitated by salience calculations.

1.5.4. Limitations, considerations, and future directions

Of the limitations to this study, the absence of an unequivocal attention suppression ERP component in the fixation task presents the most pressing issue for its internal validity. Across the full sample, distractor stimuli failed to elicit a significant mean amplitude difference between contralateral and ipsilateral electrode sites during the Pd time window. However, there was a significant positive amplitude difference during the

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[5] A supplemental rANCOVAs tested Ppc amplitude differences between tasks for moderation by psychopathy. These analyses each included two within-subjects factors of *task* (search or fixation) and *electrode site* (contralateral or ipsilateral) and a PPI-R or SCI score covariate. The initial rANOVA produced significant main effects of *task* (a 0.603 μV increases in bilateral P1 amplitude during task 1 visual search; $F_{task}(1,72) = 39.150$, $p < .001$, $\eta_p^2 = .352$) and *electrode site* (a 0.170 μV contralateral-minus-ipsilateral electrode difference for the Ppc during both tasks; $F_{site}(1,72) = 16.833$, $p < .001$, $\eta_p^2 = .189$). When controlling for PPI-R or SCI, these significant main effects were replaced by significant interactions of *electrode site* with the covariate, confirming moderation of the between task difference by these measures ($F_{site*PPI-R}(1,71) = 4.195$, $p = .044$, $\eta_p^2 = .056$; $F_{site*SCI}(1,71) = 6.459$, $p = .013$, $\eta_p^2 = .083$).

ensuing early and late CDA windows. Amplitude of the CDA to target stimuli is typically negative, and correlate with maintenance or manipulation of N2pc selected items in visual working memory. Positive amplitude here was taken as indicative a suppression mechanism similar to the Pd.

Although this positive CDA activity fell beyond the typical time range of the Pd, there are several compelling reasons to believe that it reflected ongoing suppression of distractors. While the correlation of positive CDA amplitude and RT failed to reach significance, a small negative association at least hinted the possibility of an inverse relationship between the component and distractor interference. In addition, visual inspection of the contralateral-minus-ipsilateral difference waveforms calculated from the group grand averaged data also suggested that the positive CDA effect may be a continuation of activity that began during the Pd window. In a recently published Pd study of working memory, a similar sustained difference is evident in contralateral-minus-ipsilateral PO7/PO8 waveforms for lateral-distractor vertical-midline-target search arrays (Gaspar et al., 2016). In this image, individuals with high working memory capacity present with an initial positive amplitude Pd peak, which is followed by sustained positive activity that continues into the CDA time window. Another important point is that during visual working memory recall of search arrays, a positive amplitude CDA-like component has previously been reported, supporting the notion that the mechanism indexed by the Pd may be generalized beyond item selection, and employed at multiple cognitive stages (Fortier-Gauthier et al., 2012).

If the effect was indeed evidence of suppression, its lateness could have been caused by several factors. It could be that the filter settings used for ERP processing caused temporal smearing of the data (as discussed by Luck, 2014, ch. 7). However given that the N2pc in task 2 showed typical timing, and a modest high-pass filter was chosen, this seems unlikely. The distribution could reflect between subject variability in the timing of the suppression response. Given that the Pd is thought to resolve competition between items, the timing of the effect may also relate to when competition actually occurred. Because the target in task 2 was spatially invariant, it likely faced little competition from the distractor at the orienting stage. However, the distractor may have subsequently held enough weight in visual working memory to necessitate suppression during target luminance discrimination.

Consideration of the frequency information underlying visual suppression may provide a functional explanation of why it presented as a sustained positivity beginning during the Pd and continuing on into the CDA. EEG, electrocorticography (ECoG), and magnetoencephalography (MEG) have been used extensively to examine the role of alpha-band (8 – 14 Hz) oscillatory activity in sensory and cognitive processing. This body of research has established that alpha-band activity over visual and other sensory cortices serves to gate the access of sensory information to neural regions responsible for higher-order cognition (Foxe & Snyder, 2011; Jensen & Mazaheri, 2010; Rihs, Michel, & Thut, 2007). Behavioral indices of efficient visual target selection are correlated with highly localized decreases in alpha activity (alpha-desynchronization) over cortical regions responsible for processing retinotopic target and cue locations. Increases in alpha activity (alpha-synchronization) over regions that processes non-target and salient distractor locations are also associated with decreased distractor interference. Although firm links have yet to be drawn between oscillatory and ERP indices of distractor suppression, it seems highly plausible that the N2pc, Pd, and the CDA reflect some aggregation of these alpha-band onsets and offsets in response to frontal cortex signals mediated by oscillations within other frequency bands.

An additional limitation that impacts the extent to which findings can be generalized is the fact that participants were undergraduate students rated on a self-report measure of psychopathic traits. As such, their ERP and behavioral responses may have differed from those that would be observed with a clinical or forensic psychopathy sample. Enhanced distractor Ppc amplitude would likely also be present in severe patient cases, given that the effect indexes a reflexive cost of being unable to constrict attention. However, in a clinical or forensic high-psychopathy sample it is possible that Ppc enhancement would not be followed by a positive amplitude CDA component. This effect during task 2 was assumed to reflect a compensatory Pd-like mechanism that enabled participants with high PPI-R scores to achieve a similarly level of performance to those with lower scores. But, while I speculate that post-perceptual distractor suppression likely incurred a higher cognitive cost than vigilantly constricting focus, it is important to note that no measure of subjective frustration was taken. Additionally, neither the Ppc nor the positive amplitude CDA in this task were significant predictors of behavioral performance. It is therefore possible that approaching this task with a generally widened window and suppressing distractors after their detection is the adaptive response. But in opposition to such an interpretation, it appeared to be the SCI factor of the PPI-R that drove the scale's overall association with these ERP responses. Given that SCI predicts a host of maladaptive outcomes, antisocial externalizing behavior, substance abuse, and negative affect (Kastner et al., 2012), it seems unlikely for a cognitive response strategy associated with it to be highly adaptive. It remains to be seen whether the association of these ERP components with SCI (and convergent association with TriPM disinhibition) reflects specific contributions of *psychopathic* impulsive-instability, or a more general effect of trait impulsivity.

Finally, after participant exclusions and attrition the sample size for task 1 was 75. As such, statistical *r* tests on the correlations of ERP effects with PPI-R total and factor scores had power = .75 to detect significant effects of medium size. This fell below Cohen and colleagues' (2003) recommendation of power ≥ .80.

These limitations notwithstanding, this study extends attention-based theories of psychopathic personality by identifying three critical characterises of visual-cortical response to salient targets and distractors. First, intentional deployment of selective attention to salient targets was not altered by psychopathy, discounting an explanation premised solely on enhanced or over selective attention. Second, peripheral distractors received heighted pre-attentive processing in individuals higher in psychopathy, indicating greater perceived salience to these participants, and suggesting poor goal-directed control of attention. While this may be cause by diminished capacity to constriction spatial/feature-based focus, or increased baseline reactivity to peripheral stimuli, both explanations further discount an attention enhancement explanation. Third and finally, heightened early distractor reactivity predicted what appeared to be subsequent goal-directed spatial suppression. Thus, it seems attention abnormalities in psychopathic personality may arise from an interactive competition between exaggerated perception of salience, and habitual hyper-control by internal systems.

1.6. Study 1 Tables

Table 1-1 Study 1 Psychopathic Personality Inventory-Revised covariance matrix

		1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**	**11.**
1. Total score	*m*	**277.00**										
	s^2	*827.17*										
2. Self-Centered Impulsivity	*r*	.764**	**139.32**									
	cov	431.36	*385.86*									
3. Fearless Dominance	*r*	.681**	.106	**107.61**								
	cov	349.41	37.13	*318.11*								
4. Coldheartedness	*r*	.244*	.064	-.049	**30.08**							
	cov	46.41	8.37	-5.83	*43.86*							
5. Machiavellian Egocentricity	*r*	.698**	.800**	.128	.311**	**42.40**						
	cov	156.66	122.74	17.83	16.09	*60.95*						
6. Rebellious Nonconformity	*r*	.557**	.635**	.259*	-.164	.330**	**33.20**					
	cov	106.70	83.13	30.82	-7.24	17.20	*44.42*					
7. Carefree Nonplanfulness	*r*	.432**	.662**	-.064	.083	.452**	.192	**34.25**				
	cov	79.31	83.10	-7.29	3.50	22.52	8.17	*40.82*				
8. Blame Externalization	*r*	.437**	.698**	-.034	-.085	.400**	.283*	.257*	**29.47**			
	cov	88.69	96.88	-4.23	-3.97	22.07	13.34	11.58	*49.89*			
9. Fearlessness	*r*	.664**	.316**	.752**	-.074	.254*	.409**	.042	.173	**32.61**		
	cov	179.15	58.11	125.66	-4.62	18.56	25.58	2.53	11.43	*87.87*		
10. Stress Immunity	*r*	.269*	-.197	.555**	.257*	-.076	-.093	-.134	-.256*	.152	**29.74**	
	cov	50.45	-25.31	64.65	11.11	-3.86	-4.03	-5.61	-11.81	9.32	*42.66*	
11. Social Influence	*r*	.447**	.024	.770**	-.200	.043	.149	-.071	-.059	.326**	.208	**45.26**
	cov	119.80	4.33	127.79	-12.32	3.13	9.27	-4.21	-3.85	28.47	12.67	*86.65*

Note: *N* = 80; bolded and italicized values within cells on the diagonal are mean and variance (respectively) for the given scale; *cov* = covariance; *r* = Pearson correlation coefficient; *m* = mean; s^2 = variance
** $p \le .01$ (2-tailed).
* $p \le .05$ (2-tailed).

Table 1-2 Study 1 test battery questionnaires

	n	*Mean*	*Standard Deviation*
TriPM total	75	72.78	14.41
TriPM Disinhibition	75	17.11	7.21
TriPM Boldness	75	38.42	8.14
TriPM Meanness	75	17.24	7.90
Behavioral Activation System (*BAS*)	74	40.63	4.85
Behavioral Inhibition System (*BIS*)	74	22.57	3.39
Barratt Impulsiveness Scale 11a total (prorated)	74	64.94	11.35
State-Trait Anxiety Inventory-State (*STAI-I*)	74	37.90	10.22
State-Trait Anxiety Inventory-Trait (*STAI-II*)	74	42.82	10.02
Toronto Alexithymia Scale-20 (*TAS-20*)	73	48.25	10.80
Childhood Abuse and Trauma Scale (*CAT*)	74	67.01	24.67
Positive Affect[1]	71	30.48	6.60
Negative Affect[1]	71	20.68	8.12
Beck Depression Inventory-II	71	11.66	10.06

[1] Positive Affect Negative Affect Schedule (PANAS; timeframe = *in the last week*); *PPI-R* = Psychopathic Personality Inventory-Revised; *TriPM* = Triarchic Psychopathy Measure

Table 1-3 Study 1 ERP component amplitudes (µV)

Visual search task (*n* = 75)	**Ppc 75 – 125 ms *M* (*s*) ***	**N2pc 250 – 310 ms *M* (*s*) ***	**CDA 350 – 410 ms *M* (*s*) ***	**CDA 450 – 510 ms *M* (*s*) ***
Contralateral	1.3305 (2.23544)	1.3491 (3.41925)	4.5403 (3.48054)	3.6447 (3.11782)
Ipsilateral	1.2184 (2.23724)	2.9269 (3.55810)	4.7523 (3.55444)	4.0347 (3.19470)
Fixation target task (*n* = 78)	**Ppc 75 – 125 ms *M* (*s*) * †‡**	**Pd 250 – 310 ms *M* (*s*)**	**CDA 350 – 410 ms *M* (*s*) * †‡**	**CDA 450 – 510 ms *M* (*s*) * †‡**
Contralateral	.7843 (2.10086)	3.4656 (4.55121)	5.4861 (3.96617)	4.4625 (2.95830)
Ipsilateral	.6946 (2.07730)	3.3667 (4.50393)	5.3141 (3.96082)	4.2908 (2.92739)

Note: Ppc values were calculated at contralateral and ipsilateral electrode sites O1/O2; N2pc, Pd, and CDA values were calculated at contralateral and ipsilateral electrode sites PO7/PO8; µV = microvolts; *M* = mean; *s* = standard deviation.

* Significant main-effect of contralateral versus ipsilateral electrode site, $p \leq .005$;

† Significant interaction of site with Psychopathic Personality Inventory-Revised total score, $p \leq .05$;

‡ Significant interaction of site with Self-Centered Impulsivity factor score, $p \leq .05$

1.7. Study 1 Figures

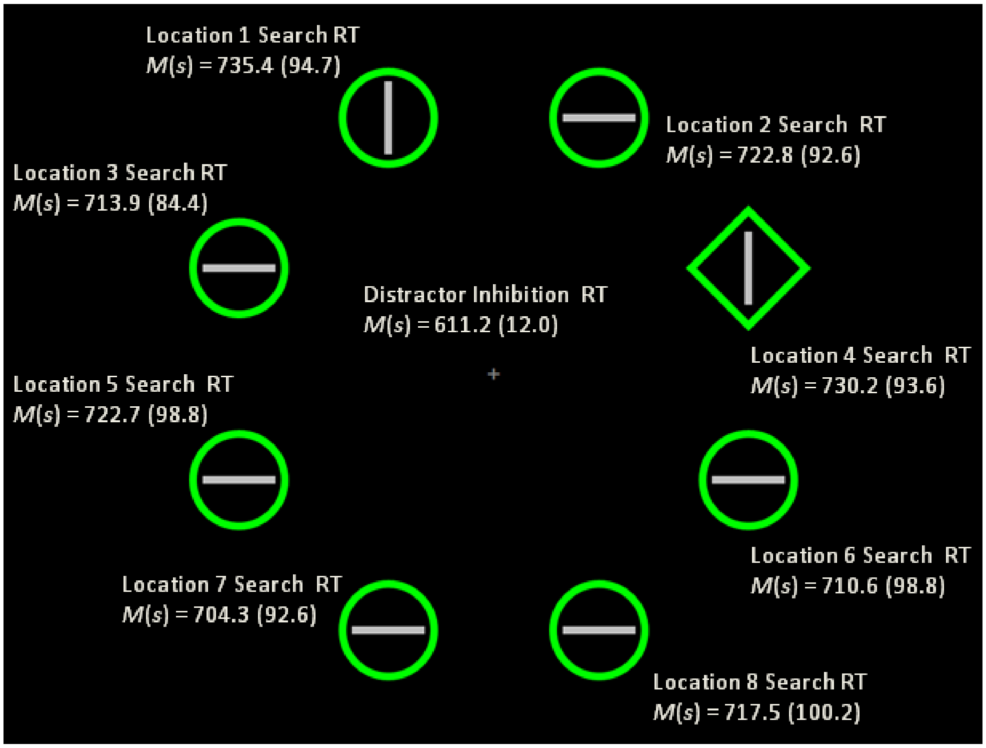

Figure 1-1 **Study 1 stimulus display; Task 1 (peripheral search) reaction times (RTs) provided at each potential singleton location; Task 2 (fixation target, peripheral distractor inhibition) RT across all singleton locations provided at the fixation point. Note that during ERP analyses trials were grouped by the singleton's by proximity to the vertical meridian: "outer" locations were 3 – 6, and "inner" locations were 1, 2, 7, and 8.**

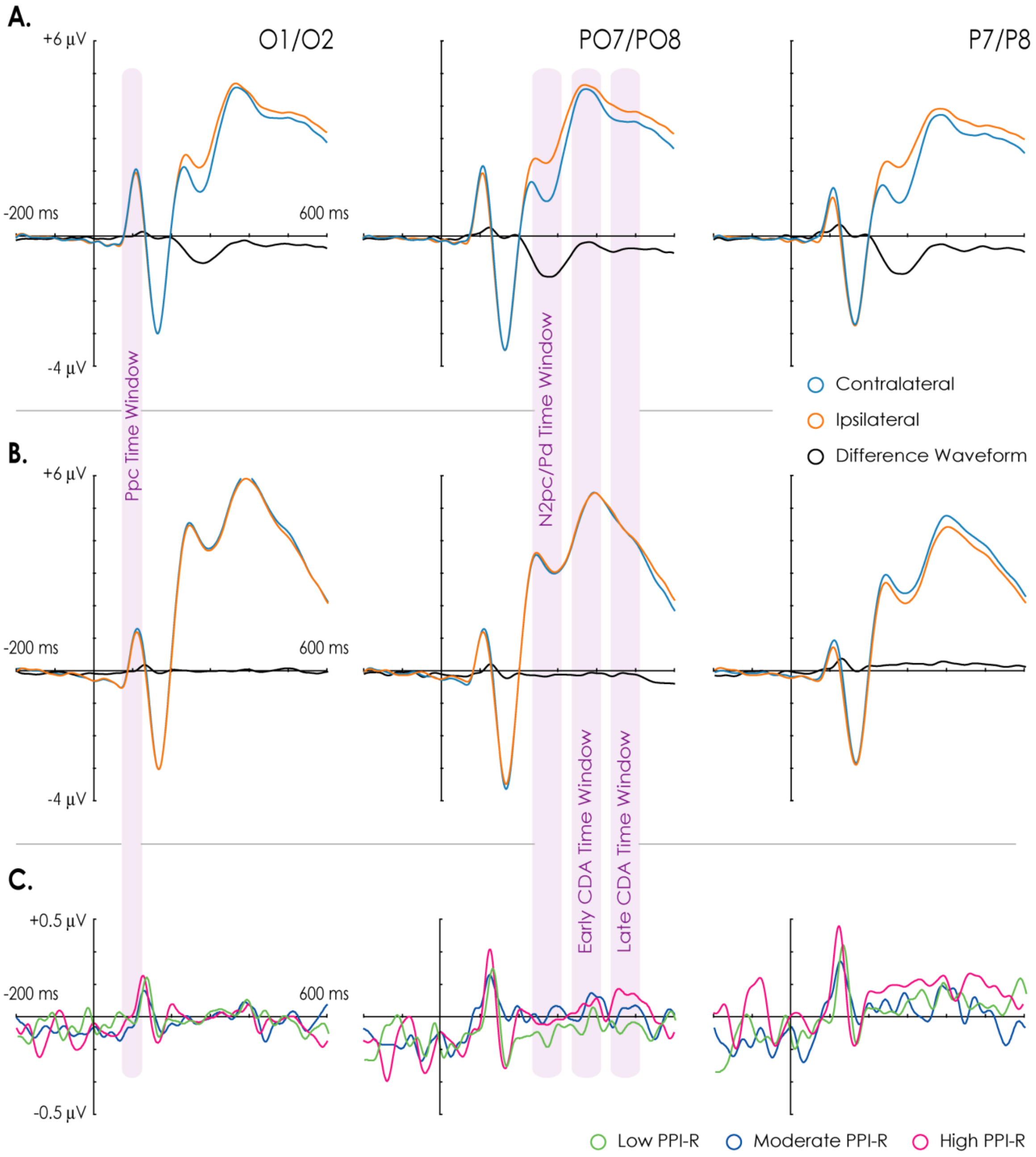

Figure 1-2 Study 1 ERP data (µV) at three occipital and parietal electrode sites over the grand average epoch (-200 ms to 600 ms); A. Grand average ERP waveforms during the visual search task for target contralateral and ipsilateral electrode sites, and contra-minus-ipsi difference; B. Grand average ERP for the same waveforms during the distractor inhibition task; C. Distractor inhibition task ERP contra-minus-ipsi difference waveforms by PPI-R low, medium, and high groupings (note different y-axis scale).

Chapter 2.

Psychopathic personality impacts working memory representations, not spatial attention deployment during visual search for faces: an ERP study

2.1. Abstract

Psychopathic personality is characterized by blunted physiological measures of affective response, and small but reliable behavioral deficits in the ability to identify emotional facial expressions. The question of whether these deficits extend to event-related potential (ERP) components elicited by angry, fearful, or happy expression target faces presented within neutral crowds was investigated in a sample of 73 undergraduate students. Analyses examined the covariance of Psychopathic Personality Inventory-Revised scores (PPI-R; Lilienfeld & Widows, 2005) with three posterior components linked to visual-spatial attention mechanisms (Ppc, N2pc, and CDA) and four posterior components sensitive to face-processing and emotional fluctuations (P1, N170, EPN, and LPP). Tests on Ppc and N2pc amplitudes revealed no association of psychopathy with pre-attentive salience or selection of emotional targets. In this regard, data were similar to the results from the study presented in Chapter 1, which found no association of psychopathy with salience or selection of basic targets. In contrast, PPI-R scores were negatively associated with CDA amplitudes for happy and angry targets, which suggested weaker representation of those items in visual working memory. This may have been attributable to specific working memory or object recognition abnormalities, either for faces or for complex stimuli in general. Across the entire sample, emotional faces did not evoke a significant Ppc component. Emotional faces did elicited significant N2pc and CDA components, but these responses were strongest for happy expressions despite the fact that stimulus arousal and intensity were controlled. As such, results call

into question the notion that spatial attention is guided by negativity bias, stimulus arousal, or threat detection.

2.2. Introduction

2.2.1. Psychopathic personality is characterized by affect generation and expression recognition deficits

Although impulsive antisocial behavior is critical to the conceptualization of psychopathic personality, arguably it is its associated affective and empathic deficits that make it a compelling topic of study. Assessing psychopathy involves substantial consideration of an individual’s propensity and capacity to experience emotion. Furthermore, high ratings on psychopathic personality scale are typically associated with psychometric and physiological external measures indicative of blunted affect generation. Thus without a doubt, psychopathy can be thought of as a disorder of emotional experience. However, it is also important to consider that psychopathy is characterized by behavioral and physiological evidence of reduced insight into the internal emotional-worlds of others. While not typically incorporated into assessments of psychopathy, deficits in the ability to identify other’s emotions may cause, result from, or reciprocally interact with dysfunctional affect generation. Emotion recognition deficits are also thought to play a key role in the aggression and violence associated with the most extreme presentations of the condition (Blair, Colledge, Murray, & Mitchell, 2001).

Interpersonally, individuals high in psychopathy present with glib superficial charm, shallow emotions (i.e. immature, fleeting, or exaggerated), ruthlessness, fearlessness, and callousness. Items examining these traits are commonplace in psychopathic personality clinical assessments and self-report scales. Either through data-driven factor-analytic methods or by intentional design these items tend to coalesce on emotionality facets, separate from facets composed of items relating to more to impulsivity and externalizing behavior. For example, the Psychopathic Personality Inventory-Revised (PPI-R; Lilienfeld & Widows, 2005) features a two-factor structure; Fearless Dominance (FD) captures low anxiety, fearlessness, and social boldness, whereas Self-Centered Impulsivity (SCI) captures blame externalization, rebelliousness, lack of planning, and egocentricity. This is somewhat mirrored by factor analyses of the revised version of the Hare Psychopathy Checklist (PCL-R; Hare, 1991/2003), widely considered to the definitive tool for clinical assessment of psychopathy. Research suggests that a three or four factor model underlies the scale, and that each of these factors corresponds to a key facet or cluster of symptoms within the disorder (Cooke & Michie, 2001). The first facet, Arrogant and Deceitful Interpersonal Style, captures manipulativeness, grandiosity and glib superficial charm; the second, Deficient Affective Experience, captures shallow emotions and lack of empathy; the third, Impulsivity and Irresponsible Behavioral Style, captures recklessness and self-destructive behavior; and finally the fourth, Antisocial, captures criminal misconduct, though many researchers have questioned the validity of this last facet. Childhood measures of the condition reflecting PCL-R criteria, such as the Antisocial Processes Screening Device (APSD; Frick & Hare, 2001) also feature a similar three facet structure of Callous-unemotional, Narcissism, and Impulsivity traits (Blair, Budhani, Colledge, & Scott, 2005). An interesting psychometric characteristic of such factor structures is the differential association of affective and impulsive facets with negative emotional experience. Although PPI-R FD is negatively correlated with measures of behavioral inhibition, negative affect, and anxiety, SCI is positively associated with impulsivity, negative affect, anxiety, and depression (Kastner et al., 2012; Ray et al., 2011; Uzieblo et al., 2010). Despite this, the nomological net of its psychometric correlates converges with the conceptualization of psychopathy as a disorder of affective experience.

Physiological data also shows that individuals high in psychopathic personality traits are characterized by a unique affective and conditioning profile. Some of the earliest evidence of this comes from research finding diminished skin conductance response to highly emotional stimuli (Blair et al., 1997) and reduced startle potentiation to conditioned and unconditioned threat stimuli (Patrick, 1994). Several studies have reported blunted electroencephalographic (EEG) event-related potential (ERP) responses to positive and negative affective images, particularly for the late positive potential (LPP). Amplitude of the LPP component is a sustained positive voltage enhancement for emotional versus neutral stimuli over central and posterior parietal scalp, beginning approximately 400 ms after stimulus presentation (Weinberg & Hajcak, 2010). This activity is thought to represent heightened allocation of working memory and cognitive resources to motivationally notable stimuli, which in a sense are *always* relevant. Data from community (Anderson & Stanford, 2012; Carolan et al., 2014; Medina, Kirilko, & Grose-Fifer, 2016) and incarcerated samples (Venables, Hall, Yancey, & Patrick, 2015) has shown that this differentiation is blunted in individuals high in psychopathic traits. Additionally, reduced ERP variation for negative valence versus neutral stimuli has also been observed between 200 to 300 ms (the early anterior positivity or EAP over frontal scalp, and the early posterior negativity or EPN over occipital scalp), potentially reflecting diminished early response to threat related stimuli (Carolan et al., 2014). However, as noted in the previous chapter, numerous studies have reported that startle conditioning, Stroop effects, affective responding, and error feedback processing can be normalized in high psychopathy by task manipulations that make external information congruent with attention set (Krusemark et al., 2016; Newman et al., 2010). This suggests the possibility that these observed deficits in affective experience may actually be the product of poor sensory, perceptual, or cognitive registration of emotionally evocative stimuli rather than a true internal limit on the ability to generate an emotional response.

Many studies have indeed found impoverished emotion recognition in high psychopathy. In a seminal study, Blair and colleagues (Stevens et al., 2001) found that children with psychopathic traits showed impaired accuracy when identifying the emotions conveyed within facial and vocal expressions, relative to problematic but non-psychopathic peers. Effects were carried by strong selective deficits for fearful and sad facial expressions, and sad vocalizations. These results sparked several further attempts to determine whether such deficits are associated with psychopathy in adult samples, which emotional expressions recognition is impaired for, and what conditions most readily manifest these effects. Sadness and fear recognition deficits have been replicated in several studies (Blair et al., 2005; Blair et al., 2001), and selective deficits have also been observed for anger (Fairchild, Stobbe, van Goozen, Calder, & Goodyer, 2010; Fairchild, Van Goozen, Calder, Stollery, & Goodyer, 2009), happiness (Blair et al., 2005), disgust (Kosson, Suchy, Mayer, & Libby, 2002), and surprise (Bagley, Abramowitz, & Kosson, 2009). Impairments have been observed in response to multiple expression modalities, including body language (Muñoz, 2009). Meta-analyses of a substantial body of work has suggested that psychopathy is associated with small, but consistent deficits in the speed and accuracy of identifying expressions of fear, sadness, anger, disgust, surprise, and happiness across a wide array of developmental stages and criminal risk levels (Dawel, O'Kearney, McKone, & Palermo, 2012; Wilson et al., 2011).

Some researchers have argued that the variability with which selective deficits have been observed may be attributable to associations between symptom clusters and emotion categories, with specific facets of psychopathy related to recognition deficits for certain emotions (Hansen, Johnsen, Hart, Waage, & Thayer, 2008). Such authors have argued that specific facets of Psychopathic Personality Disorder are more related to recognition of certain emotions, a view that seems to be amenable to the existing literature. For example, in adults, Arrogant Interpersonal Style and Deficient Emotional Experience related traits of the PCL-R have been correlated with increased error rates for sadness and fear (Blair et al., 2002; Blair et al., 2005), and disgust recognition (Hansen et al., 2008). In contrast, impulsivity has actually been linked to increased *accuracy* of disgust recognition (Hansen et al., 2008). In children, Narcissism has been correlated with increased error rates for fear identification (Blair et al., 2005), and Callous-unemotional traits have been correlated with increased error rates for fear and happiness (Blair et al., 2005), and sadness (Blair et al., 2001; Blair & Coles, 2000). However, alternate patterns have also been observed, with one study finding positive correlations between accuracy for fearful face identification with total and FD scores from an earlier iteration of the PPI-R (Del Gaizo & Falkenbach, 2008). Savage, Becker, and Lipp (2016) have found that even amongst images chosen from the same database, the speed at which emotional faces can be detected is more attributable to differences between individual face stimuli, rather than broad differences between emotional categories. It therefore possible that variable reports of specific expression recognition accuracy and speed deficits may simply reflect inconsistencies in the stimulus sets used in different studies.

Leading cognitive-neuroscience accounts of psychopathy differ in the functional mechanisms (i.e. detection, reorientation, or affective response to emotionally evocative stimuli) and neural substrates they deem critical to emotion integration. Attention-based models of psychopathy were addressed in the previous chapter, but in short, they attribute the condition’s emotional symptoms to prefrontal cortex irregularities that impair the ability to reorient focus to peripheral stimuli (Glass & Newman, 2006). In contrast, integrated emotion-system, fearlessness, and empathy models of psychopathic disinhibition all center on the notion that a distinct neural architecture processes the emotions of others (Blair, 2005; Blair & Coles, 2000). This system first discriminates affective cues, then assumes the cue giver’s perspective, and finally generates an emotional response in kind. Blair has argued that this integrated emotion system mediates typical socialization and the development of a moral conscience (Blair et al., 2001). Recognition of fear or sadness evoked in another person by one’s own aggression is followed by empathic embodiment of that negative affect. This serves as an aversive unconditioned stimulus, inhibiting future violence. Psychopathy is thought to involve dysfunctions within this neural architecture that impair the ability to respond to social cues of happiness, fear, or threat, resulting in confrontational and violent interactions. These dysfunction may arise from asynchronous communication between the amygdala, striatum, orbitofrontal cortex, sensory and motor cortices, insula, or other cortical and subcortical regions that have shown reduced activation or connectivity during perspective-taking in individuals high in psychopathy assessed with functional magnetic resonance imaging (Decety, Chen, Harenski, & Kiehl, 2015; Decety, Skelly, & Kiehl, 2013). But despite the different claims made by attention-based and emotion-system model, they share a common theme: the idea that impoverished integration of social emotional cues mediates the perpetration of goal-directed violence. With this in mind, it would be helpful to determine the stage of processing facial emotions these dysfunctions begin to arise.

2.2.2. Emotional and spatial modulation of ERP components evoked by faces

Electrophysiological investigations conducted on typical and clinical samples have demonstrated the complexity of neural processing for faces of all expression types. Almost intrinsically, faces draw heavily on the sensory, perceptual, and cognitive mechanisms that are encompassed within the concept of directed attention. Differentiation of the cortical response to faces versus other objects can be seen early in visual processing with the N170 effect – a negative voltage enhancement across occipito-temporal scalp between 100 to 200 ms – and the corresponding fronto-polar vertex positive potential (VPP; Rossion & Jacques, 2012). There is debate regarding whether these components reflect face specific processing or a more general effect of object expertise. However, a parsimonious account is that they are modulations of the posterior visual N1 component that correlate with subjective reports of having perceived a face. These effects likely represent early structural coding of low-level characteristics. Either because of variation in these low-level features across different type of expressions, or because of differential contribution by dedicated emotion-processing neural architecture, studies have found stronger responses for emotional that neutral faces, or between different emotional expressions (Blau, Maurer, Tottenham, & McCandliss, 2007; Foti, Olvet, Klein, & Hajcak, 2010). Emotional expression related modulations can also be seen for a middle latency effect that peaks across fronto-central scalp approximately 250 ms after stimulus presentation (Eimer & Holmes, 2007). Given the similarity of its timing and spatial distribution to that of the EAP (Foti, Hajcak, & Dien, 2009), this component may reflecting initial rapid assessment of the subjective emotional value of faces. These effects appear to continue as a sustained positive deflection over parietal scalp, likely indexing the same processes as the LPP (Eimer & Holmes, 2007; Holmes, Nielsen, & Green, 2008).

It therefore seems fair to say that faces and emotional expressions capture attention in-so-much as they are inherently allocated more neural resources than other stimuli. But it is less clear whether faces and emotional expressions are able to capture spatial attention by triggering reorientation toward their location. In reviewing behavioral data from many studies, Wolfe and Horowitz (2004) note that a stimulus' *emotionality* in-and-of-itself does not seem to be registered early enough to during visual processing to guide spatial attention. It is most likely that searches for emotional faces are guided by the co-occurrence of critical feature-variations (orientation, or local contrast) within their gestalt. As noted previously, the characteristics of an individual face, and not its discrete emotional categorization, best predict behavioral search efficiency (Savage et al., 2016). But even though emotionality does not efficiently guide visual-spatial selection, emotional faces can elicit lateralized ERP components indicative of attention reorienting. Eimer and Kiss (2007) found that when participants were required to focus on a central fixation point surrounded by a crowd of task irrelevant faces, an N2pc component was evoked by lateralized angry faces (greater negative amplitude at occipito-temporal electrode sites contralateral to the visual hemifield occupied by the angry face than electrode sites ipsilateral to the face[6]). Because faces were always task-irrelevant, the authors argued that this N2pc reflected involuntary attention capture by the high emotional salience of angry faces. McDonald and colleagues (2013) have noted that an N2pc to task-irrelevant stimuli does not inherently represent spatial capture. But regardless, the findings of Eimer and Kiss (2007) indicate that to some degree, visual-spatial attention can be oriented to emotional face distractors. This conclusion is supported by reports of N2pc responses to angry and happy emotional singleton face targets in experiments using visual search arrays composed of naturalistic photos (Feldmann-Wüstefeld, Schmidt-Daffy, & Schubö, 2011) and schematic line drawings (Fan et al., 2016).

In many visual search studies, a target N2pc is followed by the contralateral delay activity (CDA), a lateralized ERP component thought to index representation and maintenance of stimuli in visual short-term memory (Vogel & Machizawa, 2004; also sometimes referred to as the sustained posterior contralateral negativity or SPCN, see Jolicœur et al., 2008). The CDA is topographically similar to the N2pc, and is characterized as a negative voltage enhancement at target-contralateral relative to ipsilateral occipital scalp sites. This amplitude differentiation occurs during the retention of lateralized visual-spatial information, and during identity discrimination of lateralized visual search targets (Gaspar & McDonald, 2014; Gaspar et al., 2016). Although the CDA and is often studied with simple stimuli such as basic shapes, Towler and colleagues (2015) have shown that the component can index the load and capacity of maintaining representations of faces in working memory. Additionally, in a search task where participants simply identified the presence or absence of an emotional face within a neutral crowd, Feldmann-Wüstefeld and colleagues (2011) reported CDA activity for angry target faces but not happy target faces. Given the selectivity of this effect for angry

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[6] Note: Unless otherwise stated, for the remainder of this chapter the term "contralateral" refers to electrodes/scalp sites contralateral to the visual hemifield containing the singleton, whereas "ipsilateral" refers to electrodes/scalp sites ipsilateral to the visual hemifield containing the singleton (rather than being contralateral or ipsilateral to some other reference point, such as another electrode).

faces, and the previous research indicating that basic shapes only seem to elicit a CDA during search if a target's identity must be discriminated (compound search as opposed to simple detection, see Mazza et al., 2007), Feldmann-Wüstefeld and colleagues (2011) took this finding as evidence of threat detection advantage during visual search.

The N2pc can also be preceded by a posterior contralateral positivity, the Ppc. This lateralized ERP component occurs across occipital scalp, overlapping the time windows of the P1 and N1 (approximately 125 to 180 ms; Christie et al., 2015; Fortier-Gauthier et al., 2012; Hopfinger & Ries, 2005; Jannati et al., 2013; Livingstone et al., 2017). It is elicited as an increased positive voltage at sites contralateral to a singleton contained within a homogenous array, and is thought to reflect that item's bottom-up salience. To date, a significant Ppc effect has not been observed to an emotional face presented with an array of non-emotional faces.

2.2.3. The present study: does psychopathy impact spatial and emotional ERP components evoked by faces?

Paralleling physiological deficits in affective response and behavioral deficits in facial expression recognition, several studies have also reported reduced ERP response to emotional faces among individuals high in psychopathic personality traits. Previous research has found a negative correlation between the FD factor of the PPI-R and absolute amplitude of the N170 component elicited by faces with emotional and neutral expressions (Almeida et al., 2014). Whereas social and trait anxiety have been associated with enhanced N170 amplitude, the authors proposed that FD may constitute a psychophysiological correlate of low-trait anxiety. Moderate latency (200 to 300 ms) fronto-central ERP components to faces show little differentiation in response to angry, sad, and neutral faces in individuals with high behavioral activation and low behavioral inhibition (a profile characteristic of hostile aggression; Bediou, Eimer, d'Amato, Hauk, & Calder, 2009). There is limited evidence however that it is associated with LPP reductions to emotional faces. Finally, in a study comparing the performance of participants sampled from incarcerated and community populations on a flanker task featuring emotional faces (Munro et al., 2007), offenders with a history of violence made more errors in the emotional task, and those with high scores on the PCL-R showed reduced error related negativity response (ERN). Psychopathy therefore seems to be characterized by diminished cortical electrophysiological markers of rapid facial expression processing, and subsequent learning from faces. But a major gap in the existing literature is the question of whether psychopathic traits are associated with visual-spatial attention for faces. Examination of this question with lateralized visual-spatial ERP components has the potential to identify the specific stages at which emotion recognition deficits occur.

The current study conducted such an investigation by recruiting a large sample of undergraduate students to perform an affective visual search task, in which they identified the genders of happy, angry, and fearful faces presented in a crowd of neutral faces. Several visual-spatial orienting mechanisms and affective responses were operationalized in terms of specific posterior ERP components elicited during search for these emotional target faces. The Ppc, N2pc, and CDA components to lateralized emotional singleton targets respectively indexed those faces' pre-attentive salience prioritization, spatial-selection, and representation in visual working memory. Assessing whether emotional faces presented alongside non-emotional faces are capable of evoking a significant and reliable Ppc component was of particular interest, given that has yet to be assessed in the broader ERP face visual search literature. The P1, N170, EPN, and LPP components to medial emotional singletons respectively indexed low-level stimulus feature encoding, rapid face-specific coding, early emotional/threat valuation, and motivational relevance. The overarching objectives of this study were to 1) determine which ERP effects are differentiated for the various target expressions, and 2) identify specific visual search and emotional response ERP effects moderated by individual differences in psychopathic personality traits.

2.3. Methods

Prior to data collection, this study was reviewed by the Simon Fraser University Office of Research Ethics, and received a minimal risk designation.

2.3.1. Participants and procedure

Power analyses conducted prior to data collection and statistical tests determined that to achieve adequate power (.80) for tests of r at $\alpha = .05$ (two-tailed), a sample size of 84 or 28 would be needed to detect significant effects of medium ($r = .30$) or large ($r = .50$) size, respectively (Cohen et al., 2003). Based on these considerations, a sample of 76 undergraduate students (age $M = 20.51$, $s = 1.990$); 19 male, 57 female; 5 left-handed; 2 colorblind; 38 English first-language speakers) completed a demographics and medical questionnaire (Appendix A), a battery of personality and temperament measures (Appendix B) that included the Psychopathic Personality-Revised (PPI-R; Lilienfeld & Windows, 2005), and an affective visual search task accompanied by EEG data recording. Sessions were approximately 2-hours. Participants received course credit through the Department of Psychology's Research Participation System. Of these participants, eight reported a previous diagnosis of depression, anxiety disorder, bipolar disorder, obsessive compulsive disorder, and/or eating disorder; one of these participants and one other reported having been diagnosed with attention-deficit/hyperactivity disorder; and one participant reported having epilepsy. Additionally, two of the participants diagnosed with depression/anxiety as well as seven others reported having had a head injury resulting in a concussion or loss of consciousness, and two reported a history of migraines.

Participant exclusions and attrition

Data for 3 participants were excluded due to poor EEG quality (see below), resulting in a final sample of 73 for behavioral and ERP amplitude analyses. Additionally, for several participants N2pc latency could not be extracted for all three target expression conditions due to the absence of an appropriate peak/trough in the component time window, further reducing the sample for latency analyses (noted where relevant).

2.3.2. Affective visual search task

The experimental task was built and run using E-Prime 2.0.8 on a Windows PC. Participants were seated with their faces 80 cm from a 19-inch LCD monitor (1024 x 786 resolution, 60 Hz refresh rate). Responses were made with the right hand using a Logitech gamepad. Stimuli consisted of an array of four faces around a 1 x 1.3 cm light grey (E-Prime color attribute = “silver”) fixation cross, on a black background (see figure 2.1). Faces were selected from the Karolinska Directed Emotional Faces database (KDEF; Lundqvist, Flykt, & Öhman, 1998). Angry, fearful, happy, and neutral expressions of 10 unique male and 10 unique female Caucasian faces (identified in Table 2-1) were grey-scaled and placed in oval frames to remove jaw- and hairlines. Faces were scaled to 7.5 cm high by 5 cm wide. They were distributed evenly on the vertical and horizontal meridians with their centers 5 cm from the middle of the screen, and 5 cm from the center of neighboring faces. Paired samples *t*-tests assessed normative arousal and intensity ratings for each expression of each face (supplied by Goeleven, Raedt, Leyman, & Verschuere, 2008). These values are scored on a 9-point Likert-type scale ranging from 1 “calm” to 9 “aroused” for arousal, and 1 “not at all” to 9 “completely” for intensity of the relevant emotion. Tests confirmed that the mean ratings for angry ($M_{arousal} = 3.87$; $M_{intensity} = 5.88$), fearful ($M_{arousal} = 3.59$; $M_{intensity} = 5.52$), and happy ($M_{arousal} = 3.63$; $M_{intensity} = 5.95$) faces did not significantly differ from one another (all $|t(19)| \leq 0.613$, $p \geq .547$, two-tailed), but were all significantly greater than ratings for neutral faces ($M_{arousal} = 2.60$; $M_{intensity} = 4.70$; all $|t(19)| \geq 8.402$, $p < .001$, two-tailed).

On every trial, each stimulus location featured a unique, randomly chosen male or female face with a neutral expression, with the exception of one at a randomly chosen location that displayed a randomly chose angry, fearful, or happy emotional expression. Participants were instructed to identify the gender of the emotional singleton quickly and accurately, though they were given no specific instructions about what emotional expressions they would see. Stimuli offset 10 ms after response and were followed by a jittered interstimulus interval (1000 to 1500 ms) before the onset of the next array. Participants completed 12 blocks of 50 trials, with 15 second breaks between blocks. Trials were rejected from analyses if participant reaction time (RT) was too fast or too slow (300 ms < RT < 4500 ms).

2.3.3. EEG recording and processing

EEG activity was recorded using an electrode cap with sintered Ag/AgCl active electrodes at 64 standard Modified Combinatorial Nomenclature sites (Biosemi Active Two amplifier, Amsterdam). Additional bilateral active electrode pairs were placed over mastoids, external canthi (for horizontal eye movements), and infraorbital locations (for vertical eye movements and blinks). Voltages were recorded against a common mode sense (CMS) active electrode. Data were sampled at a rate of 512 Hz.

All offline EEG data processing and extraction was conducted in MATLAB (R2016a) using the Field Trip Toolbox (version 2016.05.10; Oostenveld, Fries, Maris, & Schoffelen, 2011). For each participant, segments of EEG time-locked to stimulus onset were sampled from continuous EEG (correct response trials only), demeaned, and re-referenced to average mastoid. Independent component analysis (ICA) decomposed the data to 20 unique spatial-temporal signals, from which up to 4 representing ocular artifacts (vertical and lateral saccades, blink propagation, or electromyographic activity) were identified and removed on the basis of visual inspection.[7] Recomposed data was digitally high-pass filtered (0.05 Hz, 4th order, Butterworth) and aligned to a -200 to 0 ms baseline. Any trials remaining contaminated by blinks, saccades, or skeletal muscle movement were identified and removed through visual inspection aided by a semiautomatic artifact detection procedure.

Time-locked ERP averages were computed for each subject, collapsed across male and female targets within each emotional expression type and location array configuration. For lateral-target trials, ERPs for three pairs of bilateral occipito-parietal electrode sites (O1/O2, PO7/PO8, and P7/P8) were collapsed across left and right electrodes, and left and right visual hemifields to produce waveforms ipsilateral and contralateral to the singleton and eliminate any brain-hemisphere specific effects. Trials with horizontal meridian targets were collapsed across left and right visual hemifield and gender for each expression type. Trials with vertical meridian targets above the fixation point were also collapsed across gender for each expression type, though trials with

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[7] Visual inspection identified components with temporal characteristics and topographical distributions similar to ocular artifacts described by (Jung et al., 1998; Jung et al., 1998).

targets below the fixation point were excluded from further analyses to reduce ERP variance and the number of statistical tests. This resulted in 6 conditions based on target location and expression: *medial-angry, medial-fearful, medial-happy, lateral-angry, lateral-fearful,* and *lateral-happy*. Subject with fewer than 30 artifact-free trials in any condition were excluded from further analyses. Contralateral-minus-ipsilateral ERP difference waveforms were computed to isolate lateralized singleton-related activity. Finally, before export for statistical analyses or grand average visualizations, subject averages were digitally low-pass filtered with a 28 Hz cut-off for mean amplitude values or a 10 Hz cut-off for latency values (both 4th order Butterworth), and rereferenced to average reference to better isolate emotional modulations of the EPN and N170 (Hajcak et al., 2012).

Visual search ERP components (lateral-target trials)

Latency of the N2pc was defined as the *50% fractional negative area* of the PO7/PO8 contralateral-minus-ipsilateral difference wave over a 175 to 400 ms post-stimulus interval (as recommended by Luck, 2014). Because this operation is not included in the standard Fieldtrip toolbox, values were derived using customized script (available on request) built with the Matlab functions *trapz( ), max(y,0),* and *min(y,0)*. Mean amplitude of the Ppc, N2pc, and CDA components were extracted from bilateral electrode pairs (contralateral and ipsilateral to the singleton) selected on the basis of previous literature, across time windows centered on appropriate peaks or troughs of grand average contralateral-minus-ipsilateral difference waveforms. Ppc mean amplitude was calculated at occipital sites O1/O2 (Jannati et al., 2013) from 110 to 160 ms. Mean amplitude of the N2pc was calculated at occipito-parietal sites PO7/PO8 (Gaspar & McDonald, 2014; Luck, 2012, 2014) from 275 to 335 ms. CDA mean amplitude was calculated at the same occipito-parietal sites as the N2pc from 470 to 600 ms (Gaspar & McDonald, 2014; Jannati et al., 2013; Jolicœur et al., 2008; Mazza et al., 2007)

Emotionally modulated ERP components (medial-target trials)

Mean amplitude of the P1, N170, EPN, and LPP components were extracted across time windows centered on appropriate peaks or troughs of grand average waveforms, from either bilateral electrode pairs or regions of interest (ROIs) selected on the basis of previous literature. P1 mean amplitude was calculated across an ROI consisting of occipital sites O1 and O2 from 110 to 160 ms (Luck 2014), and N170 was calculated across temporal sites P7 and P8 from 165 to 215 ms (Rossion & Jacques, 2012). EPN was calculated across an ROI consisting of two bilateral occipito-parietal electrode pairs, O1 and 02, and PO7 and PO8, from 220 to 280 ms (Olofsson, Nordin, Sequeira & Polich, 2008). Finally, the LPP was calculated over a medial parietal ROI including sites P1, Pz, P2, and POz, from 450 to 600 ms (Weinberg & Hajcak, 2010).

2.3.4. Data reduction and analyses

All statistical analyses were conducted in SPSS Statistics (version 19.0.0; IBM, 2010). Those incorporating PPI-R values treated total and factor scores as continuous interval variables (unit-weighted composites; see measure description in Appendix B), though percentile scores were used to separate participants into low- (≤ 33rd), medium- (34th to 66th), and high-trait (≥ 67th) groupings for graphical depictions. Paired-samples *t*-tests were used to assess mean accuracies (ACCs) and median correct response RTs for each target location, collapsing across target genders and emotions (Figure 2-1). Repeated measures analysis of variance (rANOVA) tests using within-subject factors of *target gender* (male or female), and *target expression* (angry, fearful, or happy) were run on RT and ACC collapsed across singleton locations (see Table 2-1). These were followed by repeated measures analysis of covariance (rANCOVA) tests that added PPI-R total or factor score covariates to assess moderation of behavioral performance by psychopathy.

In order to confirm the presence of significant effects in the grand averaged group data, rANOVAs compared mean amplitudes of contralateral versus ipsilateral electrode sites during each visual search component time window (Ppc, N2pc, and CDA). These analyses used two within subjects factors of *electrode site* (contralateral versus ipsilateral) and *target expression* (angry, fearful, or happy).Follow-up paired samples *t*-tests with the Bonferroni family-wise error correction evaluated significant effects and interactions. Differences in the localizability of emotional target types were assessed through rANOVA on N2pc latency, using a within-subject factor of *target expression* (angry, fearful, or happy). To assess the dependence of behavioral performance on selection time, N2pc latency was correlated with median RT for each target emotional expression type. Emotionally modulated component mean amplitudes (P1, N170, EPN, and LPP for medial-target trials) were assessed across ROIs with rANOVA tests, using a single within-subject factor of *target expression*.

Moderation of component latencies and amplitudes by psychopathic personality was examined through the incorporation of PPI-R total, SCI, or FD scores as covariates in rANCOVAs using the same variables and within-subject factors as rANOVAs. For rANCOVAs revealing significant effects, outcome variables (i.e. fractional latency, contralateral-minus-ipsilateral electrode amplitude difference, or ROI amplitude) were correlated with the relevant PPI-R score to determine the direction of the relationship. Moderation of the association between RT and N2pc latency by psychopathic personality was tested though multiple linear regressions incorporating PPI-R total or factor scores and component latency by scale interaction terms (as described by Baron & Kenny, 1986; Cohen, Cohen, West & Aiken, 2003). Convergent validity of observed associations was examined by testing the correlation of effects with relevant external measures, including Triarchic Psychopathy Measure (TriPM) total and subscale scores, Behavioral Activation System/Behavioral Inhibition System (BAS/BIS), Barratt Impulsiveness Scale-Version 11a (BI-11a), State Trait Anxiety Inventory (STAI-I/II), Toronto Alexithymia Scale-20 (TAS-20) and Child Abuse and Trauma Scale (CATS) all of which are discussed in Appendix B. Multiple linear regressions were used to test for potential mediating effects. Finally,

2.4. Results

A covariance matrix of PPI-R total, factor, and subscale scores can be found in Table 2-2. Means and standard deviations for the remaining test battery questionnaires can be found in Table 2-3. ERP and RT outcome variable scores can be found in Table 2-4. ERP data electrode plots can be found in Figure 2-2, and topographic maps in Figure 2-3.

2.4.1. Behavioral performance and manipulations checks

Analyses on participant RT and ACC supported averaging of trials across left and right hemifield singletons, and within emotion emotional expression types. Paired t-tests indicated that RTs and ACCs were comparable for horizontal meridian targets in the left and right visual hemifields (RT was 24 ms faster for the left visual hemifield; $t_{left\text{-}right}(72) = -2.053$, $p = .262$). Although ACC for vertical meridian targets was comparable, RT was considerably slower (64.9 ms) when emotional faces appeared below the fixation point than above it ($t_{upper\text{-}lower}(72) = -5.001$, $p \leq .001$). The rANOVA on median RT found significant main-effects and interactions of *gender* and *expression* ($F_{gender}(1,72) = 7.161$, $p = .009$, $\eta_p^2 = .090$; $F_{expression}(2,144) = 91.635$, $p < .001$, $\eta_p^2 = .560$; $F_{gender*expression}(2,144) = 49.362$, $p < .001$, $\eta_p^2 = .407$). This was paralleled for mean ACC ($F_{gender}(1,72) = 29.145$, $p < .001$, $\eta_p^2 = .288$; $F_{expression}(2,144) = 173.830$, $p < .001$, $\eta_p^2 = .288$; $F_{gender*expression}(2,144) = 166.960$, $p < .001$, $\eta_p^2 = .699$). Follow-up *t*-tests suggested that this was driven by substantially lower accuracy and slower responses for angry female faces when compared to all other singleton types. PPI-R total and factor scores had no significant impact on RT tests (for all interactions and main effects of PPI-R covariates, $F \leq 0.674$, $p \geq .511$, $n_p^2 \leq .009$). However, for tests on ACC, PPI-R total score interacted significantly with target gender ($F_{gender*PPIR}(1,71) = 7.658$, $p = .007$, $\eta_p^2 = .097$). This appeared attributable to small to moderate negative correlations of PPI-R total score with the accuracy of identifying happy ($r = -.279$, $p = .017$) and fearful ($r = -.201$, $p = .087$ (n.s.) male faces.

2.4.2. Visual-spatial ERP components during affective search

Analyses on Ppc component mean amplitude showed that target emotional expression singletons were ascribed little more pre-attentive salience than neutral faces (Figure 2-2, upper panel), and that the component was unassociated with psychopathy. Across emotional expression types, the difference between contralateral and ipsilateral electrodes (.107 μV) failed to reach significance, and there was no indication of a significant main effect of interaction of expression ($F_{site}(1,72) = 3.627$, $p = .061$, $\eta_p^2 = .048$; $F_{expression}(2,144) = 0.809$, $p = .447$, $\eta_p^2 = .011$; $F_{site*expression}(2,144) = 1.235$, $p = .294$, $\eta_p^2 = .017$). Exploratory paired samples t-tests comparing mean amplitudes at target-contralateral and target-ipsilateral electrodes sites during the Ppc time window indicated that the difference was not significant for fearful ($t_{contra\text{-}ipsi}(72) = -.624$, $p = .535$) or angry faces ($t_{contra\text{-}ipsi}(72) = 1.174$, $p = .244$). Although happy faces appeared to elicited a marginal lateralized positive voltage difference, it did not meet the significance threshold after the Bonferroni correction for family-wise error ($t_{contra\text{-}ipsi}(72) = 2.119$, $p = .038$, *n.s.*). ANCOVAs incorporating PPI-R total and factor score covariates revealed no significant moderation effects (all main effects and interactions of scale scores, $F(2,142) \leq 1.703$, $p \geq .186$, $\eta_p^2 \leq .023$). To ensure that the failure to detect a significant difference of the Ppc was not simply due to misspecification of the component time window, analyses were rerun on the positive signed area of contralateral-minus-ipsilateral difference waveforms from 75 to 200 ms for each expression type (see Luck, 2014). As with mean amplitude, there were no significant Ppc differences between happy, angry, and fearful faces in the rANOVA ($F_{expression}(2,142) \leq 0.945$, $p = .391$, $\eta_p^2 = .013$), nor main effects or interactions of PPI-R total or factor scores in rANCOVAs.

In contrast to results for the Ppc, emotional faces did evoke an N2pc during visual search. This effect was strongest for happy faces, but was unassociated with psychopathy. The initial rANOVA on mean amplitudes indicated a significant contralateral-minus-ipsilateral N2pc (-1.799 μV) across target types, and a significant interaction of this effect with emotional expression ($F_{site}(1,72) = 151.735$, $p < .001$, $\eta_p^2 = .678$; $F_{expression}(2,144) = 1.821$, $p = .166$ (n.s.), $\eta_p^2 = .025$; $F_{site*expression}(2,144) = 13.252$, $p < .001$, $\eta_p^2 = .155$). Paired *t*-tests on N2pc mean amplitudes at contralateral and ipsilateral sites revealed significant effects in the appropriate direction for happy (-2.505 μV), fearful (-1.322 μV), and angry (-1.571 μV) faces, replicating previous observations of N2pc response to lateralized emotional face singleton (for all, $t(72) \geq 8.185$, $p < .001$; see Table 2-4). Furthermore, rANOVA and follow-up *t*-tests on contralateral-minus-ipsilateral difference scores indicated that this effect was significantly stronger for happy faces than fearful or angry faces (see Figure 2-2 upper row). Given that the N2pc was strongest for happy faces, there was no evidence of a threat or negativity bias during visual search. The rANCOVAs testing for moderation of the effect by psychopathic personality found no significant effects or interactions, although the interaction of SCI with contralateral-minus-ipsilateral N2pc amplitude across expressions approached but failed to reach significance ($F_{site*SCI}(1,71) = 3.133$, $p = .081$, $\eta_p^2 = .042$). As such psychopathy did not appear to moderate the strength of spatially selecting a target emotional face within a neutral crowd.

Analyses on N2pc latency indicated some overall consistency in the speed at which participants were able to select emotional singleton faces. Although for happy targets N2pc latency was correlated with median RT, the component was only weekly associated with RT for angry and fearful faces. N2pc latency of the 62 participants for whom it could be extracted for all three target types did not vary significantly for different emotional expressions ($F_{expression}(2,122) = 0.768$, $p = .466$, $\eta_p^2 = .012$). This effect was not moderated by PPI-R total or factor scores when included as rANCOVA covariates (interaction of N2pc latency and scale for all tests $F(2,120) \leq 2.243$, $p \geq .111$, $\eta_p^2 \leq .036$). Across the sample, RT was only weakly correlated with N2pc latencies for angry ($r = -.085$, $p = .492$, $n = 68$) and fearful faces ($r = -.080$, $p = .522$, $n = 67$). In contrast, a significant medium-strength relationship was observed between RT and N2pc latency for happy singleton targets ($r = .238$, $p = .047$, $n = 70$). Psychopathic personality did not to moderate any associations between N2pc latency and RT.

As with the N2pc, emotional singleton faces evoked a negative CDA component, which was further differentiated by expression type ($F_{site}(1,72) = 16.878$, $p < .001$, $\eta_p^2 = .190$; $F_{expression}(2,144) = 3.105$, $p = .048$, $\eta_p^2 = .041$; $F_{site*expression}(2,144) = 3.427$ $p < .035$, $\eta_p^2 = .045$). Follow-up *t*-tests probing the significant interaction indicated that CDA mean amplitudes at contralateral and ipsilateral electrode sites differed significantly for happy (-1.242 µV; $t_{contra\text{-}ipsi}(72) = -4.459$, $p < .001$) and angry (-0.903 µV; $t_{contra\text{-}ipsi}(72) = -3.594$, $p < .001$) emotional singletons, but not for fearful ones (-0.530µV; $t_{contra\text{-}ipsi}(72) = -1.942$, $p = .056$). Intriguingly, PPI-R total score moderated the overall contralateral-minus-ipsilateral electrode difference across emotional expressions. The significant main effect of *electrode site* was accompanied by a significant interaction with the covariate in the subsequent rANCOVA ($F_{site*PPI\text{-}R}(1,71) = 5.505$, $p = .022$, $\eta_p^2 = .072$; $F_{site}(1,71) = 8.219$, $p = .532$, $\eta_p^2 = .005$). Correlations between PPI-R total score and CDA difference score averages across expression types found that as total psychopathic personality-trait score increased, the strength of the CDA decreased (i.e. negative amplitude became more positive, thus a positive correlation; $r = .268$, $p = .022$; see Figure 2-2, second row from top). Correlations with subscale scores suggested that the association between

PPI-R and CDA amplitude was driven by contributions from both SCI (r = .207, p = .080) and FD (r = .226, p = .055), and may have been driven by an underlying negative association between the effect for happy faces and SCI (r = .236, p = .044), and for fearful faces and FD (r = .248, p = .034)[8]. Correlation of TriPM scores with CDA amplitude were generally non-significant, and so provided only limited convergent support for these effects. There was a significant correlation of the Meanness subscale with CDA amplitude for happy faces (r = .277, p = .020; note again that a positive correlation with a negative amplitude component indicates a negative association), and a weak correlation of TriPM total score with average CDA amplitude though this latter effect failed to reach significance (r = .159, p = .188).

2.4.3. Emotional component amplitudes

ROI mean amplitude of the P1 ($F_{expression}(2,144) = 2.567$, p = .080, $\eta_p^2 = .034$) and N170 ($F_{expression}(2,144) = 1.527$, p = .221, $\eta_p^2 = .021$) were found not to vary significantly by *target expression* (Figure 2-2 Study 2 ERP data (µV) electrode sites over the averaging epoch (-200 ms to 600 ms); A. Grand average ERP waveforms for lateral targets at three occipital and parietal electrode sites (contralateral and ipsilateral sites, and the contra-minus-ipsi difference); B. Grand average ERP waveforms for lateral targets the same sites by PPI-R low, medium, and high groupings; C. Grand average ERP waveforms for medial targets at five posterior electrode sites., bottom row). These effects were not moderated by PPI-R scores when entered as rANCOVA covariates. However, the effect did vary significantly for ROI mean amplitudes of the EPN ($F_{expression}(2,144) = 3.347$, p = .038, $\eta_p^2 = .044$) and LPP ($F_{expression}(2,144) = 3.824$, p = .024, $\eta_p^2 = .050$). Follow-up tests indicated that the effect of *expression* on both EPN and LPP was driven by significantly greater amplitudes for happy targets than angry targets (figure 2.2.c). Neither the EPN nor LPP *target expression* effects were significantly moderated by psychopathic personality traits, though the main effect of the SCI

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[8] When the CDA amplitude difference between contralateral and ipsilateral electrodes for fearful stimuli was retested within a rANCOVA using FD as a covariate, there was a significant amplitude difference for the site main effect, and a significant interaction of site with FD ($F_{site}(1,71) = 5.563$, p = .021, $n_p^2 = .073$, previously *n.s.* for the paired t-test; $F_{site*FD}(1,71) = 4.205$, p = .044, $n_p^2 = .056$).

covariate did approach significance for the LPP ($F_{expression*SCI}(1,71) = 3.937$, $p = .051$, $\eta_p^2 = .053$). Exploratory correlations following up on the absence of an effect indicated that SCI score was negatively associated with LPP amplitude for each target type (happy: $r = -.209$, $p = .076$; fearful: $r = -.252$, $p = .032$; angry: $r = -.177$, $p = .135$).

To test whether past trauma, anxiety, or alexithymia impacted the presence of an association between PPI-R scores and LPP, several multiple linear regressions were performed on the component ROI amplitude differences between happy and angry target trails. Regressions testing for the moderation by past trauma used PPI-R score (total, SCI, or FD), CATS total score, and a PPI-R by CATS interaction term as standardized predictors. Tests for moderation by anxiety and alexithymia used the same predictors but substituted STAI-II (*Trait*) and TAS-20 total scores respectively in place of the CATS. No significant moderation the associations between LPP amplitude and PPI-R total and subscale scores was found for trauma (for all interaction terms, $|b^*| \leq .193$, $p \geq .224$), anxiety (for all, $|b^*| \leq .160$, $p \geq .225$), or alexithymia (for all, $|b^*| \leq .174$, $p \geq .208$).

2.5. Discussion

Whereas a substantial body of work indicates that psychopathic personality is associated with speed and accuracy deficits when identifying the emotional expressions of others, the present study addressed whether these deficits extend to ERP components that indexing spatial-attention and emotional processing for faces. Across all participants the pre-attentive salience of emotional faces did not substantially exceed that of neutral faces (Ppc amplitude), but emotional face targets elicited lateralized posterior ERP components indicative of item selection (N2pc amplitude) and manipulation in working memory (CDA amplitude). Individual differences in psychopathic traits had little impact on the pre-attentive salience and selection of faces. Instead, the presence of these traits appeared to moderate the strength of participants’ working memory representations once emotional faces were attended to, as suggested by diminished CDA amplitude in individuals scoring highest on the PPI-R self-report measure. Somewhat surprisingly, no associations of psychopathy were observed with emotionally modulated N170, EPN, and LPP components. In considering the implications of these findings, it is useful to first consider the study's broader implications for theories of visual search for emotional stimuli.

2.5.1. The salience of an emotional face in a crowd

Early behavioral tests of visual-search suggested that emotional faces are detected and processed rapidly due an evolved mechanism (Hansen & Hansen, 1988), and despite research demonstrating the role of confounds in this original work as well as studies that replicated its effects, the notion that faces are capable of rapidly reorienting spatial attention because of heighten emotionality is still strongly maintained in ERP studies. In particular, threat salience has been proposed to be a critical factor guiding spatial attention deployment to faces in behavioral and ERP studies (Eimer & Holmes, 2007; Feldmann-Wüstefeld et al., 2011; Holmes, Bradley, Nielsen, & Mogg, 2009). However, there is mounting behavioral and computational evidence that spatial attention is directed to emotional faces by their perceptual characteristics, rather than their broad emotional properties (Lundqvist, Bruce, & Öhman, 2015; Savage et al., 2016). Data from the present study aligned with the view that visual-spatial reorientation is guided to faces by the same low-level features that have been propose for simple non-emotional stimuli (Wolfe & Horowitz, 2004).

First, differences between contralateral and ipsilateral electrode amplitudes for the Ppc were not significant for targets of any facial expression type, though the difference did approached significance for happy faces. This indicated that participants' cortical computations of the perceptual-salience of emotional singletons did not reliably exceed that of neutral fillers. This is spite of the fact that normative ratings for the selected images (supplied by Goeleven et al., 2008) confirmed that the average arousal for each group of target expressions was significantly greater than that of the neutral filler stimuli. Ppc amplitude increases as singletons become more distinct, and decreases as fillers become more heterogeneous (Christie et al., 2015). Despite the emotional heterogeneity of neutral fillers and distinctiveness of targets, the variability of features between faces seemed to have determined their salience in the visual-search perceptual-sense.

Second, a large significant contralateral versus ipsilateral electrode amplitude difference was observed for the N2pc to all expression types. Relative to fearful or angry faces the difference for happy faces was significantly greater. Notably, happy faces were the only targets for which N2pc latency and RT correlated significantly. In visual search tasks, the ability to locate a target stimulus and shift attention to is critical to behavioral performance. Timing of this orientation shift is indexed by latency of the N2pc (Dowdall, Luczak, & Tata, 2012). The lack of association for angry and fearful expressions, coupled with overall reductions of their evoked N2pc amplitude suggested the reliability of detecting them from trial-to-trial was limited. It was also notable that while a significant CDA component was observed, the effect was restricted to happy and angry expression targets in follow-up analyses. This illustrated that strong CDA amplitude is dependent on reliable N2pc selection, given that the same expression elicited the greatest effects for both components. But, these findings were contrary to reports of stronger N2pc responses to angry faces than happy faces when using schematic stimuli (Fan et al., 2016), or natural faces selected from the Ekman (Feldmann-Wüstefeld et al., 2011) and NimStim (Holmes et al., 2009) databases. They were also inconsistent with reports of significant CDA components for angry but not happy Ekman singletons (Feldmann-Wüstefeld et al., 2011).

In these previous studies, N2pc and CDA enhancements for angry singletons relative to happy singletons have been attributed to overall negativity bias, or an evolutionary threat detection advantage. A similar explanation is often given in behavioral studies finding faster responses and more efficient search for angry faces than happy faces (Öhman, Lundqvist, & Esteves, 2001). Replication of stronger N2pc response for fearful or angry stimuli chosen from an alternate database (KDEF) would have support the notion that threat detection guides visual search. This was not the case here, calling the threat detection explanation into question. Lundqvist and colleagues (2015) have proposed that stimulus salience on measures of arousal may be more predictive of efficient search than salience on measures of valence. However, this argument is still incongruent with the differentiation of N2pc amplitudes for angry, fearful, and happy faces presented here, given that the normative arousal and intensity ratings of the stimuli were controlled. Instead, the best remaining explanation is that of Savage and colleagues (2016), who have argued that search efficiency depends on characteristics of individual faces and not their broad emotional classifications. *"Emotional"* in-and-of-itself is not a visual search *guiding feature* (Wolfe & Horowitz, 2004). Rather, spatial attention shifts toward such stimuli depend on the presence of true guiding features such as color, size, orientation, and spatial contrast that are contained within their overall gestalt.

Emotional response is spatially gated

Taken together, Ppc, N2pc, and CDA data in the current study indicated that the cortically computed perceptual salience of emotional stimuli did not align with the emotional salience of those stimuli, and the ability to locate stimuli was not predicted by a threat detection model. But this is not to say that threatening or highly affective stimuli are not subject to enhanced/differential processing once detected and spatially selected. On the contrary, EPN and LPP component amplitudes elicited by stimulus arrays with emotional singletons on the vertical meridian showed significant differences between expression types. Given that happy faces elicited the greatest effects, these components showed no evidence of threat or negativity bias; however they did still indicate that emotionality of the stimuli moderated ERP response. Notably, there was no differentiation of the N170 or posterior P1 by emotional expression types, but this was actually in line with previous research indicating that emotional responsiveness is gated by spatial attention. Holmes, Vuilleumier, and Eimer (2003) conducted a study in which participants viewed an array consisting of two faces and two houses surrounding a fixation point. An exogenous cue preceded each trial, and indicated where to direct spatial attention. When houses rather than faces appeared at the attended locations, amplitude of the N170 component was reduced, and the subsequent fronto-polar positivity was undifferentiated for fearful versus neural expressions. In another study, Holmes, Kiss, and Eimer (2006) presented faces at fovea, flanked by a pair of lines of varying lengths, and had participants identify repetitions of either line pairs or faces. When responding to face repetitions, emotional expressions relative to neutral expressions elicited an enhanced fronto-polar positivity 160 ms after onset, which was sustained for up to 600 ms. In contrast, when responding to the line pair, significant emotional modulations were seen only from 160 to 220 ms, indicating the influence of structural coding responses the task-irrelevant faces that were presented at fixation. Thus the neural architecture receptive to the evaluation of highly affective stimuli seems to be rapidly engaged *if* those stimuli are presented at fixation, but does not seem to have any privileged links to visual reorienting systems.

This conclusion also does not preclude the possibility that emotional stimuli can be detected more efficiently that non-emotional stimuli or that certain classes of emotional stimuli might be more efficiently oriented to than others. However, emotional expressions are useful predictors of a faces' capacity to guide spatial attention in-so-much as they represent stimulus conditioning in the analysis of variance sense; *on average*, emotionality of a face might moderate search efficacy due to differential rates of guiding properties occurring within each expression category. Furthermore, it is logical that a stimulus which has been rapidly attended to due to its high guiding feature salience should elicit an affective fluctuation independent of the object's semantically derived emotional significance. The directionality of this relationship has been reversed in the existing neuro- and cognitive-behavioral literature examining attention capture (both spatial and cognitive) to emotional faces, largely based on the assumption that specific emotional categories represent privileged, evolved stimuli sets that are inherently distinct from others (Eimer & Holmes, 2007; Eimer & Kiss, 2008; Hansen & Hansen, 1988; Öhman et al., 2001). Constructionist theories of emotion, such as the conceptual act model (Barrett, 2006a, 2006b, 2009) have proposed that ongoing contextualized fluctuations of arousal, valence, and motivation characterize affective states that are impacted by emotionally evocative stimuli. The perception of categorical emotions within oneself arises from the contextualized appraisal of one's current affective state. This theory parallels the visual search model proposed by Jannati and colleagues (2013) in which visual scans compute ongoing salience maps that are used to drive attention shifts that may be reflexively initiated due to the 'inherent' salience of perceived stimuli, intentionally guided for goal directed purposes, or interactively guided by the endogenous enhancement of task relevant stimulus features. One of the few things that facial expression attention researchers seem to agree on unequivocally is that controlling for low-level stimulus features in emotional attention studies is difficult (Fan et al., 2016; Lundqvist et al., 2015; Savage et al., 2016). Instead of viewing emotional stimuli as confounded because they possess salient low-level attention guiding properties, maybe the ability to guide spatial attention *is* one of the properties (if not the *only* property that is not established through associative learning) that determines a stimulus’ capacity to fluctuate the internal affective barometer. That is to say, perhaps certain stimuli are more often categorized as emotional *because* of their ability to guide spatial attention (among other reasons). Emotional things do not capture attention; things that capture attention are emotional.

2.5.2. The impact of psychopathy on emotional visual search

As noted previously, psychopathy did not moderate the strength of ERP components indexing relative salience of emotional targets versus neutral stimuli (Ppc amplitude), efficiency of target location (N2pc latency), strength of spatial selection (N2pc amplitude), or post-localization resolution of target stimuli (correlation of N2pc latency with RT) for any emotional expression type. This was perhaps unsurprising, given that Ppc results indicated emotional salience was insufficient to impact perceptual salience map calculations across the entire sample, and N2pc findings indicated that spatial deployment was not guided by threat detection. These results paralleled findings of the non-emotional visual search task presented in Chapter 1, in which psychopathy was found not to impact any index of goal-directed spatial attention deployment.

Psychopathic personality did moderate ERP correlates of post-orienting stimulus representation of different facial expressions, with PPI-R total scores negatively correlated with absolute amplitude difference between contralateral and ipsilateral electrode sites for the CDA (i.e. as scores went up, the typically negative amplitude component became more positive). The CDA is thought to represent visual working memory representation and manipulation of stimuli, therefore this globally diminished responding suggested reduced relevance of items or capacity for face stimuli in individuals with higher PPI-R scores. Additionally, the FD factor of the PPI-R was correlated with diminished amplitude for fearful faces, and SCI with diminished amplitude for happy faces. Due to the issues with evaluating specific expression dependent differences discussed above, these effects were difficult to interpret. CDA reduction for fearful images in higher FD participants may have reflected an inverse relationship between empathy and short-term memory representation of fear, similar to the predictions of empathy system models. The negative association between SCI and happy faces was even less clear, though it may have related to SCI’s association with measures of negative affect.

A follow-up analysis conducted on study 1 data for the visual search task indicated that from 470 to 600 ms (the CDA time window in this study), there was a significant amplitude difference between contralateral and ipsilateral electrode sites ($F_{site}(1,73) = 17.114$, $p < .001$, $n_p^2 = .190$), but this effect was not moderated by PPI-R total or factor scores when these were incorporated as covariates in rANCOVA tests (for all main effects and interactions of *site* and covariates, $F(1,73) \leq .376$, $p \geq .542$, $n_p^2 \leq .005$). The targets presented here and in study 1 varied greatly both in terms of affective salience, but also in terms of visual complexity. It is therefore difficult to conclude whether this dissociation of CDA effect reflected a true effect of blunted emotionality, or simply an effect of perceptual load and working memory capacity. But as noted previously, the removal of task load confounds from emotional stimuli and contexts is inherently challenging, and I would argue that load in and of itself might be thought of as an affectively modulating object property.

There was no moderation of any emotional components by psychopathy in the present study. This was surprising for the N170 given previous reports of correlations with FD (Almeida et al., 2014). A possible explanation for the absence of an N170 association may parallel the absence of an emotionally driven effect across the sample. The N170 correlates with reported detection/perception of faces, and the substitution of faces within stimulus array seemed to have not substantively impacted the effect. The absence of an LPP effect was even more surprising for two reasons, the first being that blunted LPP differentiation has been the most consistent finding in affective ERP studies of psychopathy (Anderson & Stanford, 2012; Medina et al., 2016; Venables et al., 2015). The LPP is often thought to reflect the inherent personal relevance of emotional stimuli (Hajcak, Weinberg, McNamara & Foti, 2012) – they are *always* target-like by virtue of semantic value or evolutionary relevance. But, blunted LPP differentiation is typically reported for complex affective stimuli such as images selected from the International Affective Picture System database (IAPS; Lang, Bradley, & Cuthbert, 2008), rather than faces. IAPS stimuli are highly rated on arousal and valence, and are often rich context. Perhaps psychopathy is associated with impoverished mulling of rich emotional contexts. The LPP may represent a post stimulus encoding of emotional salience, or some other memory manipulation process, leading to the second reason for which the absence of an LPP association with psychopathy was surprising: the presence of a significant association for the CDA. The CDA reflects representation of stimuli within visual spatial working memory, which would be expected to covary with the LPP if it does indeed represent a memory encoding process. But, to draw an analogy, perhaps the CDA represents the scrap paper of cognition whereas the LPP represents the library stacks. While there are both memory processes, perhaps they are orders of magnitude apart in terms of elaboration. It is also possible that the absence of an “emotional” LPP modulation by psychopathy in the presence of a CDA modulation by psychopathy indicates that the latter reflected perceptual capacity for face stimuli in this task. It is possible that the observed CDA modulation was more akin to diminished N170 processing that would characterize the evaluation of an attended face. This interpretation would align with previous studies finding only N170 abnormalities and not LPP abnormalities in high psychopathy individuals viewing emotional faces. It remains to be seen whether these effects are driven by differences in emotional responsiveness, perceptual encoding of faces, or a more general abnormality in working memory capacity. But of note, the CDA measurement does contain some control for visual complexity in that target stimulus related activity is effectively baselined within trials by distractor related activity recoded at ipsilateral scalp.

2.5.3. Limitations, conclusions, and future directions

An important caveat is that within the blocks of the current study, emotional expressions were intermixed. As such, participants were not able to rely on a single specific feature configuration to establish an attention set. Instead, three to six separate feature configurations had to be maintained in working memory in order to reliably detect happy, angry, and fearful expressions of male and female faces. Work by Towler and colleagues (2015) suggests that visual-working memory capacity is limited to a single face. Had stimuli been blocked, it is possible that participants would have been able to rely on a particular feature of each expression to guide search (e.g. search for a “V” shaped brow during angry blocks), which theoretically could have resulted in a Ppc component. Significant Ppc effects to color singleton shapes within an array composed entirely of singletons has shown that non-salient targets can still evoke a significant Ppc (Christie et al., 2015). Whether or not it is possible to employ such an approach during visual search for faces could be tested in a future study that controls for valence and arousal of faces, tests speed of responding to blocked versus intermixed expressions, and employs open-ended response questions to qualitatively assess search strategies (“how did you find the emotional faces?”).

The absence of significant target expression related differences for the amplitudes of P1 and N170 components evoked by arrays containing different target should also be addressed. Strength of these early components, particularly the N170, typically correlates with subjective reports of face perception (Rossion & Jacques, 2012). Substitution of various facial expression targets within the present study produced only minimal differences in the overall rapid face-related structure coding of visual search arrays prior to visual-spatial attention deployment to emotion critical locations. However, this finding confirms earlier work indicating that emotional response is gated by spatial attention (Holmes et al., 2006, 2003).

As with the results presented in Chapter 1, the power of the statistical tests presented here were somewhat of a concern. After participant exclusions and attrition the final sample size was 73. Statistical *r* tests on the correlations of ERP effects with PPI-R total and factor scores therefore had power = .73 to detect significant effects of medium size. This fell below Cohen and colleagues’ (2003) recommendation of power ≥ .80. Also mirroring the considerations of Chapter 1, the fact that participants were undergraduate student rated on a self-report measure of psychopathic personality traits should be taken into consideration when generalizing the results of this study. Additionally, the absence of clear significant correlations between CDA amplitude and the TriPM external criterion measure was somewhat concerning. However, the validity of the PPI-R has been demonstrated in both community and correctional samples (for a discussion, see Appendix B). As such, for individuals with clinically relevant scores on the PPI-R or other measures of psychopathy, who are sampled from a forensic population, the emotional face working memory abnormalities indexed by reduced CDA would presumably be even more pronounced. Finally, the between studies comparison of CDA amplitudes for basic versus face targets implied a selective abnormality for facial expression representation in psychopathic personality. It remains unclear whether this is a specific effect for faces, or a more general effect for complex stimuli.

Ultimately, in the current study psychopathic personality traits did not impact early visual-spatial attention orienting stages during search for emotional faces, such as salience calculation or goal-directed deployment. Instead, these traits diminished the strength of visual working memory representations of faces following their detection. No association was found between psychopathy and emotional modulation of the N170, EPN, or LPP. Effects and associations were not moderated by individual levels of anxiety, negative affect, alexithymia, or past childhood trauma. As such, the results of the current study indicate little impact of psychopathy with spatial capture by emotional faces, but also call into question whether such effects actually occur. Psychopathy may be associated with reduced representation of emotional faces, reduced representation of faces, or reduced representation of complex stimuli in general.

2.6. Study 2 Tables

Table 2-1 Study 2 singleton stimuli and behavioral performance

Male targets	**Angry *M* (*s*)**	**Fearful *M* (*s*)**	**Happy *M* (*s*)**
RT (ms)	1128.0 (221.7)	1111.6 (220.7)	1042.8 (185.8)
ACC	.838 (.100)	.799 (.125)	.861 (.109)
KDEF stimuli	M01, M05, M08, M09, M10, M12, M14, M24, M27, M28		
Female targets	**Angry *M* (*s*)**	**Fearful *M* (*s*)**	**Happy *M* (*s*)**
RT (ms)	1285.4 (314.5)	1108.2 (222.3)	1000.5 (201.1)
ACC	.5912 (.148)	.809 (.139)	.852 (.096)
KDEF stimuli[1]	F01, F02, F03, F05, F09, F13, F14, F20, F21, F25		

Note: *M* = mean; *s* = standard deviation; KDEF = Karolinska Directed Emotional Faces (Lundqvist, Flykt, & Öhman, 1998)

Table 2-2 Study 2 test battery questionnaires

	n	***Mean***	***Standard Deviation***
TriPM total	73	74.61	16.96
TriPM Disinhibition	73	18.16	7.58
TriPM Boldness	73	38.51	7.97
TriPM Meanness	73	17.93	7.83
Behavioral Activation System (*BAS*)	74	41.68	5.02
Behavioral Inhibition System (*BIS*)	74	21.82	3.41
Barratt Impulsiveness Scale 11a total (prorated)	73	65.59	11.01
State-Trait Anxiety Inventory-State (*STAI-I*)	69	38.33	9.62
State-Trait Anxiety Inventory-Trait (*STAI-II*)	69	43.18	9.16
Toronto Alexithymia Scale-20 (*TAS-20*)	68	49.41	10.46
Childhood Abuse and Trauma Scale (*CAT*)	65	62.94	15.85
Positive Affect[1]	68	30.87	7.14
Negative Affect[1]	68	20.25	7.21
Beck Depression Inventory-II	67	11.65	9.18

[1] Positive Affect Negative Affect Schedule (PANAS; timeframe = *in the last week*); *TriPM* = Triarchic Psychopathy Measure

Table 2-3 Study 2 Psychopathic Personality Inventory-Revised covariance matrix

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Total score	*M*	**277.25**										
	s^2	*1258.56*										
2. Self-Centered Impulsivity	*r*	.837**	**138.73**									
	cov	597.68	*404.95*									
3. Fearless Dominance	*r*	.832**	.440**	**108.86**								
	cov	553.08	165.77	*350.89*								
4. Coldheartedness	*r*	.456**	.201	.292*	**29.66**							
	cov	107.80	26.97	36.43	*44.40*							
5. Machiavellian Egocentricity	*r*	.672**	.780**	.332**	.290*	**42.66**						
	cov	201.70	132.73	52.62	16.34	*71.51*						
6. Rebellious Nonconformity	*r*	.737**	.720**	.572**	.141	.413**	**32.81**					
	cov	194.40	107.72	79.69	7.00	25.98	*55.31*					
7. Carefree Nonplanfulness	*r*	.354**	.507**	.078	.135	.174	.226	**34.17**				
	cov	77.52	62.92	9.06	5.54	9.05	10.34	*38.01*				
8. Blame Externalization	*r*	.477**	.688**	.178	-.039	.422**	.295**	.122	**29.08**			
	cov	124.07	101.58	24.40	-1.91	26.19	16.08	5.51	*53.81*			
9. Fearlessness	*r*	.623**	.422**	.726**	-.001	.269*	.553**	.093	.210	**34.13**		
	cov	199.14	76.62	122.61	-.09	20.48	37.05	5.18	13.91	*81.26*		
10. Stress Immunity	*r*	.499**	.092	.665**	.509**	.068	.221	.042	-.086	.246*	**29.83**	
	cov	119.10	12.41	83.87	22.83	3.85	11.05	1.76	-4.25	14.90	*45.26*	
11. Social Influence	*r*	.682**	.393**	.794**	.212	.345**	.437**	.035	.207	.302**	.363**	**44.89**
	cov	234.84	76.74	144.41	13.69	28.30	31.59	2.12	14.74	26.45	23.70	*94.26*

Note: *N* = 76; bolded and italicized values within cells on the diagonal are mean and variance (respectively) for the given scale; *cov* = covariance; *r* = Pearson correlation coefficient; *M* = mean; s^2 = variance

** $p \le .01$ (2-tailed).

* $p \le .05$ (2-tailed).

Table 2-4 Study 2 ERP and behavioral outcome variables (*n* = 73)

	Angry		**Fearful**		**Happy**	
	M	***s***	***M***	***s***	***M***	***s***
Medial target trials ROI amplitude (µV)						
P1	3.114	3.374	2.745	3.241	2.639	3.245
N170	-0.654	2.260	-0.827	2.174	-0.891	2.178
EPN	2.685	4.374	2.442	4.014	2.165	4.093
LPP	2.429	3.729	2.701	4.171	3.226	4.024
Lateral target trials						
RT	1142.267	251.062	1066.370	203.040	991.479	187.630
Ppc						
Contralateral (µV)	3.093	3.165	2.830	3.171	*2.924*	3.303
Ipsilateral (µV)	2.920	3.078	2.960	3.432	*2.645*	3.007
t	1.174		-0.624		2.119	
p	0.244		0.535		0.038	
N2pc						
Contralateral (µV)	*1.373*	3.466	*1.525*	3.739	*0.531*	3.661
Ipsilateral (µV)	*2.944*	3.962	*2.847*	3.767	*3.036*	3.998
t	-8.228		-8.185		-10.205	
p	≤0.001		≤0.001		≤0.001	
50% Latency (ms)†	312.350	26.881	307.507	33.622	307.184	21.566
CDA						
Contralateral (µV)	*3.391*	4.088	4.130	4.185	*3.975*	4.129
Ipsilateral (µV)	*4.293*	3.914	4.660	3.783	*5.218*	4.130
t	-3.594		-1.942		-4.459	
p	≤0.001		0.056		≤0.001	

Note: µV = microvolt; *M* = mean; *s* = standard deviation; † Calculated across subsample of 62 participants with valid negative peak during N2pc interval

2.7. Study 2 Figures

Figure 2-1 **Study 2 stimulus display; reaction time (RT) and accuracy (ACC) provided for each potential location.**

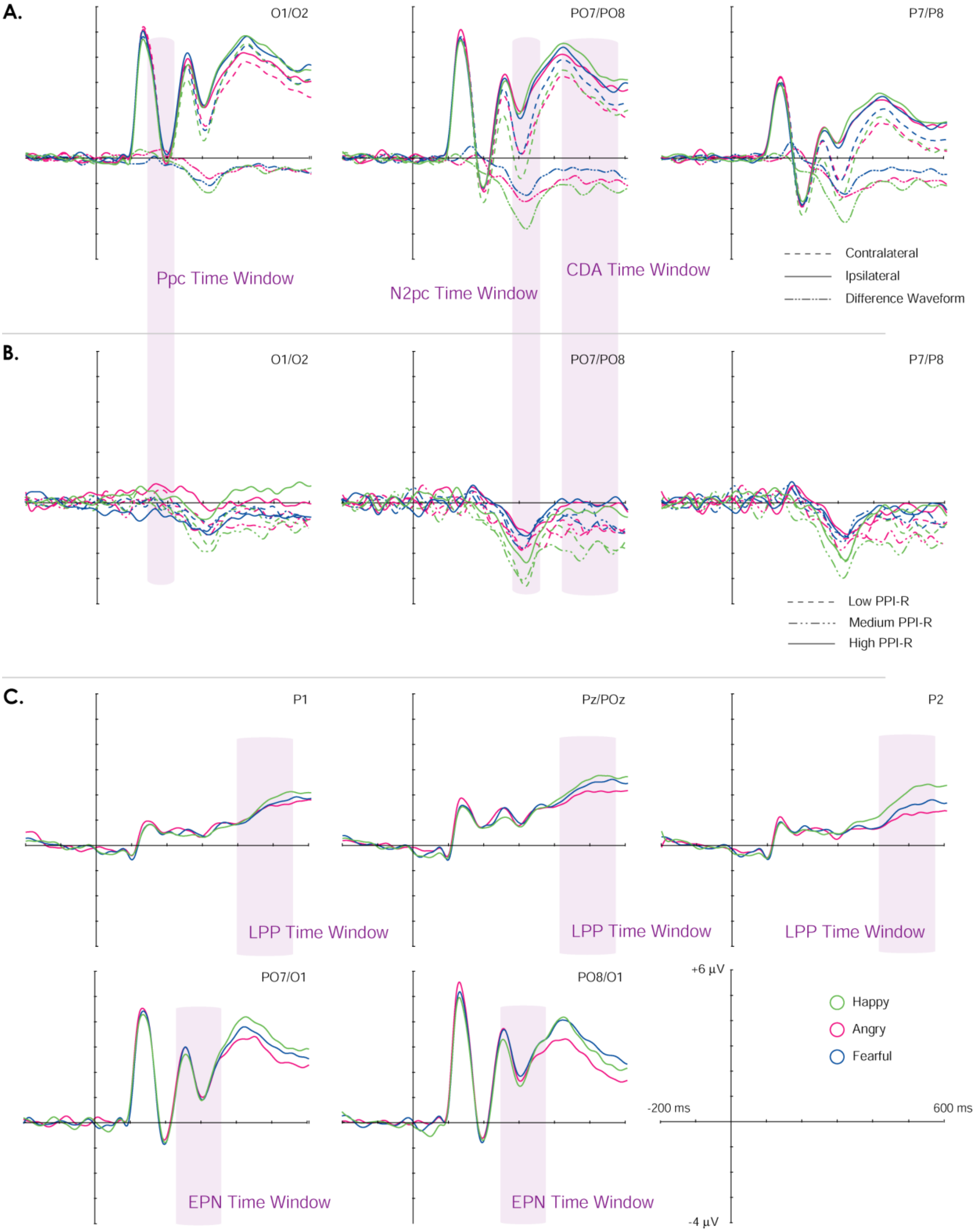

Figure 2-2 Study 2 ERP data (µV) electrode sites over the averaging epoch (-200 ms to 600 ms); A. Grand average ERP waveforms for lateral targets at three occipital and parietal electrode sites (contralateral and ipsilateral sites, and the contra-minus-ipsi difference); B. Grand average ERP waveforms for lateral targets the same sites by PPI-R low, medium, and high groupings; C. Grand average ERP waveforms for medial targets at five posterior electrode sites.

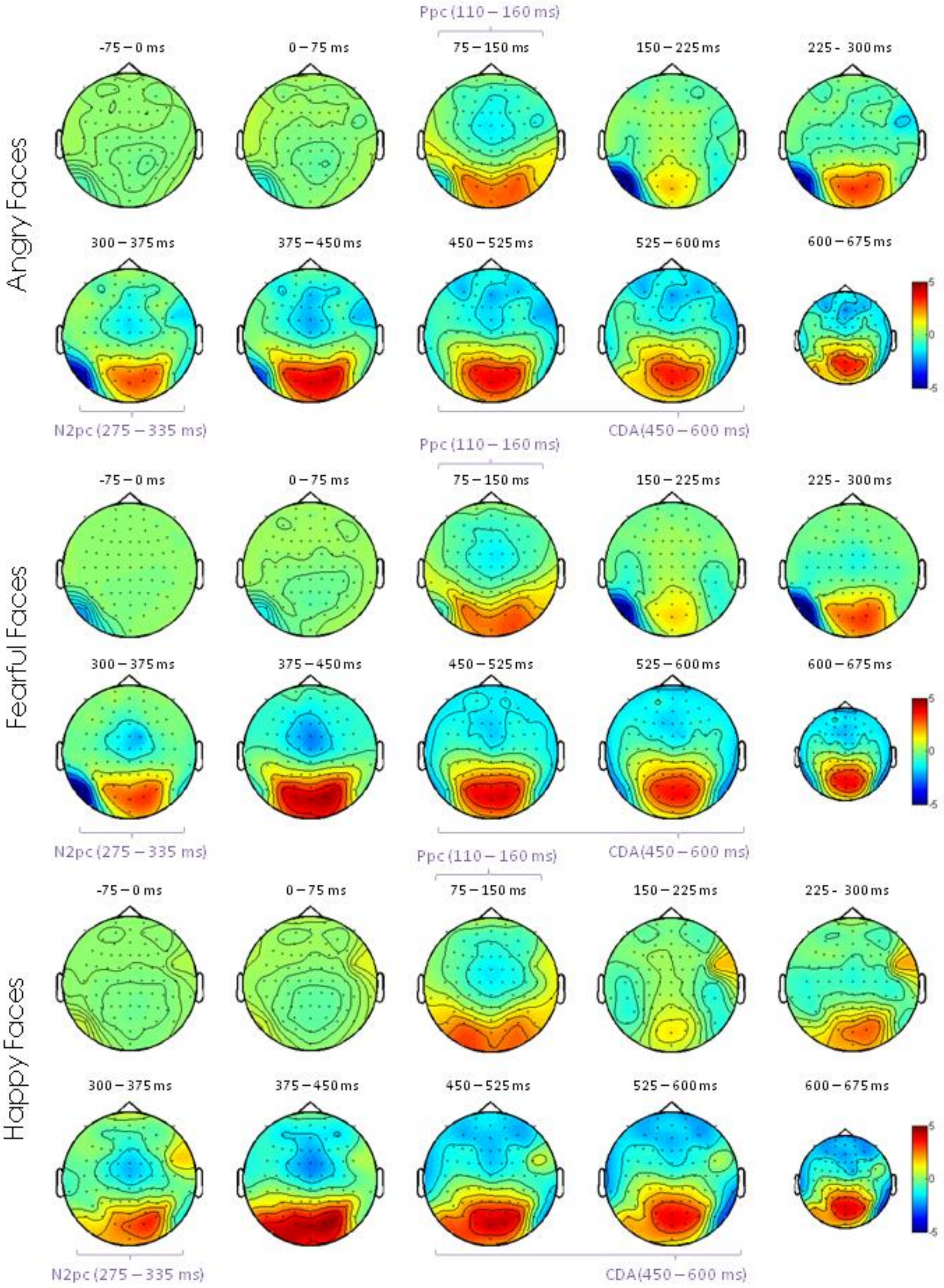

Figure 2-3 Study 2 topographical distribution of grand average ERPs to each emotional face target category (medially presented singletons).

Chapter 3.

Visual search for emotional faces is inefficient, regardless of psychopathic personality traits

3.1. Abstract

Low-level “pop-out” features such as color, orientation, and size are rapidly detected during visual scans of a scene, and are thought to guide spatial attention deployment during visual search. Early studies suggested that detection of emotional faces (an emergent property of low-level features) may also be rapid and thus indicative of automatic/preferential processing, but those results have been difficult to replicate. The current study tested efficiency of emotional face detection, and examined whether this effect was moderated by psychopathic personality. A sample of 77 undergraduate students identified emotional singleton faces (angry, fearful, or happy) embedded within circular arrays of neutral-expression distractors as either male or female. Across blocks, displays varied in the number of items (set-sizes: 4, 6, 8, or 10). Repeated measures ANOVA indicated that median reaction time (RT) varied significantly across set-sizes, and singleton emotions. Search slopes calculated across set-sizes (i.e. RT increase per display item) suggested that search was inefficient regardless of singleton emotional expression (all slopes exceeded 54ms/item). Subsequent repeated measures ANOVA on search slopes for angry, fearful, and happy expressions showed a significant effect of emotion type, with the smallest search slope for happy faces. Contrary to predictions, effects were not moderated by total or factor scores on the Psychopathic Personality Inventory-Revised (PPI-R; Lilienfeld & Widows, 2005) when added as covariates in repeated measures ANCOVA. Correlations between the PPI-R and search slopes were non-significant, with small absolute values suggesting a negligible impact of psychopathy on the pop-out status of emotional faces.

3.1.1. Visual search efficiency

In a typical visual search task, a participant scans an array of largely homogeneous (if not identical) filler items to detect the presence of a *singleton item,* one that differs from the other stimuli on a distinguishing feature dimensions. Upon detecting a target singleton, if the task requires that it be identified, visual-spatial attention must then be oriented (overtly or covertly) to its location in order to assess response features. Performance on such tasks can be separated into three broad categories based on the difficulty of detecting the target. The first category consists of rapid, seemingly automatic search for highly salient items, ones that differ substantially from filler stimuli on dimensions of color/luminance, orientation, size/spatial frequency, or motion (Wolfe & Horowitz, 2004). These items are said to "*pop-out*" because search time does not increase with the addition of filler items. The second category is search that requires item-by-item *serial deployment* of visual-spatial attention to detect the target. The third and final category consists of search for stimuli that do not immediately pop-out, but nevertheless can be detected without performing multiple spatial attention deployments within the stimulus array (*direct deployment* of spatial attention to the target and only the target). These searches are further characterized in terms of *efficiency,* which is the delay incurred by the addition of fillers. Response speed for efficient direct search increases by only a few milliseconds per filler item. Pop-out search could be thought of as reflecting a special, perfect case of efficient search, in that the delay incurred per filler is 0 ms (Christie et al., 2015). However, the reaction time increase for very inefficient search might be as much as 30 ms per item or more. The primary method for evaluating search type/efficiency in all cases is calculation of *search slope,* which is the change in response latency as a function of the number of items in a search display. For search functions with a slope of 0 ms there is clear evidence of pop-out detection given that no additional response time is needed to assess filler items. Traditionally, a 10 ms increase per item was thought to demarcate pop-out versus serial search (Fox et al., 2000). However, given the difficulty of distinguishing highly inefficient direct search from serial search, more recent approaches assess efficiency as a continuous slope measurement (Greene & Wolfe, 2011).

The most influential models of search have been premised on the notion that human vision occurs in two stages (Wolfe & Horowitz, 2004). As initially proposed by Neisser (1967) and elaborated in Treisman and Gelade's (1980) feature integration model, the first pre-attentive stage handles parallel (simultaneous) processing of low-level (“early” or “primitive”) features within a given scene. This stage precedes selective attention to individual objects. During the second feature-binding stage, attributes extracted during stage one are integrated for specific items that were then subjected to object recognition and in-depth identification. The more recent guided feature search model (Wolfe, 2007; Wolfe & Horowitz, 2004) has proposed that ongoing cursory visual scans (analogous to stage one vision) compute *salience maps* or *guiding representations* of the environment. These representations then mediate the deployment of selective attention in order to handle object recognition (analogous to stage two). The guided feature search model holds that not all attributes encoded at the earliest stages of vision are used to reorient attention. For example, line intersection does not seem to trigger reflexive shifts, or facilitate goal directed ones. Instead color, orientation, size, and motion are thought to be selected by a visual-spatial guidance neural module that sits outside of the primary object processing stream often referred to as the “ventral *what* pathway” (Wolfe & Horowitz, 2004).

The feature integration model attributed pop-out search to detection of basic stimulus features extracted at the pre-attentive stage, and serial search to guided selective deployment during the second stage. Under this framework pop-out and efficient search were synonymous, as were serial and inefficient search. However, as supported by event-related potential (ERP) evidence (Christie et al., 2015), the guided feature search model allows for non-serial inefficient search. Inefficient search may indeed be serial in cases where there is (functionally) no salient enough feature available to guide search to a target. This may occur when the target is defined by the absence of a feature (Dowdall et al., 2012), when the difference between the targets and fillers is extremely subtle, or when fillers are highly heterogeneous (Wolfe & Horowitz, 2004). Inefficient direct search appears to result from disruption/prolonging of pre-attentive salience map calculation (selection time) by the presence of filler/foil items that are as, or more, salient to the target. The guided search model has been extended to the realm of visual ERP. Jannati and colleagues (2013) proposed that activity over occipital scale electrode sites contralateral to the visual hemifield of a lateral singleton, occurring in the time range of the visual P1 and N1s (the posterior contralateral positivity or Ppc) reflects the salience calculation process. The resulting salience map then guides the deployment of spatial selection (N2pc) *or* suppression (Pd) mechanisms to the locations of the most salient items in order to satisfy task demands.

3.1.2. Affective search

Several studies have attempted to determine what stimuli, or stimulus features, beyond size, color, and orientation are able to guide attention selection. In an early study testing whether emotional faces could be detected rapidly during visual search, Hansen and Hansen (1988) found that an angry singleton face presented within an array (“crowd”) of happy faces was detected more rapidly than a happy singleton within an angry array. Additionally, the search slope for angry faces suggested that their detection was automatic/pop-out. This finding was particularly intriguing within the feature integration framework because it suggested automatic pre-attentive processing of an emergent stimulus property (emotionality), and was attributed to the biological relevance of threat stimulus detection. However, this effect has proven difficult to replicate, and follow-up studies have suggested that it was actually caused by a low-level confound; discriminable differences in local contrast between happy and angry images. As described by Purcell, Stewart, and Skov (1996), Hansen and Hansen converted their Ekman database photos into sketch-like images by ‘thresholding’ their continuous gray values up to black or down to white. This created large, dark marks on the necks and chins of several angry faces. When the same faces were tested as gray-scale images, pop-out effects were absent (Purcell et al., 1996).

Fox and colleagues (2000) conducted a series of studies employing schematic (line-based) emotional faces, and tested whether angry and happy faces showed patterns of automatic processing when displayed within arrays of neutral faces. Their results suggested that slower RT on happy-singleton angry-crowd trials than angry-singleton happy-crowd trials could potentially be caused by interference from the *distractors* within predominantly angry arrays, rather than the rapid detection of angry faces within happy arrays. Additionally, when testing the impact of additional neutral distractors within a search array, they found that although angry singletons were detected faster than happy singletons in arrays of 4 and 8 neutral distractors, RT increased by approximately 17 ms per distractor, suggesting that although search for angry faces may sometimes be efficient*,* it is not automatic.

Lundqvist, Juth, and Öhman (2014) have proposed that stimulus salience on measures of arousal may be more predictive of search speed than emotional categorizations, or salience on measures of valence. This is supported by their re-evaluation of seven previously collected data sets, which found that arousal ratings predicted reaction times better than a threat detection account. Additionally, when controlling for the perceptual salience of visual search array face stimuli with objective measurements and subjective ratings, arousal is more predictive of response time than valence or stimulus potency (Lundqvist et al., 2015). However, Lundquist and colleagues have also acknowledged the undisputed importance of perceptual factors in guiding search. Additionally, these studies were conducted on fixed size search arrays, precluding the calculation of search slope measures and thus limiting the conclusions that can be drawn regarding the impact of stimulus arousal on search efficiency. Savage and colleagues (2016) have instead argued that search efficiency depends on the characteristics of individual faces rather than broad emotional categorizations. These authors found that even amongst images chosen from the same database, the speed at which emotional faces can be detected is more attributable to differences between individual face stimuli, rather than broad differences between emotional categories. It therefore possible that variable reports of specific expression recognition speed may simply reflect inconsistencies between different stimulus sets. This is in line with the view that emotional value is not a true visual search *guiding feature* (Wolfe & Horowitz, 2004). Rather, whether spatial attention shifts toward such stimuli depends on the presence of guiding features such as color, size, orientation, and spatial contrast that are contained within them.

Using behavioral measures, the experiment presented here tested whether emotional face search efficiency is influenced by psychopathic personality traits. Similar to the experiment conducted by Fox and colleagues (2000), stimulus arrays consisted of neutral faces, with emotional singletons. However, this experiment employed a mixed emotion design (angry, fearful, and happy expression targets), allowing tests across multiple emotional categories. As discussed in the previous two chapters, psychopathic personality is characterized by a blunted psychometric and physiological affective responsive profile. Therefore, assessment of search slope in relation to psychopathy, as measured with the Psychopathic Personality Inventory-Revised (PPI-R; Lilienfeld & Widows, 2005), allows a limited test of the role of affect in emotional singleton target detection. If affective salience is indeed able to guide the detection of emotional stimuli, reduced affective response should delay salience calculation, and therefore psychopathy should be positively correlated with search slope. However, if stimulus arousal does predict search efficiency, psychopathy and search slope should be uncorrelated. Correlations were assessed for PPI-R total score, as well as Self-Centered Impulsivity and Fearless Dominance (FD) factor scores, given the differential associations between each factor and measures of negative affect (see Appendix B). Similar to the results presented in Chapter 2, data from this investigation showed little association between psychopathy with search efficiency for faces, regardless of expression. As will be described, search for emotional faces was inefficient across the entire sample, which further supported for the notion that affect as a stimulus feature does not guide orientation of visual-spatial attention.

3.2. Methods

Prior to data collection, this study was reviewed by the Simon Fraser University Office of Research Ethics, and was designated minimal risk.

3.2.1. Participants and Procedure

Power analyses conducted prior to data collection and statistical tests determined that to achieve adequate power (.80) for tests of *r* at α = .05 (two-tailed), a sample size of 84 or 28 would be needed to detect significant effects of medium (*r* = .30) or large (*r* = .50) size, respectively (Cohen et al., 2003). Based on these considerations, a sample of 77 undergraduate students (age *M* = 19.87, *s* = 3.172; 41 female and 36 male; 4 left-handed; none colorblind; 52 English first-language speakers) completed a demographics and medical questionnaire (Appendix A), a battery of self-report questionnaires including the PPI-R, BI-11a, BIS-BAS, CATS, PANAS, and the BDI-II (described in Appendix B), and a behavioral experimental task. Sessions were approximately 1.5 hours, and participants received course credit through the Department of Psychology's Research Participation System. Of these participants, nine reported have having had a head injury resulting in a concussion or a loss of consciousness. Five reported a previous diagnosis of depression and/or bipolar disorder, one reported an anxiety disorder, one reported attention deficit/hyperactivity disorder, and one reported a sleep disorder.

Participant exclusions and attrition

One participant was excluded from behavioral analyses due to not completing any blocks of the set-size 10 condition, resulting in a final sample of 76.

3.2.2. Affective visual search task

The task was performed using E-Prime 2.0.8 on a 19-inch LCD monitor (1024 x 786 resolution, 60 Hz refresh rate) connected to a Windows PC or laptop. Responses were made with the right hand on a keyboard regardless of hand dominance. Stimuli consisted of a circular array of faces around a .5 cm x .5 cm silver fixation cross, on a black background (see Figure 3-1). Faces were selected from the Karolinska Directed Emotional Faces database (KDEF; Lundqvist, Flykt, & Öhman, 1998). Angry, fearful, happy, and neutral expressions of 10 unique male, and 10 unique female Caucasian faces[9] were selected, gray-scaled, and placed in oval frames to remove jaw- and hairlines. The number of faces within the array varied across blocks (set-size: 4, 6, 8, and 10). Faces were scaled to 4.6 cm vertically by 3.3 cm horizontally. They were distributed evenly around an imaginary circle, with their centers 11 cm from the center of the screen, and 15.5 cm, 11 cm, 8 cm, or 6.5 cm from the center of neighboring faces in set-sizes 4, 6, 8, and 10 respectively.

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[9] The same faces were used for the study presented in Chapter 2. Note that angry, fearful, and happy faces were equated for normative arousal and intensity rating, but also differed significantly from neutral faces on these values. Male faces: M01, M05, M08, M09, M10, M12, M14, M24, M27, M28; Female faces: F01, F02, F03, F05, F09, F13, F14, F20, F21, F25.

Each trial was preceded by a fixation cross displayed for a jittered interstimulus interval (1000 to 1500 ms), followed by the onset of the stimulus array. On every trial, each stimulus location featured a unique, randomly chosen male or female face. All faces displayed a neutral expression, with the exception of one at a randomly chosen singleton location that displayed a randomly chosen emotional expression (angry, fearful, or happy). Participants were instructed to identify the gender of the emotional face quickly and accurately using the number pad of the response keyboard, though they were given no specific instructions about the emotional expressions. Stimuli offset 10 ms after response, and were followed by a jittered interstimulus interval (1000 to 1500 ms). Participants completed 3 blocks of 40 trials for each of the set-sizes, with 15 second breaks in between blocks. Trials were rejected from analyses if participant reaction time (RT) was too fast or too slow (150 ms < RT < 3000 ms).

3.2.3. Data reduction and analyses

All statistical analyses were conducted in SPSS Statistics version 19.0.0 (IBM, 2010). Manipulation checks were performed on accuracy (ACC) and correct response median reaction time (RT) data collapsed across all set-sizes using repeated measures analysis of variance (rANOVA) with within-subject factors of *singleton gender* (male or female) and *singleton expression* (angry, fearful, or happy). Whether participants used parallel or serial search was assessed for male emotional singletons with a rANOVA on RT using within-subject factors of *set-size* (4, 6, 8, or 10 faces) and *singleton expression*. Significant *F* values for main effects or interactions of *set-size,* accompanied by an RT increase greater than 10 ms per additional distractor would indicate that search was serial. To further characterize these effects, subject search slopes were computed for each expression type. Whether psychopathic personality moderated pop-out effects within and between emotional expression types was assessed through the addition of PPI-R total, SCI, or FD scores as covariates in separate repeated measures analysis of covariance (rANCOVA) tests using the within-subject factors described above. Significant main effects and interactions were characterized through correlation of PPI-R scores with RTs or search slopes.

3.3. Results

A covariance matrix of PPI-R total, factor, and subscale scores, as well as the remaining test battery questionnaire scores for all participants can be found in Table 3-1 and Table 3-2 respectively.

3.3.1. Do emotional faces “pop-out”?

Manipulation checks indicated that ACC varied by the gender and expression of the singleton, and as a function of their interaction ($F_{gender}(1,76) = 4.213$, $p = .044$, $n_p^2 = .053$; $F_{expression}(2,152) = 7.334$, $p = .001$, $n_p^2 = .088$; $F_{gender*expression}(2,152) = 23.679$, $p < .001$, $n_p^2 = .238$). The addition of *participant gender* (male or female) as a between-subject grouping variable did not impact the effects nor produce any significant interactions. Reaction time data showed similar main effects and interactions of *singleton gender* and *expression.* Based on these findings, further analyses were limited to male singletons in order to reduce variability of RT measures within subjects, and the number of statistical tests conducted.

A significant rANOVA effect of *set-size* indicated that RT increased substantially with the number of distractors, and supported the interpretation that participants used an inefficient search process to detect emotional singleton faces ($F_{size}(3,225) = 9.469$, $p < .001$, $\eta_p^2 = .112$). This difference was driven primarily by a significant RT increase of 71.3 ms from set-size 4 to set-size 6, though RT increased by 20.1 ms from set-size 6 to set-size 8, and by 43.5 ms from set-size 8 to set-size 10. Additionally, a significant main effect of *singleton expression* ($F_{expression}(2,150) = 44.190$, $p < .001$, $\eta_p^2 = .371$), and significant *post hoc* differences between all marginal means indicated that participants responded fastest to happy singletons (1400.0 ms), followed by fearful singletons (1516.0 ms), and slowest to angry singletons (1575.5 ms). There was no significant interaction of the two factors ($F_{size*expression}(6,450) = 1.356$, $p = .231$, $\eta_p^2 = .018$), indicating that RT increased consistently with the addition of distractors regardless of the discrete emotional expression displayed by the target. Serial search for emotional faces was further supported by search slopes of 17.2 ms per item for happy singletons, 20.2 ms for fearful singletons, and 26.0 ms for angry singletons. Although one-sample t-tests indicated that only the search slope for angry faces was significantly different from 10 ms per item, all slope values were significantly different from 0 ms.

3.3.2. Does psychopathic personality impact affective search?

Moderation analyses found no impact of SCI on RT differences between emotional expression types, set-sizes, or any interactions, nor was there a main effect of SCI on RT scores overall (for all main effects and interactions, $F \leq 1.980$, $p \geq .142$, $\eta_p^2 \leq .026$). Similarly, PPI-R total score did not significantly moderate RT effects, though the main effect of *singleton expression* remained significant and the three-way interaction of *PPI-R score* by *set-size* by *singleton expression* approached, but failed to reach, significance ($F_{expression}(2,148) = 3.915$, $p = .022$, $\eta_p^2 = .050$; $F_{size*expression*PPIR}(6,444) = 1.888$, $p = .081$, $\eta_p^2 = .025$).

A marginal effect of FD on RT was observed in the rANCOVA testing for moderation by the scale. The main effect of *singleton expression* remained significant, and the previously non-significant *expression* by *set-size* interaction approached, but failed to reach, significance ($F_{expression}(2,148) = 7.256$, $p = .001$, $\eta_p^2 = .089$; $F_{size*expression}(4,444) = 1.867$, $p = .085$, $\eta_p^2 = .025$). Additionally, the interaction of *FD score* with the *expression* main effect, and the three-way interaction of *FD score* by *set-size* by *singleton expression* also approached, but failed to reach, significance ($F_{expression*FD}(2,148) = 2.824$, $p = .063$, $\eta_p^2 = .037$; $F_{size*expression*FD}(6,444) = 2.113$, $p = .051$, $\eta_p^2 = .028$). The three-way interaction was probed with a rANCOVA on search slopes with *singleton expression* as a within-subject factor and FD as a between-subject covariate. This test found a significant main effect of *expression*, and a significant interaction of *expression* by *FD score,* suggesting at least some moderation by FD on the difference between search slopes for angry, happy, and fearful expressions ($F_{expression}(2,148) = 4.817$, $p = .009$, $\eta_p^2 = .061$; $F_{expression*FD}(2,148) = 5.020$, $p = .008$, $\eta_p^2 = .064$). Follow-up correlations suggested that as FD score increased, participants' per item RT cost decreased for fearful singleton trials ($r = -.258$, $p = .025$).

3.4. Discussion

Results of this investigation of the impact of psychopathic personality on the efficiency of visual search for emotional faces were congruent with previous research finding inefficient, rather than pop-out detection of emotional faces across normative samples. Regardless of the target face’s emotional expression, median RT values differed significantly between set-sizes, and search slopes were substantially greater than 0 ms per item. Furthermore, individual differences in psychopathic personality traits were largely unassociated with measures of search speed and efficiency. PPI-R total and SCI factor scores did not moderate RT differences across expressions or between set-sizes. Although marginal effects were seen for tests incorporating FD, they were non-significant. Exploratory analyses conducted on the correlations between this factor and search slopes for each emotional expression category suggested that if any association exists, it was that high FD scores facilitated search. Thus these results provided further evidence that the ability to orient toward emotional targets is largely unaltered by psychopathic personality traits. Instead, emotional recognition deficits associated with the condition are more likely driven by abnormal cognitive resource allocation or affective responsiveness once items have been attended. Contrary to Lundqvist and colleague's proposals (2015, 2014) these results also seemed to indicate relatively little importance of stimulus arousal to target orienting, as the arousal and intensity of these expressions was controlled based on normative ratings. And as opposed to threat bias accounts, the fastest responses were to happy faces, whereas the slowest were to angry faces (Feldmann-Wüstefeld et al., 2011; Öhman et al., 2001). Therefore, for now, perceptual salience of basic guiding features remains the most plausible explanation for search efficiency. These results, as they pertain to the research presented in the previous two chapters will be addressed in more detail in the final chapter.

3.5. Study 3 Tables

Table 3-1 Study 3 Psychopathic Personality Inventory-Revised covariance matrix

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Total score	*m*	**287.40**										
	s^2	*1131.09*										
2. Self-Centered Impulsivity	*r*	.77**	**145.43**									
	cov	529.56	*419.93*									
3. Fearless Dominance	*r*	.71**	.13	**111.76**								
	cov	442.69	50.46	*347.95*								
4. Coldheartedness	*r*	.63**	.39**	.32**	**30.21**							
	cov	158.85	59.16	44.27	*55.41*							
5. Machiavellian Egocentricity	*r*	.62**	.76**	.07	.51**	**44.25**						
	cov	176.00	132.40	11.34	32.25	*71.43*						
6. Rebellious Nonconformity	*r*	.77**	.70**	.52**	.23*	.39**	**33.79**					
	cov	197.42	109.89	74.25	13.29	24.88	*58.31*					
7. Carefree Nonplanfulness	*r*	.47**	.69**	-.04	.34**	.39**	.33**	**36.61**				
	cov	115.39	103.01	-5.76	18.14	23.83	18.08	*52.67*				
8. Blame Externalization	*r*	.18**	.54**	-.23*	-.09	.22	.17	.17	**30.78**			
	cov	40.75	74.63	-29.36	-4.52	12.27	8.62	8.45	*45.29*			
9. Fearlessness	*r*	.68**	.39**	.70**	.25*	.19	.56**	.25*	.03	**34.52**		
	cov	205.70	71.14	117.79	16.77	14.74	38.30	16.14	1.95	*80.76*		
10. Stress Immunity	*r*	.38**	-.19	.77**	.33**	-.12	.19	-.19	-.42**	.30**	**31.35**	
	cov	96.89	-28.45	106.83	18.52	-7.85	10.76	-10.43	-20.93	20.39	*56.00*	
11. Social Influence	*r*	.48**	.04	.76**	.14	.06	.38**	-.18	-.18	.21	.47**	**45.90**
	cov	140.10	7.78	123.34	8.99	4.45	25.19	-11.48	-10.38	16.65	30.44	*76.25*

Note: *N* = 77; bolded and italicized values within cells on the diagonal are mean and variance (respectively) for the given scale; *cov* = covariance; *r* = Pearson correlation coefficient; *m* = mean; s^2 = variance
** *p* ≤ .01 (2-tailed).
* *p* ≤ .05 (2-tailed).

Table 3-2 **Study 3 test battery questionnaires**

	n	***Mean***	***Standard Deviation***
Behavioral Activation System (*BAS*)	73	41.5959	4.85245
Behavioral Inhibition System (*BIS*)	73	21.0411	3.48329
Barratt Impulsiveness Scale 11a total (prorated)	73	67.3834	11.30556
Childhood Abuse and Trauma Scale (*CAT*)	40	62.7534	15.55320
Positive Affect[1]	72	29.6389	8.17813
Negative Affect[1]	72	22.6111	7.99746
Beck Depression Inventory-II	68	14.5294	8.28678

[1] Positive Affect Negative Affect Schedule (PANAS; timeframe = *in the last week*)

Table 3-3 **Study 3 median reaction times (ms) by set-size and target emotion**

	Angry			**Fearful**			**Happy**		
Stimuli	***M***	***s***	***ΔRT***	***M***	***s***	***ΔRT***	***M***	***s***	***ΔRT***
Male Targets									
Search slope	26.0	50.2		20.2	57.6		17.2	47.1	
Set-size									
4	1481.4	241.5	-	1440.6	271.8	-	1346.5	271.2	-
6	1569.6	294.7	88.2	1538.5	268.4	97.9	1374.1	220.7	27.7
8	1608.2	282.2	38.6	1499.4	296.0	-39.2	1434.9	250.3	60.7
10	1643.0	260.8	34.7	1585.5	323.9	86.1	1444.5	240.4	9.7
Female Targets									
Search slope	39.1	52.8		42.4	50.6		32.4	44.2	
Set-size									
4	1538.3	261.3	-	1412.1	262.5	-	1281.7	238.2	-
6	1669.8	281.0	131.6	1599.3	282.6	187.1	1322.6	229.9	40.9
8	1740.1	363.9	70.3	1638.9	262.6	39.7	1382.6	249.6	60.0
10	1779.7	320.3	39.5	1688.2	322.0	49.2	1484.0	297.2	101.4

Note: *M* = mean; *s* = standard deviation; *ΔRT*= change in reaction time from previous set-size to current set-size

3.6. Study 3 Figures

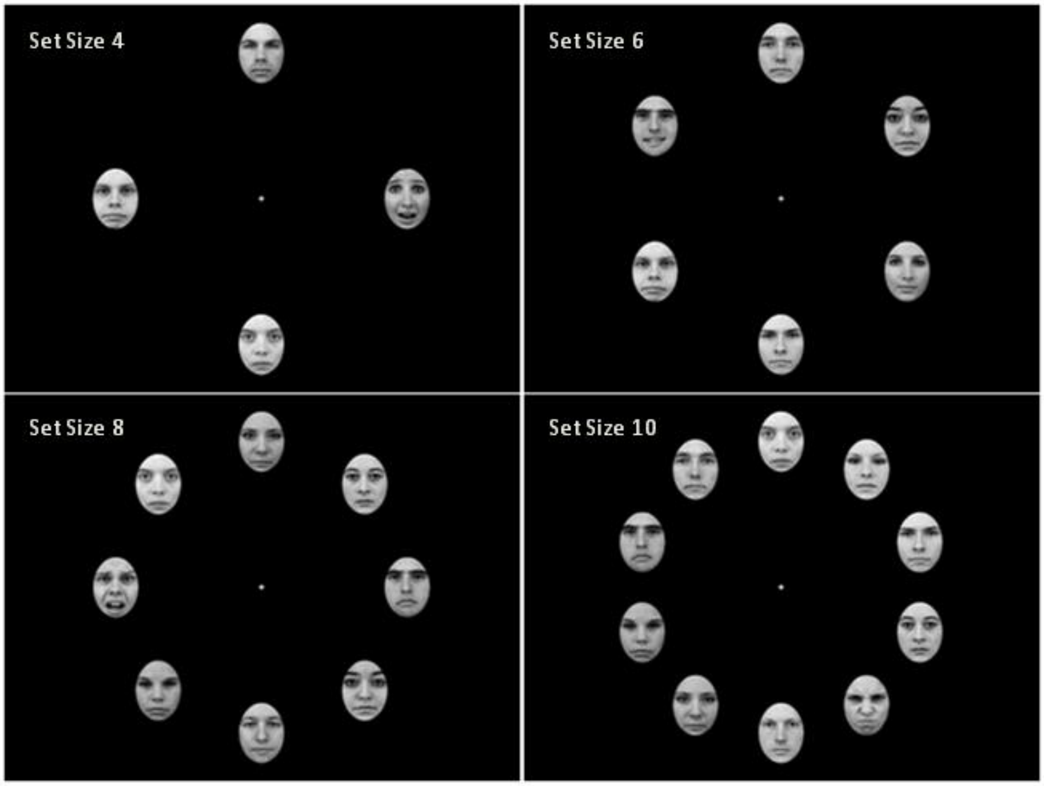

Figure 3-1 Study 3 stimulus displays at each set size.

Chapter 4.

General Discussion and Future Directions.

Throughout this dissertation two major themes have been repeated. The first of these themes relates to the characterization of attention in psychopathic personality. Specifically, it is the question of whether visual-spatial attention abnormalities are associated with psychopathic traits, and if so, how such abnormalities interact with or even produce poor emotion recognition and blunted affective response. Influential models such as the response modulation theory have proposed that selective attention (feature-based and/or spatial) is enhanced in high psychopathy, limiting the access of peripherally presented information to higher-order processing if it is incongruent with immediate goals (Glass & Newman, 2006; Hiatt et al., 2004; Zeier et al., 2009; Zeier & Newman, 2013). Results from this investigation partially supported this theoretical account, but also offered new insights into the specific mechanisms underlying these attention effects.

The second theme relates to the broader relationship of affect with visual-spatial attention. An extensive body of research has demonstrated that emotionally relevant stimuli weigh heavily in visual cortical systems of the normally functioning brain (Carretié, 2014; Pourtois, Schettino, & Vuilleumier, 2013). This may reflect online parallel/reentrant contributions from subcortical networks, or global tuning of associative cortex receptive fields to well-learned and relevant stimuli. Regardless, affective-related moderations of cortically mediated ERP activity arise within 200 ms after stimulus onset, even when controlling for low-level effects such as luminance (Schettino, Keil, Porcu, & Müller, 2016). These effects are somewhat dependent on presentation of emotional stimuli at spatially attended locations (Holmes et al., 2003). They can occur even when access to foveally presented emotional stimuli is limited by forcing orientation away from centrally presented faces with a challenging peripheral item discrimination task (Eimer, Holms, & McGlone, 2003; Holmes et al., 2006), by rapidly masking emotionally expressive faces with neutral ones (Eimer, Kiss, & Holmes, 2008), or by presenting affective images for short durations (Schupp, Junghöfer, Weike, & Hamm, 2004), though these effects are largely dependent on conscious registration of stimuli. Independent of psychopathic personality related analyses, results from this study concur with the notion that these rapid emotional processing effects are spatially gated, rather than spatially guiding. These two themes are further explored in the following sections, and summaries of this project's critical conclusions, remaining questions, and implications for future research are proposed.

4.1. What visual-spatial abnormalities characterize psychopathic personality, and how do they relate to emotion recognition and affective response deficits?

Within the response modulation theory, inattentiveness to peripheral stimuli has largely been presumed to reflect target over selection due to enhanced spatial or feature-based selective attention (Glass & Newman, 2006; Hiatt et al., 2004; Zeier et al., 2009; Zeier & Newman, 2013). However the visual search studies in Chapter 1 task 1, Chapter 2, and Chapter 3 indicated that psychopathic traits were unassociated with ERP markers of salience attribution to, or spatial selection of task-relevant targets, regardless of their complexity and emotional relevance (i.e. target Ppc and N2pc for both shapes and faces). However, whereas psychopathic traits were unassociated with later stage cognitive/working memory discrimination for simple targets in Chapter 1 (CDA for shapes), they were negatively associated with this process for faces in Chapter 2. This raises the question of whether psychopathy is characterized by reduced affective response (i.e. absence of the privileged processing typically seen for affective stimuli), or a more generalized reduced ability to represent complex stimuli. This is an ongoing problem within the field of affective neuroscience; at what point does cognitive complexity equate with emotional salience? Although additional careful empirical investigation is probably needed to answer this question, a meaningful philosophical discussion of how the field should demarcate the concepts of affective relevance, perceptual complexity, and semantic information will likely prove equally, if not more, important.

Additionally in task 2 of Chapter 1, when required to constrict visual-spatial attention to a narrow location, psychopathic personality was actually associated with increased attribution of salience to simple peripherally presented distractors (Ppc amplitude). This finding discounts the notion that psychopathy can be characterized exclusively by spatial or feature-set attention enhancements. However, this early hyper responsiveness to external stimuli was met with a later ERP response at discriminatory stages (positive CDA amplitude). This later response was interpreted as representing suppression of those stimuli, given its similarity to earlier spatial suppression mechanisms observed in previous visual search studies (e.g. Fortier-Gauthier et al., 2012; Gaspar et al., 2016). It was further interpreted as a habitual compensatory hyper reaction to earlier salience; strength of the earlier effect mediated the association of psychopathic traits with the latter. Perhaps then, psychopathy can be characterized as a condition of reactive sensory gating; a condition in which the access of task irrelevant stimulation to higher-order cognition is controlled *post hoc* rather than *a priori*. Sustained focus in psychopathic personality is lackadaisical and laissez-faire, as opposed to deliberate and vigilant. It remains to be seen is whether this pattern of response is reproduced when peripherally presented distractors are complex stimuli. If so the roles of stimulus complexity and affective relevance should also be examined.

4.1.1. Summary of conclusions regarding psychopathy and visual-spatial attention

1. Psychopathic personality is unrelated to deliberate spatial selection of task relevant items (target N2pc), regardless of their complexity/emotional relevance.

2. It is also unrelated to salience attributions for target stimuli (Target Ppc).

3. However, psychopathic personality involves a selective abnormality in the allocation of cognitive resources to emotional stimuli, or perhaps all complex targets (i.e. weaker visual working memory representation if those items).

4. Finally, for peripheral distractors, psychopathic traits predict heightened salience attribution (Ppc), subsequently necessitating greater suppression of those items within visual-spatial working memory.

4.1.2. Remaining questions, recommendations, and future studies

Conclusions 3 and 4 raise the question of what would happen for spatially separated emotional distractors. Behavioral evidence with non-emotional stimuli suggests spatially separated distractors cause less interference in high psychopathy (Hiatt et al., 2004; Zeier et al., 2009). Future studies could test whether this extends to peripheral distractors that are complex and emotional (e.g. faces), or complex but non-emotional (e.g. houses)?

4.2. *Spatialgate*: affective response is spatially gated, not spatially guiding

Together, the results presented in Chapter 2 and Chapter 3 provide further evidence that affective value does not predict the efficiency of rapid visual-spatial reorienting to stimuli. ERP and behavioral measures of emotional face target selection efficiency (search slope, and N2pc latency), strength (N2pc amplitude), and salience attribution (Ppc amplitude) were strongest or most reliable for happy faces relative to angry or fearful faces. This is contrary to threat advantage (Eimer & Kiss, 2007; Feldmann-Wüstefeld et al., 2011; Hansen & Hansen, 1988; Öhman et al., 2001) and arousal (Lundqvist et al., 2014) models of visual-spatial attention capture. But as stated earlier, this does not downplay the importance of affect to the cognitive and sensory processes that collectively make up attention. In a study that found global scene properties such as depth and navigability cannot be used as visual-spatial attention guiding features, Greene and Wolfe (2011) noted that previous research has demonstrated that these properties can still be *inferred* rapidly with only a brief glance at an image. For complex scenes, this highlights the separation of visual-spatial orienting versus visual object identification. These two processes are broadly encompassed within the concept of attention, but ultimately are handled by very different neural pathways. This same orienting versus identification dissociation likely applies to emotional stimuli.

There is substantial ERP evidence that the affective value of items is rapidly extracted. Even for presentations as brief as 120 ms, EPN and LPP components evoked by affective images are dissociable from those evoked by neutral images (Schupp et al., 2004). Additionally, for faces presented for only 17 or 50 ms before being backward-masked by a neutral expression, fearful expressions modulate an early (i.e. 150 ms after stimulus onset) face-specific fronto-polar positive amplitude component (Eimer et al., 2008). Notably this effect is dependent on reported conscious perception of an emotional face (Eimer et al., 2008). ERP evidence of rapid emotional object identification is contrasted with clear evidence that visual-spatial attention gates emotional responding. Holmes, Vuilleumier, and Eimer (2003) conducted a study in which participants viewed arrays composed of two faces and two houses surrounding a fixation point. An exogenous cue preceded each trial and indicated where to direct spatial attention. When houses rather than faces appeared at the attended locations, amplitude of the N170 component was reduced, and the subsequent fronto-polar positivity was undifferentiated for fearful versus neural expressions. In another study, Holmes, Kiss, and Eimer (2006) presented faces at fovea, flanked bilaterally by a pair of lines of varying lengths. Participant either identified repetitions of line pairs or repetitions of faces from previous trials. When responding to faces, those with emotional expression elicited an enhanced fronto-polar positivity 160 ms after onset, which was sustained for an additional 600 ms. In contrast, when responding to the line pair, significant emotional modulations were seen only from 160 to 220 ms, indicating that structural coding responses rapidly reflected the emotional value of the task-irrelevant faces that were presented at the point of initial fixation, but reorienting to the periphery gated higher-order processing of that information. Thus the neural architecture receptive to the evaluation of highly affective stimuli is rapidly and dramatically engaged, but, its engagement is constrained to the location of spatial focus. This is likely the same dorsal-occipital visual orienting mechanism that, for non-emotional stimuli, at attended locations amplifies ventral-occipital processing of targets, and at unattended spatial locations within or even between sensory modalities blocks projection of task-irrelevant information to higher-order processing (Foxe & Snyder, 2011; Jensen & Mazaheri, 2010; Woldorff et al., 2002).

As discussed in Chapter 2, I propose that normative and subjective ratings of valence and arousal, and discrete categorical emotion labels applied to affective stimuli are predictive of those stimuli’s capacity to guide visual-spatial attention only to the extent that they represent commonly reoccurring guiding feature configurations that are associated in time with motivationally relevant outcomes (e.g. angry faces are a commonly reoccurring configuration of features that communicate social disapproval or threat). Furthermore, it is possible that the experience of having spatial attention forcibly modulated by a highly salient stimulus feature[10], causes affective fluctuations, resulting in attribution of emotional relevance to such items beyond their semantic or associatively-acquired value. *Affective* is not a stimulus feature that *guides* visual-spatial attention; instead, the rapid processing of emotionally evocative stimuli can be tempered by reorienting focus from such objects. *Affective* is therefore a stimulus feature that is *gated* by visual-spatial attention.

Notably, given the efficiency with which affectively relevant stimuli are processed (Carretié, 2014; Pourtois et al., 2013) it is logical that they have the capacity to override the constraints imposed by visual-spatial gating. Task-irrelevant and unattended stimuli that have high normative affect ratings, are of high relevance to clinical symptoms, or are simply over learned have an almost unquestionable capacity to disrupt target-focused attention during Stroop-like and other distractor interference tasks (Carretié, 2014; Grupe & Nitschke, 2013; Liotti et al., 2007; Liotti, Woldorff, Perez III, & Mayberg, 2000; Taake, Jaspers-Fayer, & Liotti, 2009). Should this occur, emotional stimuli subsequently seem to trigger further downstream modulation of spatial constraint mechanisms, possibly through frontally or subcortically mediated reentry to earlier points in the dorsal attention stream. Functionally, the result is enhanced P1 ERP response and faster behavioral reaction to probes appearing at locations previously occupied by emotional stimuli (Santesso et al., 2008). In this regard, even though emotional salience may appear to modulate spatial attention, the term ‘capture’ is something of a misnomer; emotional stimuli do not capture visual-spatial attention so much as supersede its constraints.

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[10] Some examples of such stimuli might include: an abrupt onset movement, like that of a darting spider or snake; a high contrast flash of light, such as a lighting strike; an extraordinarily loud abrupt sound, like a crashing tree; or a sharp pain, such as stepping on a piece of glass or being struck from behind. This idea that non-associative (i.e. innate or truly unlearned) affective value (aversive high-arousal in particular) is defined by the capacity to capture spatial attention is almost taken as granted for non-visual sensation. Extending this thought experiment from high-arousal aversive stimuli, perhaps appetitive awe inspiring stimuli, such as a sweeping vista, derive non-associative affective value from the capacity to trigger global sensory-motor decoupling akin to the mechanisms of mind wandering described by Kam and Handy (2013).

4.2.1. Summary of conclusions relating to affect and visual-spatial attention

1. *Affective* is not a stimulus feature that *guides* visual-spatial attention. This was indicated by incongruence of ERP and behavioral measures of target salience attribution (Ppc), of target selection (N2pc), or of search efficiency (search slope) with predictions based on the normative arousal ratings or threat classifications of the face stimuli.

2. *Affective* is instead a stimulus feature that is *gated* by visual-spatial attention. This was indicated by the absence of significant P1 and N170 modulations prior to spatial orientation toward target emotional faces.

4.2.2. Remaining questions, recommendations, and future studies

The variability of behavioral and ERP effects evoked by different emotional expression categories in this and other studies highlights the difficulty of interpreting or predicting which stimuli will “capture” spatial attention, or the exact features that can/will be used to guide spatial attention. In addition to thoughtful discussion regarding definitional issue within the affective neuroscience community, two recommendations should be considered. First, future high caliber methodological work should investigate the factors that drive attention orientating to faces, determine the factors that influence subjective affect ratings for attended faces, and distill the results of investigations that have already been conducted. Second, research examining visual search for affective stimuli should assess participant search strategies using open ended, qualitative questions. Such introspective responses will likely provide valuable insight regarding the mechanisms at play.

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Appendix A.

Demographics and Medical Questionnaire

- What is your date of birth? ________________________(DD/MM/YY)
- What is your age? _____________
- What is your gender? ____________
- What is your major (if known)? ___________
- Years of post-secondary education? __________
- GPA? _____________
- Were you born in Canada? Yes / No
    - If 'No' what is your country of origin? _____________
- Is English your first language? Yes / No
    - If 'No' for how many years have you spoken English fluently? ___________
- What is your dominant hand (the hand that your write with)? Left / Right
- Are you wearing glasses or contacts? Yes / No
- Is your vision normal or corrected to normal with glasses/ contacts? Yes / No
- Are you color-blind? Yes / No
- Have you been diagnosed by a mental health professional and/or treated for any of the following:
    - Depression Yes No
    - Anxiety Yes No
    - Attention-Deficit Disorder Yes No
    - Thought Disorder Yes No
    - Other (specify): ____
- Have you ever seen a neurologist or been to an emergency room for:
    - Loss of motor or sensory function Yes No

Loss of consciousness	Yes	No
Head concussion	Yes	No
Sleep disorder	Yes	No
Migraines	Yes	No
CT scan, MRI scan or Electroencephalogram	Yes	No

- Have you been told you have a learning disorder or disability, such as dyslexia (i.e. a reading disorder)? Yes / No
    - If Yes, please explain:____
- Do you have a serious medical condition? Yes / No
    - If Yes, please explain:____
- Are you currently taking any prescription medication? Yes / No
    - If Yes, please explain:____
- Do you use non-prescription drugs (optional) Yes/No
    - If Yes, please explain (optional):____
- Which/how many alcoholic beverages do you typically have in a week: ____________________
- How many hours do you typically sleep? ___________
- How many hours did you sleep last night? __________

Appendix B.

Test Battery Measures: Descriptions and Procedure

Participants in the EEG studies presented in chapters 1 and 2 completed the following test battery of personality and temperament questionnaires in the order presented below. After completing the demographics and medical questionnaire (Appendix A), these participants began the Psychopathic Personality Inventory-Revised (PPI-R) while the EEG cap and electrodes were applied. Participants proceeded through each questionnaire as they were completed, until the EEG equipment was applied and the computerized tasks were ready to begin. Any remaining questionnaires were completed following the EEG task. However, participants were unable to begin the Childhood Abuse and Trauma Scale (CAT), Positive and Negative Affect Schedule (PANAS), and Beck Depression Inventory-Second Edition (BDI-II) measures until after they had completed the computerized tasks so as to avoid the potential of emotional induction due to rumination on negative material. Additionally, the CATS was only administered to participants whose age could be confirmed as 19-years or older with a valid piece of government issued photo identification, given the potential implication of sexual abuse disclosure by a minor triggering the legal reporting requirement. Finally, before completing the participant debriefing at the end of each session, the researcher reviewed the response to BDI-II item 9 *Suicidal Thoughts or Wishes*. For any participant indicating a response of 2 or greater (*"I would like to kill myself*"), the researcher gently inquired about social and professional supports, and provided contact information for the university's health and counseling center and suicide hotline during debriefing.

Test battery administration for the behavioral study presented in chapter 3 followed the same procedure as described above, however only the PPI-R, Behavioral Activation System/Behavioral Inhibition System (BIS/BAS), Barratt Impulsivity Scale Version 11a (BI-11a), CATS, PANAS, and BDI-II were incorporated. The PPI-R, BIS/BAS, and BI-11a were completed by the participant prior to beginning the cognitive task, whereas the CATS, PANAS and BDI-II were completed afterward.

Mean participant response proration was used to address missing items. Proration within each measure followed author recommendations provided in score instructions regarding the acceptable number of missing items, and whether mean scores should be calculated within subscales, or across the entire measure. Subject total and subscale scores were calculated as *unit-weighted composites* (i.e. all items within any given test were summed equally).

Psychopathic Personality Inventory-Revised (PPI-R; Lilienfeld & Widows, 2005).

The Psychopathic Personality Inventory (PPI; Lilienfeld & Andrews, 1996), and its 154-item revised version (PPI-R; Lilienfeld & Windows, 2005), are self-report measures designed to assess psychopathic traits across broad, normative samples, without the need for time intensive—and in many cases, unavailable—institutional file reviews, or personal and collateral interviews. Participants respond to items describing different personality characteristics by indicating how false or true they are as a description of themselves using a 4-point Likert-type scale with anchors of *False, Mostly False, Mostly True,* and *True*.

The PPI was constructed from self-report items designed to capture the core personality features posited in the earliest conceptualizations of psychopathy, without overtly assessing antisocial behavior or criminality (Lilienfeld & Andrews, 1996; Smith, Edens, & Vaughn, 2011). Through three successive studies using exploratory factor analysis (EFA) on undergraduate student responses, Lilienfeld and colleagues selected 187 items that loaded onto eight distinct subscales , each of which captured a unique personality dimension: *Social Influence* (ability to influence others), *Fearlessness* (lack of concern or anticipatory anxiety over physical risk-taking), *Stress Immunity* (little anxiety or panic in challenging situations), *Machiavellian Egocentricity* (ruthlessness; willingness to manipulate other personal gain), *Rebellious Nonconformity* (rejection of authority and conventions), *Blame Externalization* (failure to accept responsibility), *Carefree Nonplanfulness* (little concern for future consequences), and *Coldheartedness* (callous lack of empathy). Thus, in its original form the PPI provides a total score reflecting global psychopathy, as well as eight subscale scores reflecting lower-order facets. A large body of research has demonstrated the validity and utility of the PPI across a diverse range of samples. Scores on the PPI correlate with scores on other self-report measures of psychopathy, and the well-established Psychopathy Checklist-Revised (PCL-R; Hare 1991/2003) which is the current gold standard for interview-based assessment of the condition (Poythress, Edens, & Lilienfeld, 1998). The PPI shows good convergent and discriminant validity with external criterion measures (Kastner et al., 2012; Ray et al., 2011), and PPI total score and subscale scores have shown good or excellent internal consistency and reliability across multiple studies (Lilienfeld & Andrews, 1996; Lilienfeld et al., 2006; Poythress et al., 1998).

The PPI has received criticism for its overall length, reading level, and in some cases culturally specific or outdated content. Unexpected positive, negative, or absent subscales intercorrelations suggest the possibility of substantial heterogeneity to the lower-order components of the measure (Smith et al., 2011). Some have argued that the PPI’s failure to assess a classic, unitary personality syndrome, reflects a shortcoming, but others have proposed that it simply measures psychopathy as a compound trait of otherwise unrelated facets (Lilienfeld & Widows, 2005). Most controversial however have been the attempts to establish a higher-order factor structure within the PPI analogous to factor-analytically derived solutions that have loaded PCL-R items onto Affective-Interpersonal, and Impulsive-Antisocial domains in many studies (Hare, 2003).

Although the theoretical development and factor analytic refinement of the PPI was not guided by an explicit attempt to incorporate a higher-order factor structure across subscales, Benning and colleagues (2003) proposed a two-factor model based on principle component analysis of subscale scores that has received extensive examination. In this model, PPI-I, or *Fearless Dominance* (FD), captures emotional and interpersonal aspects of the condition, and consists of Social Influence, Fearlessness, and Stress Immunity. PPI-II, or *Self-Centered Impulsivity* (SCI), incorporates impulsive and irresponsible lifestyle components, and consists of the Machiavellian Egocentricity, Rebellious Nonconformity, Blame Externalization, and Carefree Nonplanfulness subscales. The Coldheartedness subscale however fails to load onto either factor

(Benning et al., 2003). The model's external validity has been supported by studies demonstrating preferential correlates between the two factors and external measures of personality, behavior, and pathology. FD is negatively associated with negative emotionality, shyness, and avoidance, whereas SCI is positively associated with negative emotionality and strongly associated with aggression, criminal behavior, disconstraint, juvenile conduct problems, and substance use (Kastner et al., 2012). A meta-analysis found that across 25 studies FD is positively and negatively associated with Positive Emotionality and Negative Emotionality respectively, whereas SCI is positively associated with Negative Emotionality only (Marcus et al., 2013).

Based on these findings, the two-factor PPI measurement model has clear utility vis-à-vis its relationship to the wider psychopathy nomological network. However, Benning and colleagues (2003) noted that the failure of Coldheartedness to load on a factor, and large cross-loadings of several subscales on multiple factors may indicate problems with their model. Researchers have also questioned whether the factor structure adequately captures the critical affective deficits of psychopathy, particularly lack of empathy (Benning, Patrick, Blonigen, Hicks, & Iacono, 2005). Finally, several studies have been unable to replicate this two-factor model using confirmatory factor analysis (CFA), and new EFAs have produced substantially different models, several of which have better fit when using three factors rather than two factors (Neumann, Malterer, & Newman, 2008).

Revisions and Screening Versions

The updated 154-item Psychopathic Personality Inventory—Revised (PPI-R; Lilienfeld & Widows, 2005) addressed many of the issues found in the PPI by lowering the reading level, reducing the length, rewording culturally specific content, and removing psychometrically unsound items. The revised measure yields a total score, eight subscale scores, and specifically incorporates FD and SCI higher-order factor scores within its manual. Like its precursor, the PPI-R has good reliability and external validity. In a Dutch community sample, PPI-R total and factor scores showed excellent internal consistency (Uzieblo et al., 2010). They also demonstrated good discriminate, convergent, and external validity, correlating as anticipated with subscales of other self-report psychopathy measures, and with external criterion measures of empathy, anxiety, and aggression. In a psychiatric inpatient sample, FD and SCI correlated as anticipated with measures of anger, impulsivity, drug-addition, and violence risk predictions (Edens & McDermott, 2010). Finally, in a direct comparison of the PPI and the PPI-R with a residential drug treatment sample, equivalent associations with key external variables were found for the original and revised measure, suggesting that prior relationships between the PPI and criterion measures can be generalized to the PPI-R (Ray et al., 2011).

Although the revised measure has retained the external validity of the original, and the now widely used higher-order factors appear to have utility, the internal structure of the two-factor measurement model has continued to be problematic for the PPI-R. Confirmatory factor analyses of the PPI-R have failed to support the two-factor structure in multiple studies, and several PPI-R subscales show cross-loadings on both factors (Edens & McDermott, 2010; Uzieblo et al., 2010). This has led to questions regarding the soundness of the two-factor model within the PPI-R. Though the factors may be useful due to their patterns of associations with relevant concepts, they may require revision to do so in the most efficient way.

Triarchic Psychopathy Measure (TriPM; Patrick, 2010)

The TriPM is a 58-item self-report scale designed to operationalize psychopathic personality within the framework of the triarchic model of psychopathy proposed by Patrick, Fowles, and Krueger (2009). The triarchic model draws on historical descriptions, accounts, and assessments of psychopathic personality. It was put forward to reconcile several contentious and longstanding debates within the research community regarding the condition’s conceptualization and measurement. In particular, it addresses questions regarding: psychopathy as dimensional versus typological in nature, and as a unitary syndrome or compound variable (what Lilienfeld has referred to as a “condition of interpersonal impact”; Lilienfeld, 2013, p. 86); the condition’s complex relationship with anxiety; incorporation of adaptive versus maladaptive features; instances of “successful psychopathy”; and whether criminality should be considered one of psychopathy’s defining features or one of its potential consequence (see Patrick & Drislane, 2015).

To these ends, the triarchic model conceptualizes psychopathy as the covariance of three distinct, observable, dimensional-traits (Patrick, 2010; Patrick & Drislane, 2015; Patrick et al., 2009). *Disinhibition* captures traditional externalizing tendencies toward impulsivity, poor restraint, poor emotion regulation, and aggressive hostility. *Meanness* captures callousness, lack of empathy, contempt for others, lack of close attachments, predatory exploitativeness, rebelliousness/oppositional temperament, and empowerment through destruction and cruelty. Finally, *Boldness* captures the nexus of high confidence, fearlessness, social dominance, calmness under threat, resilience following stress, and tolerance of uncertainty. Patrick and Drislane (2015) note that the triarchic model is simply a conceptual framework, which can be operationalized through the development of novel questionnaires or through the refinement of existing tools. Indeed, studies have created triarchic framework measures by adapting items of the PPI (e.g. Hall et al., 2014), Youth Psychopathic Traits Inventory (e.g. Drislane et al., 2015), and Minnesota Multiphasic Personality Inventory–2–Restructured Form (Sellbom et al., 2016). However, the vast majority of research examining the empirical utility of the model has been conducted using the 58-item TriPM.

Each item of the TriPM is a self-descriptive statement. Participants indicate how well these statements apply to themselves using a 4-point Likert-type scale with anchors of *True, Somewhat True, Somewhat False,* and *False.* In line with Patrick and colleagues' (2009) framework, item responses are composited into three distinct subscales corresponding to Disinhibition (20 items), Meanness (19 items), and Boldness (19 items). Subscale scores can be composited in turn to produce a total triarchic psychopathy score.

Items included on the Disinhibition and Meanness subscales were derived through factor analysis of the 23 subscales of the 415-item Externalizing Spectrum Inventory (ESI; Krueger, Markon, Patrick, Benning, & Kramer, 2007). TriPM Disinhibition items were taken from 9 ESI subscales that loaded most heavily onto a general externalizing subfactor, whereas TriPM Meanness items were taken from 6 ESI subscales with larger factor loadings on a callous aggression subfactor than the general externalizing subfactor. However, TriPM Boldness items were selected from an interim boldness inventory originally intended to refine the *Fearless Dominance* facet of the PPI-

R (described above). A strong correlation between TriPM and PCL-R total scores has been observed in a male prisoner sample (Patrick, 2010). Additionally, in that same sample, TriPM subscale scores were differentially predictive of PCL-R facet scores: Boldness was associated with the Interpersonal PCL-R facet, Meanness with the Affective PCL-R facet, and Disinhibition with the Lifestyle and Antisocial PCL-R facets. In a mixed-gender college sample, TriPM total score has also been shown to correlate strongly with five other commonly used psychopathic personality self-report measures, including the PPI. Taken together, these results suggest that the TriPM has good construct validity, converging as anticipated with other measures of psychopathy.

Behavioral Activation System/Behavioral Inhibition System (BIS/BAS; Carver & White, 1994).

The BIS/BAS is a 20-item scale refined through factor analyses to operationalize two distinct behavioral and affective response motivating systems. The aversive-oriented *Behavioral Inhibition System* (BIS) is sensitive to punishments, and inhibits behaviors that could result in painful experiences. In contrast, the appetitive-oriented *Behavioral Activation System* (BAS) is sensitive to reward, and associated with positive affective experience and goal directed behavior. Participants respond to statements that reflect the conceptual functioning of these two systems using a 4-point, Likert-type scale, ranging from 1 (strong agreement) to 4 (strong disagreement), with no neutral response option.

Measurement of the BIS is unidimensional within the BIS/BAS scale, with it is composited along a single subscale consisting of 7 items that assess how participants react in anticipation of punishment. BIS score is associated with the experience of negative affect, and nervousness in anticipation of painful punishments. Three distinct BAS-related subscales are assessed within the BOS/BAS: *Drive* (4-items) measures generalized goal-directed behavior; *Fun Seeking* (4-items) measures desire for novel rewards and willingness to spontaneously approach potentially rewarding situations; and finally *Reward Responsiveness* (5-items) measures positive affective response to both rewards and the anticipation of rewards (Carver & White, 1994).

Barratt Impulsiveness Scale Version 11a (BI-11a; Barratt, 1994; Patton, Stanford, & Barratt, 1995).

The BI-11a is a 24-item beta version of the standard 30-item *Barratt Impulsiveness Scale, Version 11*. Items describe ways that one might act and think, and participants rate how often they engage in each behavior using a 4 point Likert-type scale with anchors of *Rarely/Never, Occasionally, Often,* and *Almost Always/Always.*

Both the standard and beta versions of the questionnaire assess impulsivity across three domains, each represented by a subscale derived through exploratory factor analyses. Within the BI-11a, *impulsive-nonplanning* (10-items) assesses careful planning and thinking about the future, as well as enjoyment of challenging mental tasks. *Attentional-impulsiveness* (5-items) measures experience of racing/intrusive thoughts, and ability to focus on the task at hand. Finally, *motor-impulsiveness* (9-items) captures spontaneous behavioral tendencies and lifestyle consistency. The measure can be assessed across each subscale, and as a total score. Alternatively, each subscale can be broken down further into two first-order factors. To maintain consistency with other longitudinal studies conducted in our lab, the beta version BI-11a was used. However, scores presented here were prorated to match standard 30-item BI-11 scores using a technique offered by Dr. Marijn Lijffijt (available online at http://www.impulsivity.org/pdf/BIS-11Aprioration.pdf). Although there is limited data available for the BI-11a, the BI-11 itself has been shown to have relatively high rates of internal consistency, test-retest reliability, and convergent validity with external measures (Barratt, 1994; Patton et al., 1995).

State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1983)

The STAI is a 40-item self-report scale intended to operationalize two related but logically distinct conceptualizations of anxiety. The first, *state-anxiety* is an “unpleasant *emotional state* or condition…characterized by…subjective feelings of tension, apprehension, nervousness, and worry, and by activation of arousal of the autonomic nervous system” (Spielberger et al., 1983, p.1). The second, *trait-anxiety* is a relatively stable tendency toward anxiety-proneness that varies across individuals as a personality trait. This state- versus trait distinction was first highlighted by Cattell (1966) and Spielberger (1966). Whereas state-anxiety is as a transitory emotional experience taken at a temporal cross-section in a person's stream of life, trait-anxiety is an enduring pattern in the way that one perceives, reacts, and behaves to the world (Spielberger et al., 1983).

State- and trait-anxiety are assessed within the STAI by compositing items along two 20-item subscales. *STAI-State* captures current nervousness, tension, and anxiousness (*i.e.* anxiety as a transitory subjective affective state), whereas *STAI-Trait* measures relatively stable tendencies to respond with anxiousness toward perceived threats. Each STAI item is a self-descriptive statement regarding the experience of anxiousness and worry framed in terms of *"right now, at this moment"* for STAI-State or *"generally"* for *STAI-Trait*. Participants respond using a 4-point Likert-type scale with anchors of *Not At All, Somewhat, Moderately So,* and *Very Much So.* The scale has well established psychometric properties and is a leading measure of anxiety (Spielberger et al., 1983).

Toronto Alexithymia Scale-20 (TAS-20; Bagby, Parker, & Taylor, 1994; Bagby, Taylor, & Parker, 1994)

Alexithymia is persistent, stable trait, characterized by a disconnect between the production and recognition of affect response. The term was first employed by (Sifneos, 1973) to describe individuals "without words for emotions." They typically display difficulties identifying feelings and describing their affective state to others, externally-oriented though, limited introspective capacity, and impoverished fantasy and imagination (Lumley, Neely, & Burger, 2007).

While several structured professional judgment, and self-report methods have been developed for the assessment of alexithymia, those in the Toronto Alexithymia Scale family of measures are perhaps the best validated, and have received the most attention from the research and clinical communities. The original Toronto Alexithymia Scale (TAS-26; Taylor, Ryan, & Bagby, 1985) is a 26-item self-report measure designed to capture the core facets of alexithymia. Items consist of both positively and negatively phrased descriptions of alexithymic features, and participants rate the degree to which these items are true of themselves using a 5-point Likert scale. Taxonic cutoffs can be employed to diagnose alexithymia, but scores are often assessed in a dimensional fashion in both clinical and research settings (e.g. Luminet, Bagby, Wagner, Taylor, & Parker, 1999; Lumley et al., 2007). Factor analysis of the TAS-26 has shown that items load onto four distinct factors that relate to the key domains of alexithymic symptoms—(DIF) difficulties identifying emotions and distinguishing them from bodily sensations; (DCF) difficulty communication feelings; (RD) reduced daydreaming; and (EOT) externally-oriented thinking (Taylor et al., 1985).

The TAS-26 has a stronger empirical basis than earlier measures of alexithymia, and can be used to reliably assess the condition in clinical populations (Taylor et al., 1985). However, to address certain psychometric shortcomings, particularly cross loading of items on various factors, and unanticipated correlations between factors, a revised 20-item version of the scale has also been developed (TAS-20; Bagby, Parker, & Taylor, 1994). The TAS-20 shows good internal consistency (Cronbach's $\alpha = 0.81$), test re-test reliability ($r = 0.77$ after 2 weeks), and convergent and concurrent validity (Bagby, Parker, et al., 1994; Bagby, Taylor, & Parker, 1994). The revised measure features three factors similar to that of the original TAS-26, but in this sense it too has drawn criticism. During revision of the TAS-26, all items relating to the reduced daydreaming (RD) factor were dropped due to inconsistent factor loading (Bagby, Parker, et al., 1994). As such, while the authors of the scales maintain that the TAS-20 has improved construct validity, others have questioned it, and recommended against using total and factor scores in clinical settings (Kooiman, Spinhoven, & Trijsburg, 2002). These limitations aside, the TAS-20 remains the best validated measure of alexithymia, and is intricately linked to empirical investigations of the condition.

Childhood Abuse and Trauma Scale (CATS; Sanders & Becker-Lausen, 1995)

The CATS is a 38-item self-report measure developed to quantify the extent of physical, emotional, and sexual maltreatment as a function of a respondent's retrospective assessment of subjective stress during childhood and adolescence. Questions are mildly worded and presented in the context of a home environment questionnaire to avoid socially desirable responding. Items assess the frequency of psychological abuse, physical and sexual mistreatment, physical and psychological neglect, substance abuse, and witnessing of intimate-partner violence perpetrated by one's parents or primary caregivers. Respondents indicate frequency using a 5-point Likert-type scale with anchors of *Never, Very Rarely, Occasionally, Quite Often,* and *Very Often.* Items are composited across the full scale to produce a total maltreatment score. Additionally, some items can be composited into three factor-analytically derived subscales reflecting *negative home environment/neglect* (14 items)*, sexual abuse* (6 items)*,* and *punishment* (6 items) maltreatment dimensions.

The CATS is a revision of the earlier CATS-1991 (Sanders & Giolas, 1991), which showed high Guttman split-half reliability, and a moderate correlation with a measure of dissociation (Sanders & Becker-Lausen, 1995). The revised version addressed confusing wording and/or potential retrospective inaccuracy of four questions by revising one question, and replacing three with items specifically designed to load onto loneliness/neglect or sexual mistreatment factors. In two large college samples (N > 800) the revised measure has shown strong internal consistency and test-retest reliability across the full scale, and poor to moderate internal consistency for its subscales.

Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988).

The PANAS is a 20-item self-report measure that assesses two dominant dimensions of affective experience: *positive affect* and *negative affect*. Positive affect is characterized by feeling enthusiastic, energetic, active, and alert. High levels are associated with good concentration, pleasure, and engagement, and low levels with lethargy and sadness. In contrast, negative affect encapsulates distress and several aversive discrete emotional experiences including anger, disgust, guilt, and fear. High levels are associated with the experience of these states, whereas low levels are associated with serenity and calmness. The authors have noted that positive and negative affect are independent dimensions rather than opposite poles of a single dimension within this conceptualization. They argue that in essence positive and negative affect are respectively analogous to *extraversion* and *neuroticism* personality factors. Finally, these authors note that the dimensions are rotations of the *valence* (positive-negative) and *arousal* (high-low) dimensions in other models and assessments of affect found outside of the self-reported mood literature.

Each item of the PANAS is a single mood-descriptor. Participants rate the degree to which they have felt that way during a given timeframe (for the current study, *"during the past week"*) on a 5-point Likert-type scale with anchors of *very slightly or not at all, a little, moderately, quite a bit,* and *extremely.* Items are composited along two orthogonal 10-item subscales corresponding to positive and negative affect. Positive affect terms include *"interested," "inspired,"* and *"attentive,"* whereas negative affect terms include *"nervous," "hostile,"* and *upset."* The two subscales show good psychometric functioning, have high internal consistency, convergent and discriminant validity, and good test-retest reliability over time (Watson et al., 1988).

Beck Depression Inventory-Second Edition (BDI-II; Beck, Steer & Brown, 1996).

The BDI-II is a 21-item self-report scale that assesses severity of affective, cognitive, somatic, and vegetative depression symptoms in line with criteria for depressive disorders established in the *Diagnostic and Statistical Manual of Mental Disorders—Fourth Edition* (DSM-IV; American Psychiatric Association, 1994). Earlier iterations of the scale were designed to conform to depression criteria in earlier iterations of the DSM. Each item of the scale is representative of behaviors, thoughts, or feelings symptomatic of major depression, such as crying, loss of energy, guilt, and suicidal ideation. Participants respond to each item by selecting one of four alternative statements of increasing severity that best describes their experience of each symptom of depression over the past two week period. Each statement corresponds to a numeric value ranging from 0 to 3, with higher values indicating more extreme symptom presentation. Respondents' depression can be classified as minimal, moderate, or severe using cutoff scores derived from depressed and non-depressed psychiatric patient data using a receiver operating characteristic curve (available in the BDI-II manual; Beck et al., 1996). The scale has shown high internal consistency, as well as good test-retest reliability over a 1-week period.

Appendix C. Affect

The role that I believe *affect* plays within the mind and brain is central to my conceptualization of any cognitive or neural mechanism, so it feels remise not to fully unpack this term. As proposed by Barrett (2006a), an *emotion* (e.g. sadness, anger, love) is the contextualized, overt cognitive-appraisal of one's affective state into a discrete, semantically-defined experiential category. Affect refers to a collection of more elemental internal dimensions of experience. Although there is still debate regarding the orthogonality, psychometric utility, and real physical analogues of these dimensions, arousal (excitement; activation versus deactivation), valence (pleasantness versus unpleasantness), and motivation (approach versus avoid) have been proposed as the ongoing core sensations that drive our behavior. Affective states are communicated verbally, and through non-verbal expressions of emotion. Emotional, emotionally laden, emotionally evocative, affective, and affectively charged stimuli (etc. etc.) are those events, objects, and thoughts capable of eliciting notable fluctuations in affective experience. Typical examples include but are not limited to emotional scenes (e.g. videos or images of exciting or traumatic events happening to people), objects of "intrinsic" or "inherent" relevance/personal interest (e.g. succulent food, distinctive scents, loud unpredictable noises, pornography, dangerous items like guns, predatory animals, startling lateral movements), conditioned stimuli (both appetitive and aversive), or explicit expressions of some agent's emotional state (facial expressions, vocalization, body language, touch, written words). When exposed to an emotional stimulus, humans, non-human primates, and other social mammals experience somewhat predictable changes in internal arousal, valence, and motivation, leading to a variety of somewhat predictable behavioral responses. And, following affective stimulation, humans may engage in the post hoc "conceptual act" of emotion categorization (Barrett, 2009). Whether or not this occurs will likely depend on context, but as with other over-learned semantic habits (e.g. the classic color-word Stroop effect) the tendency to begin categorizing emotions can be somewhat prepotent. These ideas form the core of Barrett's (2006a and b, 2009) conceptual act model of emotion

The conceptual act model elaborates on the traditional James-Lang physiological account of emotion, which proposed that environmental stimuli produce affective changes leading to conscious feelings of emotion. These are communicated (or inferred) as categorized emotional words that likely mask the most intricate nuances of emotional life (see Barrett, 2009). In contrast, the common-sense or natural-kinds view of emotion holds that all humans experience and recognize a small set of discrete emotions according to rules carved into the human genome: upon experiencing an emotional stimulus, emotions happen absent of mediating processes, and trigger a suite of overt behavioral and physiological changes. This view is central to Darwin's (1872) *The Expression of Emotions in Man and Animals*, as well as Ekman and Friesen's (1971) seminal work that found behavioral evidence of moderate cross-cultural recognition of six "basic" emotional facial expressions. The idea that prototypical emotional states are universally experienced, communicated, and decode from other's expressions has acted as the guiding paradigm for most psychological and neuroscientific investigations of emotion (Barret, 2006b). However, the paradigm has been largely unable to predict or explain the research data generated in decades that followed Ekman and Friesen's work, with "basic emotion" categories serving as weak tools for conditioning affective stimuli within experimental tasks (Barrett, 2006a). The conceptual act model is similar to the two-factor theory of emotion in which conscious feeling of discrete emotions arise from the integration of independent mechanisms handling the cognitive appraisal of and bodily response to emotional stimuli (Schacter & Singer, 1962). However, Barrett's model highlights the capacity for affective reactions to produce observable changes in behavior even without explicit cognitive mediation, unifying observations of "emotional behavior" in humans and other non-human animals. Furthermore, it emphasizes the recursive relationship between affective and cognitive stages of emotion.

Memories and personality are prominent examples of psychological phenomena that were once viewed as unitary mental entities, but are now seen as emergent faculties of many related processes (Barret, 2006b). Most traditional models and metaphors of attention posit that it is a limited-resource causal agent (an entity) that determines what environmental information is given access to the brain’s higher order processes, but there is little explanatory utility to these ideas (Krauzlis, Bollimunta, Arcizet & Wang, 2014). By instead viewing attention as the perceptible byproduct of how information is represented at a cellular level within sensory and other regions (Di Lollo, Enns & Rensink, 2000; Krauzlis et al., 2014), the myriad causes of and influences on attention can actually be elucidated. Similarly, the conceptual act model has important implications for affective neuroscience investigation of emotional stimulus reactivity. If emotional experience is not a unitary process then step-by-step assessments of the cortical responses elicited by emotional stimuli may help clarify their often confusing patterns. Additionally, by distinguishing between reflexive affective-fluctuations in response to emotional stimuli and habitual cognitive assessment of emotion (prepotent categorization of one’s own internal affect and/or a stimulus’ emotional value), we can better understand the various attention capture effects thought to be indexed by heightened or involuntary emotional responses.