

Pupil reactivity to emotional faces among convicted violent offenders:

The role of psychopathic traits

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Abstract

Psychopathy is characteristically associated with impairments in recognizing others facial expressions of emotion, and there is some evidence that these difficulties are specific to the callousness features of the disorder. However, it remains unclear if these difficulties are accompanied by reductions in autonomic reactivity when viewing others emotional expressions, and whether these impairments are particular to expressions showing another's distress, or are more pervasive across different emotional expressions. In this study, 73 adult male prisoners with histories of serious sexual or violent offenses – who ranged across the psychopathy continuum – completed a facial emotion recognition task. For the first time in a convicted offender sample, we used pupillometry techniques to measure changes in the pupil dilation response, a measure of sympathetic autonomic arousal to affective stimuli. We found that the callousness features of psychopathy were related to impaired recognition of fearful faces. Strikingly, we also showed that increasing callousness was associated with a reduction in the pupil dilation response, and that this was pervasive across different emotional expressions. Our results highlight a potential role of the locus coeruleus-noradrenaline system in the pathophysiology of psychopathy, and demonstrate the potential of the pupillary response as a technique for understanding attention-emotion interactions in psychopathy.

Key words: psychopathy, fear, facial expression, pupillometry, antisocial behaviour

General scientific summary

We found that psychopathic traits among convicted violent offenders are associated with reduced fearful expression recognition, and reduced arousal in response to the emotional expressions of others. This study suggests that these difficulties may represent a mechanism for the callousness features of psychopathy.

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The role of psychopathic traits

Convicted psychopaths account for more severe and more frequent acts of aggression, and they engage in instrumental forms of aggression at a higher rate than non-psychopaths do (Skeem, Polaschek, Patrick, & Lilienfeld, 2011). These behaviours are thought to reflect deficiencies in emotion processing, and reduced reactivity of the autonomic nervous system [ANS] to emotional stimuli (Blair, Leibenluft, & Pine, 2014; Fanti, 2018). Psychopathy is a multidimensional construct that is characterized by callous/affective (e.g., lack of remorse or guilt, shallow affect), interpersonal (e.g., manipulative, interpersonal charm), and behavioral (e.g., recklessness, impulsivity) characteristics (Cooke & Michie, 2001; Patrick, Fowles, & Krueger, 2009). It is hypothesized that the callousness features are related to both emotional reactivity deficits (e.g., Kyranides, Fanti, Sikki, & Patrick, 2017), and a diminished ability to recognize and respond to other's emotional facial expressions (Blair et al., 2014). However, whether these difficulties are specific to expressions signalling another's distress, or are more generalized across different emotional expressions, has been the subject of some debate (Brook, Brieman, & Kosson, 2013; Dawel, O'Kearney, McKone, & Palermo, 2012). The aims of the present study were to assess the relationship of distinct psychopathic traits with accuracy of emotion recognition and autonomic reactivity to distress (fear, sad) and non-distress (disgust, happy) facial expressions in a sample of convicted violent offenders.

Historically, psychopathy has been conceptualized and measured according to a two-factor/four-facet model, with Factor 1 indexing Interpersonal and Affective features, and Factor 2 indexing Lifestyle and Antisocial features (Hare, 2003). These features can be measured in forensic samples using the interview-based Psychopathy Checklist – Revised (Hare, 2003). Alternatively, the Triarchic Model of psychopathy conceptualizes the construct along three core dimensions, namely Boldness, Meanness, and Disinhibition (Patrick et al., 2009). These trait dimensions have been reliably identified and distinguished in forensic and non-forensic samples, and have been operationalized using the Triarchic Psychopathy Measure (TriPM; Drislane, Patrick, & Arsal, 2014). Boldness refers to venturesomeness, fearlessness, and interpersonal dominance (Patrick et al., 2009),

and is positively associated with interpersonal features assessed using the Fearless Dominance subscale of the Psychopathic Personality Inventory (PPI; Lilienfeld & Andrews, 1996; Lilienfeld & Widows, 2005), and with PCL-R Interpersonal and Antisocial symptoms (Patrick & Drislane, 2015). Meanness indexes callous and affective features, and is positively related to scores on the Inventory of Callous-Unemotional Traits (ICU; Kimonis, Branch, Hagman, Graham, & Miller, 2013), the Coldheartedness subscale of the PPI, and with PCL-R Affective and Antisocial symptoms (see Patrick & Drislane, 2015 for a review). Moderate associations of Meanness with PPI Fearless Dominance and Impulsive Antisociality features have also been reported (Patrick & Drislane, 2015). Disinhibition refers to impulse control problems, emotional reactivity, and poor behavioural restraint (Patrick et al., 2009). Patrick and Drislane (2015) have highlighted positive associations of Disinhibition with PPI Impulsive Antisociality, and with PCL-R Lifestyle and Antisocial symptoms. Thus, although Boldness, Meanness, and Disinhibition appear to be preferentially associated with interpersonal, affective, and antisocial features, respectively, all three subscales have been linked with higher PCL-R Antisocial symptoms.

The ways in which Boldness, Meanness, and Disinhibition relate to measures of emotion processing and ANS reactivity remain unclear. Although several prominent accounts of psychopathy emphasize difficulties in emotional expression recognition (Blair et al., 2014; Moul, Killcross, & Dadds, 2012), there is some debate as to whether these deficits are particular to emotions signalling another's distress, most notably fear and sadness, or are more generalized across the emotional spectrum, including, for example, anger, disgust and happy (Brook & Kosson, 2013; Dawel et al., 2012). The callousness dimension in particular appears to be linked with difficulties recognizing others' distress from their emotional expressions (Brislin et al., 2018; Dargis, Wolf, & Koenigs, 2018; Gillespie, Mitchell, Satherley, Beech, & Rotshtein, 2015; Igoumenou, Harmer, Yang, Coid, & Rogers, 2017), and is associated with amygdala hypoactivity to fearful facial expressions (Jones, Laurens, Herba, Barker, & Viding, 2009; Viding et al., 2012; White et al., 2012). In contrast, the interpersonal dimension is associated with a pattern of reduced attention to the eyes that is generalized across different emotional expressions (Dargis et al., 2018; Gillespie, Rotshtein, Beech, & Mitchell, 2017; Gillespie, Rotshtein, Wells, Beech, & Mitchell, 2015). As such, there are several important questions

that require further clarification, including whether psychopathy related impairments in facial affect recognition are specific to fear and sadness, or are more generalized across the emotional spectrum; whether these impairments are primarily related to the callousness features of the disorder; and whether these impairments are accompanied by hypoautonomic reactivity while viewing emotional expressions.

ANS activity can be measured at rest, or in response to emotional stimuli. In both contexts, psychopathy is associated with attenuated ANS responses (see De Brito & Mitchell, 2018 for a review). In studies with convicted offenders, psychopathy has been linked with low resting heart rate (Armstrong, Keller, Franklin, & Macmillan, 2009; Arnett, Howland, Smith, & Newman, 1993; Patrick, 2008; Pham, Philippot, & Rime, 2000), and low resting levels of electrodermal activity (Lorber, 2004). Studies of ANS reactivity in response to emotional stimuli have also shown that psychopathy is related to reduced cardiovascular (Arnett et al., 1993; Ishikawa, Raine, Lencz, Bihrlé, & Lacasse, 2001; Patrick, 2008; Pham et al., 2000), and electrodermal reactivity (Arnett, 1997; Patrick, 2008; Rothmund et al., 2012), and an absence of, or reduction in, aversive startle potentiation – that is, the augmentation of the blink startle reflex that is normally observed in response to an aversive stimulus (e.g., an unpleasant picture) (Pastor, Molto, Vila, & Lang, 2003; Patrick, Bradley, & Lang, 1993).

In children with conduct problems, reductions in ANS activity, both at rest, and in response to emotionally salient stimuli, are related to the callousness dimension in particular (Fanti, 2018). Studies with adult community and offender samples have found negative associations of estimated scores on PPI Fearless Dominance (Benning, Patrick, & Iacono, 2005), and PCL-R Interpersonal symptoms (Verona, Patrick, Curtin, Bradley, & Lang, 2004), with electrodermal responsivity to negative stimuli, and PPI Fearless Dominance is negatively associated with electrodermal responses during anticipatory stress (Dindo & Fowles, 2011). Aversive startle potentiation is also inversely related to estimated scores on PPI Fearless Dominance (Benning et al., 2005), and PCL-R Factor 1 (Vaidyanathan, Hall, Patrick, & Bernat, 2011), but is either unrelated (Benning et al., 2005; Vaidyanathan et al., 2011), or positively related (Vanman, Mejia, Dawson, Schell, & Raine, 2003), to impulsive and antisocial features. Consistent with these findings, TriPM Boldness was associated with

reduced cardiac reactivity to violent stimuli, while Meanness was associated with low startle potentiation in a young adult sample (Kyraniades et al., 2017). Thus, reduced ANS reactivity in psychopathy appears to be most strongly associated with Boldness and Meanness.

Pupil dilation (pupillometry) is another marker of ANS reactivity that is sensitive to emotional content, yet pupillary responses to emotional expressions have not been studied in convicted offender samples. The smooth muscles involved in the pupil response are controlled by the two opposing branches of the ANS: the dilator muscle, influenced by activity of the sympathetic nervous system (SNS), and the sphincter muscle, influenced by activity of the parasympathetic nervous system (PNS). Thus, pupil size reflects the relative activation of these two systems, with pupil dilation resulting from either increased SNS activity, or reduced PNS activity.

Accumulating evidence suggests that the pupil dilation response is a robust marker of activity in the locus coeruleus (LC) (Joshi, Li, Kalwani, & Gold, 2016; Murphy, O'Connell, O'Sullivan, Robertson, & Balsters, 2014). LC neurons respond to the salience and biological significance of stimuli, and give rise to the release of noradrenalin (i.e., norepinephrine), the neurotransmitter that characterises sympathetic efferents. This release of noradrenaline is thought to facilitate the functional integration of brain regions involved in attention (Corbetta, Patel, & Shulman, 2008; Coull, Buchel, Friston, & Frith, 1999; Sara, 2009). Although no known anatomical pathways allow for a direct influence of LC on the autonomic nuclei controlling pupil diameter (Nieuwenhuis, De Geus, & Aston-Jones, 2011), this tight relationship likely reflects parallel activation of the LC and SNS by sources of common input. A likely candidate is the rostral ventrolateral medulla, a major excitatory input to the LC, and a key sympathoexcitatory brain region that receives cortical and subcortical inputs (Nieuwenhuis et al., 2011). While activation of the LC leads to noradrenergic release into the neocortex, parallel activation of the SNS causes direct activation of the pupil dilator muscle. Thus, the pupil dilation response represents a novel avenue of enquiry that could be revealing about a potential role of the LC-noradrenaline system in the pathophysiology of psychopathy.

In community adult samples, increased pupil dilation has been observed in response to both positive and negative stimuli (Bradley, Miccoli, Escrig, & Lang, 2008; Rieger et al., 2015; Snowden et al., 2016), including emotional faces, particularly those depicting threat (i.e., fear and anger)

(Schrammel, Pannasch, Graupner, Mojzisch, & Velichkovsky, 2009). Only one study has examined pupil reactivity to emotional stimuli as a function of psychopathic tendencies in non-offenders (Burley, Gray, & Snowden, 2017). Independent of psychopathic tendencies, this study replicated previous reports showing that pupil dilation is increased for negative compared with neutral stimuli, although no differences were reported for positive stimuli. More importantly, the authors did not observe significant relationships of distinct psychopathic trait dimensions with pupillary responses to any of the emotional stimuli (Burley et al., 2017). However, this null result may reflect the relatively lower levels of psychopathic tendencies found in non-offender samples.

The Present Study

The aim of this study was to examine the relationship of distinct psychopathic traits with recognition accuracy and pupillary responses to varied emotional expressions in a convicted offender sample. We assessed three core dimensions of psychopathy, namely Boldness, Meanness, and Disinhibition, described in the Triarchic conceptual framework (Patrick et al., 2009). Finally, we also measured State and Trait anxiety because negative affect is an important factor regarding heterogeneity in psychopathy (Hicks & Patrick, 2006; Kimonis, Frick, Cauffman, Goldweber, & Skeem, 2012).

We predicted that Meanness would be negatively related to accuracy of emotional expression recognition, and more pertinently, to autonomic reactivity indexed by the pupillary response. Competing theories of the emotional deficits associated with psychopathy would predict that these effects would either be specific to expressions of sadness and fear, or would be observed more generally across the emotional spectrum (see Brook et al., 2013). Thus, as a test of both theories we included a varied set of emotional expressions, depicting anger, disgust, fear, happy, sad, surprise, and neutral. Expressions (excluding neutral) were presented at varying degrees of stimulus intensity to provide more lifelike representations of emotional expressions, and to make the task more sensitive to subtle differences in emotion processing (Adolphs & Tranel, 2004; Calder et al., 1996). Furthermore, results suggest that psychopathy primarily affects the processing of moderate intensity expressions (Hastings, Tangney, & Stuewig, 2008). In line with previous findings (Brook et al., 2013; Dawel et

al., 2012), we hypothesized that relationships of Meanness with accuracy and pupil reactivity would be pervasive across expressions, but with the largest effect sizes observed for fear.

Method

Ethical Approval

Ethical approval for this study was obtained from the University of Birmingham Committee for Ethical Review and the National Offender Management Service for England and Wales. We informed potential participants that their acceptance or refusal to take part would have no bearing upon their sentencing, treatment, or parole decisions. All participants were informed of their right to withdraw their data within two weeks of participation, were provided with an information sheet, signed an informed consent form, and were debriefed following participation.

Participants

A sample of 73 adult males aged 21-72 years ($M = 38.7$, $SD = 11.7$) who were incarcerated at one of two Category B prisons in the United Kingdom took part in the study. Individuals were eligible to take part if they were over the age of 18, and had been convicted of a violent offense, defined as “any criminal charge for a violent offence against persons – e.g., assault, assault causing bodily harm, wounding, attempted homicide, homicide, kidnapping, forcible confinement, armed robbery, and all ‘hands-on’ sexual offences” (Harris, Rice, & Cormier, 2002, p. 383). Based on file information, no participants had a diagnosis of schizophrenia, bipolar disorder or psychosis, and no participants were currently using psychotropic medication. Three participants in the violent offender sample had a history of post-traumatic stress disorder, three had a history of depression, and one had a history of dissociative disorder. Recruitment in prison settings followed local procedures and included contact with offender-supervisors, searching the prisons electronic database, and poster advertising. One setting ran a research advisory group that consisted of expert-by-experience representatives from eligible wings who took part in a question and answer session with two of the researchers. Wing representatives aided recruitment on their own wings following this meeting. Most participants were white Caucasian (86%). All participants had normal or corrected-to-normal vision.

For comparison purposes, we also recruited a sample of 25 community males. Because the focus of this paper is on the relationship of psychopathic traits with pupil dilation responses in a

convicted offender sample, we present details of the community sample and comparisons between groups in Supplemental Materials 1.

Accuracy data for a sub-sample of the offenders ($n = 30$) and for the control group have previously been reported as part of a study on eye movements (Gillespie et al., 2017).

Materials

Facial expression stimuli. We used a subset of the morphed facial stimuli developed by Gillespie and colleagues (Gillespie, Mitchell, et al., 2015; Gillespie, Rotshtein, Satherley, Beech, & Mitchell, 2015; Gillespie, Rotshtein, Wells, et al., 2015; Wells, Gillespie, & Rotshtein, 2016). Original stimuli were selected from the NimStim Face Stimulus Set (Tottenham et al., 2009; <http://www.macbrain.org/resources.htm>) and consisted of five male and five female Caucasian models showing seven different expressions: neutral, angry, disgust, fear, happy, sad, and surprise. Emotional and neutral images from the same model were morphed to create images of varying levels of emotional intensity (for details of the morphing procedure see Gillespie, Rotshtein, Satherley, et al., 2015). Images used in the current study consisted of each emotion, for each model, displayed at moderate (55% expressive) and high (90% expressive) intensity. Neutral stimuli were displayed at 100% neutral (i.e., neutral stimuli did not vary in intensity). Stimuli had a resolution of 504 x 624 pixels. The positioning of each image on the canvas was manipulated such that the eyes and the mouth appeared in the same location across all stimuli. There were no differences in contrast ($F(5, 108) = .153, p = .979$) or luminance ($F(5, 108) = .214, p = .956$) as a function of emotional expression. Contrast values were greater for images showing higher intensity expressions ($F(1, 108) = 15.161, p < .001$), but there were no differences in luminance ($F(1, 108) = .783, p = .378$). Given that our main aim was to examine individual differences in pupil reactivity to the stimuli, we kept the original contrast of the stimuli to maintain more life-like expressions, and to facilitate ecological validity.

Measures. The Triarchic Psychopathy Measure (TriPM; Drislane et al., 2014) was used for the assessment of psychopathic traits. This 58-item self-report measure yields scores on three subscales: Boldness, Meanness, and Disinhibition. The TriPM Boldness scale includes items assessing interpersonal dominance, venturesomeness, and fearlessness (Patrick et al., 2009).

Callousness was assessed using the Meanness scale and entails callous-aggressiveness, lack of empathy, and a tendency toward exploiting others (Brislin et al., 2018; Drislane et al., 2014). TriPM Disinhibition indexes impulsivity, emotional reactivity, and irresponsibility (Patrick et al., 2009). Participants responded on a 4-point Likert scale (3 = *true*, 2 = *somewhat true*, 1 = *somewhat false*, 0 = *false*). Internal consistencies for the Boldness, Meanness, and Disinhibition subscales in the convicted offender sample were adequate: Cronbach's $\alpha = .68, .92$, and $.89$, respectively. Participants in the violent offender group also completed the State Trait Anxiety Inventory (STAI; Spielberger, 1983), which contains both State [STAI-S] and Trait [STAI-T] subscales. Internal consistencies for the STAI-S and STAI-T were good: Cronbach's $\alpha = .93, .93$. One participant in the violent offender group failed to complete the TriPM, and one participant failed to complete the STAI. Participants in the community sample were also asked to complete the TriPM for comparison, although two participants failed to complete the measure.

Pupillometry

We used an EyeLink 1000 corneal-reflection based portable eye tracking system (SR Research Ltd.) to record participants' pupil size. Although viewing was binocular, only pupil diameter of the right eye was recorded. Pupil size was sampled at 1000 Hz. We used a Dell Precision laptop computer to manage the recording of pupil diameter. Stimuli were displayed on a 19" LG colour monitor, using SR-Research Experiment Builder software, running on a laptop computer with a separate mouse and keyboard.

Procedure

Offender participants were tested in a private room inside the prison, whereas community participants were tested in a dedicated eye-tracking laboratory at the university. Participants sat at a desk with a chin rest of adjustable height to minimize head movements. Participants were positioned approximately 68 cm from the display monitor, and images were presented at a visual angle of 21.2°. Participants categorized the emotional expression stimuli as quickly and accurately as possible while pupil size was being recorded. Standard EyeLink calibration and validation procedures were performed, each using a series of nine fixation points. Facial expression stimuli were presented in a randomized order over four blocks using the EyeLink software. At the start of each trial the

experimenter confirmed that the participant's eye gaze fell on a fixation point presented in the centre of the screen. A fixation cross was then presented for 1000 ms, followed by an image of an emotional expression that was displayed for 2000 ms. Following display of the target expression, participants categorized the facial expression using the numeric keys 0-6. Expression labels were displayed in a vertical list alongside the relevant number key (e.g., 0. NEUTRAL).

Data Analysis

Accuracy data were analyzed as the proportion of correct responses for each stimulus category (i.e., each emotion category at each level of intensity). To control for individual differences in pupil size, and therefore expected differences in the degree of pupil change, we calculated within participant percent change difference scores for each stimulus category (see Attard-Johnson, Ó Ciardha, & Bindemann, 2018). First, for each trial we averaged pupil size across each individual fixation for the duration of the stimulus display. We then used these values to calculate an overall mean pupil size for each participant, across all trials. The percentage difference in pupil diameter for each stimulus category compared to the overall mean was calculated using the following formula:

$$\Delta P_{ic} = \frac{(\bar{x}_{ic} - \bar{x}_e)}{\bar{x}_e} * 100$$

\bar{x}_{ic} denotes the mean change for a specific category and intensity, and \bar{x}_e denotes the mean response to all conditions, ΔP_{ic} denotes the overall change in pupil diameter for a specific emotion category (c) and intensity (i) compared to the overall mean. Thus, no change in pupil size is indicated by zero, while positive or negative scores reflect relatively larger (dilation) or smaller (constriction) pupil sizes in response to each stimulus category. The use of percentage change data performs as well as other methods for the analysis of pupillary response data, including raw scores and z-scored data, and better than pre-stimulus baseline correction where carryover effects have been observed (Attard-Johnson et al., 2018). Second, to ensure that the observed changes in pupil size were due to changes in the emotional content of expressions, we contrasted percentage change in pupil size for each stimulus category with percentage change for neutral expressions (see Attard-Johnson et al., 2018). To do this, we subtracted the percentage change in pupil size for neutral expressions from the percentage change in pupil size for each stimulus category.

To understand the effects of the emotional content of the expression, expression intensity, and the effects of self-reported psychopathic traits, we computed separate ANCOVAs for accuracy and pupil reactivity. Each ANCOVA included the factors Emotion (anger, disgust, fear, happy, sad, surprise), and Intensity (55%, 90%), with scores for Boldness, Meanness, and Disinhibition included as covariates. Significant interactions were broken down using subsequent ANCOVAs. To test if any effects of psychopathic traits were due to severity of antisocial behavior, ANCOVAs on accuracy and pupil reactivity were repeated with total number of previous convictions for violence included as an additional covariate. Supplementary ANCOVAs on accuracy and pupil reactivity were also performed including a community control group, and with State and Trait Anxiety included separately as covariates. Analyses including State and Trait Anxiety allowed us to test for the effects of negative affect without controlling for important aspects of the psychopathy construct. The results of these supplementary analyses are reported in Supplemental Materials 1 and 2, respectively. As Age was unrelated to either accuracy of expression recognition (all $r < .12$ and $\geq -.23$, $p > .05$), or pupil dilation responses (all $r < .19$ and $> -.07$, $p > .12$), we did not include Age as a covariate.

Results

Table 1 shows mean scores and standard deviations for all self-report measures completed by violent offenders, along with the correlations between measures. For comparison, descriptive statistics for the TriPM subscales in the community sample are also included, as well as published comparison scores from community ($N = 496$), and forensic psychiatric samples ($N = 296$) (van Dongen, Drislane, Nijman, Soe-Agnie, & van Marle, 2017). TriPM scores among violent offenders were similar to those reported by van Dongen et al. (2017) for a separate sample of forensic psychiatric patients, while Meanness and Disinhibition scores were higher compared with community controls in this study, and community participants reported by van Dongen and colleagues. Meanness and Disinhibition were positively correlated among violent offenders, while Boldness was unrelated to either Meanness or Disinhibition, but was negatively correlated with measures of negative affect. Meanness and Disinhibition were associated with a greater number of previous convictions for violence. Table 2 shows accuracy of emotion recognition and percent changes in pupil size for convicted violent offenders as a function of Emotion and Intensity.

Accuracy: Effects of Emotion and Intensity

An ANCOVA on accuracy revealed significant main effects of Emotion ($F(5, 340) = 63.263$, $p < .001$, $\eta^2 = .482$), and Intensity ($F(1, 68) = 70.727$, $p < .001$, $\eta^2 = .510$), that were qualified by a significant two-way interaction ($F(5, 340) = 20.753$, $p < .001$, $\eta^2 = .234$). Disgust ($F(1, 68) = 57.232$, $p < .001$, $\eta^2 = .457$), happy ($F(1, 68) = 46.491$, $p < .001$, $\eta^2 = .406$), sad ($F(1, 68) = 52.460$, $p < .001$, $\eta^2 = .435$), and surprise ($F(1, 71) = 9.682$, $p = .003$, $\eta^2 = .125$) were all recognized better at high intensity, but fear was recognized better at low intensity ($F(1, 68) = 11.722$, $p = .001$, $\eta^2 = .147$). Expressions showing anger were recognized equally well at low and high intensity ($F(1, 68) = 2.866$, $p = .095$, $\eta^2 = .040$). Bonferroni adjusted comparisons for the main effect of Emotion showed that fear was recognized with least accuracy compared with all other expressions (all $p < .001$), and happy was better recognized than disgust ($p = .008$), and sad ($p = .006$).

Accuracy: Effects of Boldness, Meanness, and Disinhibition

The main effects of Boldness ($F(1, 68) = 0.270$, $p = .605$, $\eta^2 = .004$), Meanness ($F(1, 68) = 0.052$, $p = .820$, $\eta^2 = .001$), and Disinhibition ($F(1, 68) = 1.624$, $p = .207$, $\eta^2 = .023$) were all non-significant, but there was a significant interaction of Meanness with Emotion ($F(5, 340) = 3.589$, $p = .004$, $\eta^2 = .050$), suggesting a relationship that was dependent on the emotional content of the expression. All other two- and three-way interactions of Boldness, Meanness, and Disinhibition with Emotion and Intensity were non-significant (all $F < 3.12$, $p > .08$). When including total number of previous convictions for violence as a covariate, the interaction of Meanness with Emotion remained significant ($F(5, 335) = 3.542$, $p = .004$, $\eta^2 = .050$), and there were no significant main effects or interactions of previous convictions for violence (all $F < 1.70$, $p > .19$). The interaction of Meanness with Emotion also remained significant after removing 14 participants aged over 50 years ($F(5, 270) = 3.229$, $p = .008$, $\eta^2 = .056$).

Table 3 shows the zero-order and partial correlations of Meanness, controlling for Boldness and Disinhibition, with accuracy of emotion recognition. Zero-order and partial correlations showed that increasing Meanness scores were associated with poorer fear recognition. Figure 1 shows the association of Meanness scores, controlling for Boldness and Disinhibition, with accuracy of fearful

expression recognition. Partial correlations also showed that increasing Meanness scores were associated with better recognition of sad expressions.

Pupil Dilation Response: Effects of Emotion and Intensity

An ANCOVA on pupil dilation responses showed that pupil reactivity varied with the emotional content of the expression ($F(5, 340) = 5.167, p < .001, \eta^2 = .071$). Bonferroni adjusted comparisons showed that the pupil dilated more for disgust ($p = .004$), and sad ($p = .002$), compared with happy. No other comparisons were significant. A significant main effect of Intensity showed that pupil dilation was greatest for expressions at lower intensity ($F(1, 68) = 9.965, p = .002, \eta^2 = .128$), but the two-way interaction of Emotion and Intensity was non-significant ($F(5, 340) = 1.321, p = .255, \eta^2 = .019$).

Pupil Dilation Response: Effects of Boldness, Meanness, and Disinhibition

A significant two-way interaction showed that the pattern observed for Intensity was most pronounced with increasing Boldness scores ($F(1, 68) = 4.023, p = .049, \eta^2 = .056$). The remaining two- and three-way interactions of Boldness, Meanness and Disinhibition with Emotion and Intensity were all non-significant (all $F < 1.48, p > .19$). However, a significant main effect of Meanness ($F(1, 68) = 4.138, p = .046, \eta^2 = .057$) showed that increasing Meanness scores were associated with a reduction in the pupil dilation response across Emotion and Intensity. The main effects of Boldness ($F(1, 68) = 0.023, p = .881, \eta^2 = .000$), and Disinhibition ($F(1, 68) = 0.001, p = .970, \eta^2 = .000$), were both non-significant. When including total number of previous convictions for violence as a covariate, the main effect of Meanness remained significant ($F(1, 67) = 4.144, p = .046, \eta^2 = .058$), and we also found a significant interaction of previous convictions for violence with Emotion ($F(5, 335) = 2.506, p = .030, \eta^2 = .036$). The main effect of Meanness also remained significant after removing 14 participants aged over 50 years ($F(1, 54) = 4.127, p = .047, \eta^2 = .071$).

Table 4 shows the zero-order and partial correlations of Meanness, controlling for Boldness and Disinhibition, with pupil reactivity for each expression type. Zero-order correlations showed that Meanness was associated with reduced pupil dilation responses across all emotional expressions relative to neutral, excluding anger. When controlling for Boldness and Disinhibition, the effects of Meanness were apparent for expressions of fear, happy, and sad. Figure 1 shows the association of

Meanness scores, controlling for Boldness and Disinhibition, with the pupillary response to fearful expressions. Although an additional analysis revealed a significant interaction of previous convictions for violence with Emotion, all zero-order and partial correlations with the pupil dilation response were non-significant (all $p > .204$).

--INSERT FIGURE 1 HERE--

Additional Analysis

To examine if the associations of fear face accuracy and pupil dilation responses with Meanness were separate or overlapping, we included both in a regression model as predictors of Meanness standardized residuals, controlling for Boldness and Disinhibition. The model ($F(2, 71) = 5.369, p = .007, \Delta R^2 = .110$) showed that reduced pupil dilation responses ($\beta = -0.080, SE = .032, p = .015$), but not accuracy ($\beta = -1.042, SE = .535, p = .055$), predicted higher Meanness scores.

Discussion

In this study, we examined the effects of distinct psychopathic traits on accuracy of emotion recognition, and pupil reactivity to different emotional expressions in a sample of convicted violent offenders. In support of our main hypotheses, we found that self-reported levels of callousness as indexed by the Meanness scale of the TriPM were associated with reduced recognition of fearful expressions, and reduced pupil reactivity to emotional expressions of fear, happy, and sad. These findings suggest that although callousness is associated with a specific impairment in fearful expression recognition, the relationship of callousness with autonomic hypoactivity is pervasive across emotional expressions, with no specificity for fear or sadness.

Consistent with earlier findings from offenders and non-offenders, expressions of higher intensity were typically recognized with better accuracy (Gillespie et al., 2017; Schurgin et al., 2014; Wells et al., 2016), and fear was recognized with least accuracy compared with other expressions (Gillespie et al., 2017; Wells et al., 2016). The finding that callousness was associated with a specific impairment in recognizing fearful expressions is consistent with earlier studies in community adults (Brislin et al., 2018), and convicted offenders (Gillespie, Mitchell, et al., 2015; Igoumenou et al., 2017). Our results contrast with reports of more pervasive psychopathy related impairments in emotion recognition that go beyond fear and sadness (Brook et al., 2013; Dawel et al., 2012), and

instead favour theoretical accounts of psychopathy that focus on impaired recognition of others distress cues (Blair, 2013; Blair et al., 2014). However, support for these theories is tempered by an unexpected, positive relationship of callousness, controlling for Boldness and Disinhibition, with accuracy for sad expressions. Although others have reported positive relationships of both interpersonal and antisocial features of psychopathy with accuracy in offender samples (Dargis et al., 2018; Igoumenou et al., 2017), a meta-analysis showed a small, negative effect of psychopathy on recognition of sadness (Dawel et al., 2015). These findings should be interpreted in light of mixed reports on the emotion specific effects of psychopathy that may reflect limited discriminating power for emotion-specific subscales (e.g., happiness is usually recognized with high accuracy), small sample sizes, and a lack of control over confounding third variables (Olderbak, Mokros, Nitschke, Habermeyer, & Wilhelm, 2018).

Pupil reactivity varied in response to different emotional expressions, with greater responses for disgust and sad compared with happy. These findings are consistent with earlier studies showing that pupil dilation responses varied with the emotional content of a stimulus (Bradley et al., 2008; Burley et al., 2017; Snowden et al., 2016). Furthermore, we found that pupillary responses were increased for lower intensity expressions, likely a reflection of increased task difficulty and enhanced cognitive effort (Sara, 2009). This effect was exaggerated with increasing Boldness scores, indicating that the effects of Boldness on pupillary responses are dependent on stimulus intensity. In an earlier study, we reported that Boldness traits were related to differences in the processing of emotional facial expressions (Gillespie et al., 2017), and a recent study has highlighted an association of CU traits with fear intensity-modulated amygdala responses (Meffert et al., 2018). Future research should clarify the association of distinct psychopathic traits with pupillary responses that are modulated by the emotional intensity of the stimulus. Contrast differences between the moderate and high intensity expressions may also have affected responses in these conditions.

Crucially, we also found that violent offenders' pupil dilation responses were associated with levels of Meanness, and that this effect was pervasive across different expressions. Our results are the first to show a relationship between pupil reactivity and callous psychopathic traits, and are consistent with previously reported differences in autonomic reactivity in relation to callousness (Fanti, 2018;

Kyranides et al., 2017). Although Meanness was related to lower accuracy for fearful expressions only, reductions in the pupil dilation response were observed more generally, for expressions of fear, happy, and sad. Our findings for pupil reactivity are consistent with more pervasive emotional and autonomic impairments in psychopathy, while results for accuracy favour an *integrated emotions perspective* (Blair, 2013). Our findings mirror those of a systematic review by Brook et al. (2013), which showed that findings from face-morph paradigms tend to favour an integrated emotions perspective, while studies that found reduced autonomic reactivity tend to favour a more general deficit in emotion processing. An additional analysis predicting Meanness from accuracy and pupil reactivity to fear face affect showed that when entered simultaneously in to the model, only pupil reactivity was a significant predictor of Meanness, suggesting that these effects may be overlapping. This pattern of results suggests that fear recognition may rely more heavily on autonomic responses driven by sub-cortical structures, while recognition of other emotions can be achieved by different mechanisms.

To better place our findings in an overall framework of brain processes in psychopathy, it is important to consider the neural circuits underlying changes in pupil diameter. Although the pupillary response is thought to reflect activity in the LC (Joshi et al., 2016; Murphy et al., 2014), no known anatomical pathways allow for a direct influence of LC on the size of the pupil (Nieuwenhuis et al., 2011). Instead, it is thought that the LC and the SNS are activated in parallel, with the rostral ventrolateral medulla representing a source of common input. While activation of the LC leads to noradrenergic release into the neocortex (Corbetta et al., 2008; Coull et al., 1999; Sara, 2009), activation of the SNS causes direct activation of the pupil dilator muscle. Further, recent evidence suggests that noradrenaline improves sensory responses, and correlates with orienting toward behaviorally relevant stimuli (Gelbard-Sagiv, Magidov, Sharon, Hendler, & Nir, 2018). Thus, the pupil dilation response represents a novel avenue of enquiry for understanding attention-emotion interactions in psychopathy. Our results suggest that impaired functioning of the LC-noradrenaline circuit may represent a mechanism for the callousness features of psychopathy.

Strengths, Limitations, and Future Directions

Our results are subject to some limitations. First, the present study was limited to the perception of emotion from faces, and future work should employ emotional vocalizations and bodily poses, and unconditioned fear stimuli (e.g., snakes). Further, the facial expression stimuli were static, and although morphing procedures were used to create expressions of varying intensity, it would be interesting to examine these effects for more dynamic facial stimuli. Second, our sample was of a modest size and largely limited to white Caucasian participants. Future studies should seek to replicate our effects cross-culturally, as well as with female and developmental samples, and to examine the role of potential moderating factors, including general mental ability (Olderbak et al., 2018). Third, although the TriPM includes a Disinhibition subscale, this does not provide a direct measure of antisocial behavior, and the scoring of this inventory does not take in to account official records. Nonetheless, it is promising that we found a positive correlation of scores on the Meanness and Disinhibition subscales with total number of previous convictions for violence, and the relationship of Meanness with fear accuracy and pupil reactivity remained unchanged after controlling for previous convictions for violence. Strengths of this study included the dimensional approach to the assessment of psychopathy, and the measurement of negative emotionality (State and Trait anxiety). Analyses presented in Supplemental Materials 2 showed that State anxiety was negatively related to accuracy for fear. There were, however, no associations of either State or Trait anxiety with pupil reactivity. Earlier findings have shown that levels of anxiety can be used to specify discrete variants of psychopathy (Hicks & Patrick, 2006; Kimonis et al., 2012), and so it is important that future studies examine how the pupillary response varies in these variants.

Conclusions

We found that the trait dimension of callousness was associated with impaired fear recognition, and reduced pupil reactivity to varied emotional expressions in a sample of convicted violent offenders. Conversely, although Boldness was associated with pupil reactivity as a function of emotion intensity, we found little evidence that either Boldness or Disinhibition are related to face affect processing or autonomic responses. Our findings support the use of pupillometry as a measure of autonomic functioning for use with clinical and forensic samples. With a growing evidence base detailing the neural circuits underlying the pupil dilation response, pupillometry can help to inform

understanding of attention-emotion interactions in psychopathy – and other psychopathologies – and may be revealing about the role of the LC-noradrenaline circuit.

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Table 1.

Sample description and correlations between measures in convicted violent offenders, community non-offenders, and descriptive statistics reported by van Dongen et al. (2017) for community (N = 385), and forensic psychiatric samples (N = 296)

Variable	Bold.	Mean.	Disin.	STAI-S	STAI-T	Age	Previous convictions for violence ^a
Convicted offenders							
TriPM Meanness	.206	-					
TriPM Disinhibition	-.007	.616**	-				
STAI-S	-.266*	-.124	-.060	-			
STAI-T	-.316*	.112	.169	.729**	-		
Age	-.185	-.081	-.134	-.032	-.012	-	
Previous convictions for violence ^a	-.072	.237*	.355*	-.050	-.020	.005	-
Range	11-44	0-50	0-54	20-66	20-73	21-72	0-14
Mean	28.5	14.2	28.4	32.3	42.7	38.7	2.3
Median	28	11	30	29	43	36	1
SD	7.9	11.3	13.3	11.0	11.8	11.7	3.3
Community controls							
Range	9-47	2-38	2-42			18-69	
Mean	28.9	13.4	17.7			37.9	
Median	28	9	17			31	
SD	9.0	9.8	10.5			18.3	
Comparison scores							
Community Mean ^b	31.1	12.3	11.5				
Community SD ^b	8.14	7.8	7.8				
Forensic Mean ^c	30.6	16.1	26.7				
Forensic SD ^c	9.2	9.6	12.0				

* <.05, ** <.001

Note: TriPM = Triarchic Psychopathy Measure; STAI-S = State Trait Anxiety Inventory – State; STAI-T = State Trait Anxiety Inventory – Trait.

^a Previous convictions for violence excludes index offense.

^b Scores reported by van Dongen et al. (2017) for a community sample (N=496)

^c Scores reported by van Dongen et al. (2017) for a forensic psychiatric sample (N=296)

Table 2.

Mean task performance for violent offenders (n=73)

Emotion	Intensity	Accuracy	Pupil reactivity
		<i>M (SD)</i>	<i>M (SD)</i>
Anger	55%	.86 (.12)	-.03 (2.20)
	90%	.89 (.13)	-.010 (2.35)
Disgust	55%	.77 (.16)	.71 (2.01)
	90%	.87 (.14)	.03 (1.86)
Fear	55%	.60 (.24)	.46 (1.96)
	90%	.54 (.21)	-.28 (2.38)
Happy	55%	.83 (.20)	-.74 (2.33)
	90%	.96 (.10)	-.71 (2.71)
Sad	55%	.76 (.17)	.66 (2.55)
	90%	.89 (.12)	.26 (2.34)
Surprise	55%	.83 (.14)	.69 (2.33)
	90%	.88 (.12)	-.48 (2.19)
Neutral	100%	.75 (.26)	-.65 (3.07)

Table 3.

Zero-order and partial (controlling for Boldness and Disinhibition) correlations of TriPM Meanness scores with accuracy of emotion recognition by type of expression

Emotion	Zero-order r (p)	Partial r (p) (Controlling for Bold. and Disin.)
Anger	.043 (.719)	.080 (.508)
Disgust	.023 (.845)	.142 (.240)
Fear	-.256 (.030)	-.241 (.044)
Happy	-.003 (.979)	-.036 (.767)
Sad	.066 (.580)	.241 (.044)
Surprise	.012 (.918)	.082 (.501)

Note: Bold. = Triarchic Psychopathy Measure Boldness subscale; Disin. = Triarchic Psychopathy Measure Disinhibition subscale

Table 4.

Zero-order and partial (controlling for Boldness and Disinhibition) correlations of TriPM Meanness scores with pupil dilation response by type of expression

Emotion	Zero-order r (p)	Partial r (p) (Controlling for Bold. and Disin.)
Anger	-.216 (.068)	-.142 (.240)
Disgust	-.249 (.035)	-.180 (.137)
Fear	-.314 (.007)	-.298 (.012)
Happy	-.305 (.009)	-.239 (.047)
Sad	-.362 (.002)	-.306 (.010)
Surprise	-.248 (.036)	-.150 (.217)

Note: Bold. = Triarchic Psychopathy Measure Boldness subscale; Disin. = Triarchic Psychopathy Measure Disinhibition subscale

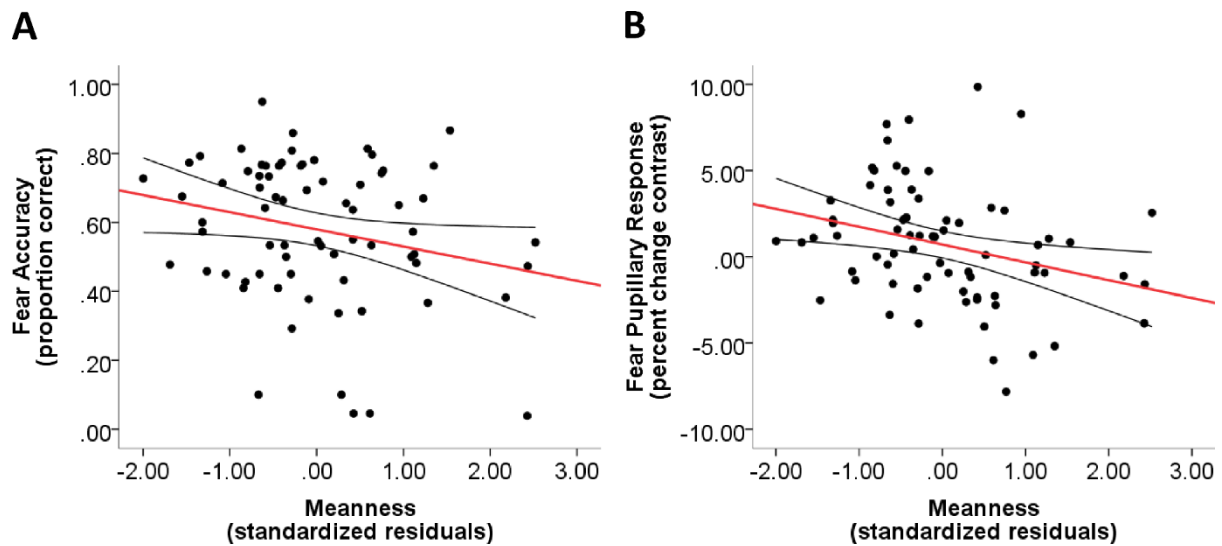


Figure 1. Scatter plot showing the relationship between Meanness psychopathic traits and (A) fear recognition accuracy, and (B) the pupillary response to fearful expressions, in violent offenders. Meanness scores represent standardized residuals controlling for Boldness and Disinhibition.

Supplemental materials 1 for “Pupil reactivity to emotional faces among convicted violent offenders:
The role of psychopathic traits”

These data report the results of comparisons on accuracy and pupil dilation responses in the convicted violent offender sample, and the community sample of non-offenders

Community participants

Community participants aged between 18 and 69 years ($M = 37.9$, $SD = 18.3$) were recruited from the community of Birmingham, UK, through advertisements placed online and through word of mouth. The only inclusion criteria were that participants were aged 25-70 years and had not been charged for violent offenses. Participants received £10 per hour of participation. All participants were white Caucasian and had normal or corrected-to-normal vision. Accuracy and eye movement data for a subset ($N = 30$) of the offender sample, and the 25 community controls, has been reported elsewhere (see Gillespie et al., 2017), and the focus of this paper is on individual differences in the pupil dilation response to emotional faces. Scores on the TriPM subscales for community non-offending controls are reported in Table 1 of the main text.

Results

Age was similar in the convicted offender and the community participant samples ($t = 0.25$, $p = .81$), and so was not included as a covariate in analyses of accuracy and the pupil dilation response.

Accuracy

Descriptive statistics for accuracy among the community participants are available as part of a previous paper looking at the effects of psychopathic traits on eye scan paths (Gillespie et al., 2017).

To compare accuracy between the convicted offender sample and the community participants, we used an ANOVA with the factors Emotion, Intensity, and Group. The main effect of Group, and the two- and three-way interactions of Group with Emotion and Intensity were all non-significant (all $F < 1.99$, $p > .08$). These results indicate that accuracy levels were broadly similar for both groups.

Pupil dilation response

Descriptive statistics for pupil reactivity in the community sample of non-offenders are available in Table S1. An ANOVA on the pupil dilation response, with the factors Emotion, Intensity, and Group, showed that the main effect of Group, and the two- and three-way interactions of Group with Emotion and Intensity, were all non-significant (all $F < .93$, $p > .36$). These results indicate that pupil dilation responses were broadly similar for both groups.

Table S1.

Mean task performance for community controls (n=25)

Emotion	Intensity	Pupil reactivity
		$M (SD)$
Anger	55%	.59 (3.01)
	90%	-.02 (2.70)
Disgust	55%	.23 (1.95)
	90%	.46 (2.06)
Fear	55%	1.08 (2.62)
	90%	.16 (3.05)
Happy	55%	-.13 (1.92)
	90%	-1.07 (2.04)
Sad	55%	.42 (2.01)
	90%	-.39 (2.15)
Surprise	55%	.48 (2.00)
	90%	-.90 (2.28)
Neutral	100%	-1.35 (3.72)

Supplemental materials 2 for “Pupil reactivity to emotional faces among convicted violent offenders:
The role of psychopathic traits”

These data report on the effects of State and Trait anxiety on accuracy of emotion recognition, and pupil dilation responses to emotional faces, in the convicted violent offender sample.

Effects of State and Trait Anxiety

Accuracy

To test for the effects of State and Trait anxiety on accuracy among convicted offenders, we ran two further ANCOVAs. State and Trait subscales were not included as covariates in the same analysis due to high overlap between the two constructs (see Table 1). The results of these analyses revealed a significant interaction of State anxiety with Emotion ($F(5, 350) = 2.846, p = .016, \eta^2 = .039$). Correlations of State anxiety with accuracy of expression recognition, collapsed across Intensity, revealed a negative relationship with fear accuracy ($r = -.251, p = .033$). All other correlations were non-significant (all $r < .23, p \geq .06$). The remaining main-effects and interactions of both State and Trait anxiety with Emotion and Intensity were non-significant (State: all $F < 1.31, p > .25$; Trait: all $F < 1.95, p > .08$).

Pupil Dilation Response

Two further ANCOVAs were used to test for the effects of State and Trait anxiety on pupil dilation responses among convicted offenders. The main effects of State and Trait anxiety, and their two- and three-way interactions with Emotion and Intensity, were all non-significant (State: all $F < 0.57, p > .53$; Trait: all $F < 1.09, p > .30$).