Pain processing and antisocial behavior: A multi-modal investigation of the roles of boldness and meanness

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Abstract

Antisocial behavior has been linked to an increased tolerance of painful stimuli; however, there is evidence that pain behavior is multi-determined. The current study used pain measures from three different modalities (pain tolerance, pain ratings, electrocortical reactivity) and assessed triarchic traits of boldness and meanness to clarify the dispositional basis of associations between pain processing and antisocial behavior. High boldness was significantly associated with blunted early neural response to painful and nonpainful stimuli as well as increased pain tolerance. High meanness was associated with blunted elaborative processing of painful images, lower ratings of perceived pain for self and others, and increased pain tolerance. Meanness also accounted for variance shared between pain processing and antisocial behavior. Findings demonstrate that boldness and meanness contribute to pain processing in different ways and suggest that meanness may uniquely account for the association between blunted pain processing and antisocial behavior.

Keywords: pain tolerance, boldness, meanness, antisocial behavior, ERP

There is a critical need to understand the mechanisms underlying antisocial behavior to aid in developing new approaches to risk assessment and management. Recent research provides evidence that individual differences in pain tolerance are associated with proneness to aggression including higher tolerance of pressure pain and electric shock tolerance associated with higher scores of self-report aggression and aggression in lab-based paradigms (Miller et al., 2014; Niel et al., 2007). These studies suggest a dispositional element to pain tolerance that relates to antisocial/aggressive behavior. Such findings have led researchers to suggest that individual differences in pain processing may represent a key element in the development of antisocial behavior (Blair, 1995; Miller et al., 2014; Niel et al., 2007; Waller & Wagner, 2019). One model posits that high personal pain tolerance leads individuals to underestimate the degree of pain experienced by others, increasing their willingness to engage in antisocial behavior that may cause pain (Niel et al., 2007). However, studies focusing on pain tolerance provide limited insight into the complex psychological experience of pain implicated in such models. Pain behaviors (i.e., self-reported experience of pain and directly observable indicants such as pain tolerance) are multi-determined, with psychological and social factors playing critical roles along with biological factors (Skevington, 1996). Therefore, multiple measurement modalities can provide non-redundant information about the experience of pain — including self-report (e.g., ratings of pain sensation), overt behavior (e.g., tolerance for pain), and physiology (e.g., brain responses to depictions of pain in others). These diverse measurement modalities are needed to clarify the basis of the observed association between pain and antisocial behavior.

Defensive Reactivity to Pain and Boldness

The affective response to pain is complex and depends, in part, on the proximity of the painful stimulus — whether it is physically experienced, imagined to be occurring, or observed in another person. Pain stimuli, which are aversive in nature and associated with threats to survival, engage psychobiological systems that detect and respond to threat (Jackson et al., 2006). Individuals vary in

their dispositional sensitivity to threat: Some exhibit extreme reactions to potential danger (e.g., an exaggerated startle response to sudden noises occurring in the context of threat), whereas others demonstrate remarkable resiliency to and even enjoyment of dangerous situations (Patrick et al., 2009, 2019). Boldness, defined by high social dominance and thrill-seeking and low stress reactivity is, in part, an index of individual differences in threat sensitivity that are relatively stable over time (Somma et al., 2015) and is associated with distinct patterns of behavior, physiological response, and clinical problems (Perkins et al., 2017; Vaidyanathan et al., 2009; Yancey et al., 2019). Of particular interest to the current study, some work has shown individual differences in boldness to be associated with antisocial behavior, particularly when accompanied by other pertinent traits (Bertoldi et al., 2021; Gottfried et al., 2019).

Given that acute pain elicits a defensive withdrawal response, it can be expected that boldness plays a role in how individuals process and respond to painful stimuli. In support of this, boldness and related traits (e.g., emotional stability, fearless dominance) have been linked to heightened pressure-pain tolerance (Miller et al., 2014) and lower reported fear of pain, pain anxiety, and pain catastrophizing (Brislin et al., 2016; Durand & Plata, 2017). Although direct empirical evidence is lacking, it seems likely that one's level of boldness would also affect reactions to images of painful situations under instructions to adopt a "self-perspective" (i.e., project themselves into the situation; Jackson, Brunet, et al., 2006; Lamm et al., 2007). Further research is needed to determine the extent to which boldness relates to these additional indices of pain responding —tolerance, reported fear of pain, and self-perspective ratings of painful situations.

Empathic Concern for Others' Pain and Meanness

Another affective process involved in pain responsivity is empathic concern, the resonant response to distress exhibited by others (Decety, 2012). In contrast to defensive reactivity, which motivates withdrawal, empathic concern for the pain of others fosters approach-oriented affiliative

responses (e.g., helping or comforting) that are adaptive for group survival. Individual differences in meanness, a construct that encompassess traits implicated in affiliative processes and social connectedness, are foundational to empathic concern (Decety, 2012). These differences a can be observed in various antagonistic forms of psychopathology (Sleep, Weiss, Lynam, & Miller, 2019; Palumbo et al., 2020), as well as in difficulties with social cognition (Brislin et al., 2018; Brislin & Patrick, 2019). Differences in meanness have also been consistently and robustly linked to antisocial behavior (weighted average effect size = .30; Sleep et al., 2019).

Given evidence for a link between pain responsivity and empathic concern (Decety, 2012), it seems likely that meanness would be associated with affective reactivity to others' pain, such as in tasks requiring participants to rate the aversiveness of pain-scenario images when adopting an "other-perspective" (Jackson, Brunet, et al., 2006; Lamm et al., 2007). However, this possibility has not yet been tested. Meanness and related traits (e.g., antagonism) have been linked to increased pressure-pain tolerance (Brislin et al., 2016; Miller et al., 2014), even when controlling for boldness (Brislin et al., 2016). This suggests that both affiliative and defensive reactivity uniquely impact pain processing and responding, alongside contextual factors and error (see Vervoort & Trost, 2017).

Event-Related Potentials and Pain Processing

In addition to the pain tolerance and picture-rating tasks described above, researchers can assess neural response during pain processing through use of event-related potentials (ERPs), which provide a non-invasive and reliable way to quantify brain reactivity to specific stimuli by measuring electrical potentials on the scalp. Early occurring ERPs typically reflect perceptual and affective reactivity whereas later occurring components reflect complex cognitive and emotional processing. Therefore, ERPs provide a useful means for quantifying individual differences in neural reactivity to vicarious pain stimuli. The use of ERPs together with experiential report-based measures can shed light on differing affective components of pain processing and how they relate to antisocial behavior.

In the pain processing literature, ERPs have typically been assessed while participants view pictures of limbs (hands and feet) in painful situations as well as pictures of non-painful (control) situations. The ERPs of interest include the N110, N240, and late positive potential (LPP) responses.

The N110 and N240 responses are maximal over frontocentral scalp sites approximately 110 and 240 ms, respectively, following picture presentation. Prior research suggests that these ERP components reflect relatively automatic encoding of the emotional content of a visual stimulus, particularly since their amplitudes do not depend on attention directed to the stimulus (Fan & Han, 2008). In pain paradigms, both the N110 and N240 have been interpreted as indexing affective sharing when viewing someone else in pain (Cui et al., 2016; Fan & Han, 2008). This interpretation is supported by evidence that instructions to imagine the painful event as occurring to oneself (self-perspective) versus someone else (other-perspective) do not modulate the N110 and N240 (Li & Han, 2010). Given that the initial affective response to pain-related stimuli entails defensive activation, the N110 and N240 in a picture-viewing paradigm may reflect a defensive withdrawal process that could covary with individual differences in boldness. Consistent with this, Li and Han (2010) reported enhanced N240 amplitude to images of pain in participants reporting higher perceived painfulness and unpleasant feelings. The current study will provide the first test of whether boldness relates to ERP indices of automatic affective sharing of pain.

The early automatic simulation of another's emotional experience is believed to form a foundation for empathy-related processes occurring later in processing of pain images (Decety, 2012). The LPP response occurs later in processing and is typically measured over parietal scalp regions from about 400 to 1,000 ms following picture presentation. LPP is indicative of active processing and depends on maintenance of attention to motivationally significant visual stimuli (Hajcak & Foti, 2020). LPP amplitude is markedly enhanced for pain-related images compared to non-pain images, with the degree of enhancement larger under self- than other-perspective viewing instructions (Li & Han,

2010). These findings indicate that the LPP response is sensitive to semantic elements. From this perspective, the amplitude of the LPP to depictions of others in pain could be expected to covary with meanness, to the extent that larger LPP in this context indexes motivational relevance regarding actions of the viewer (e.g., provision of help or comfort). Consistent with this, individual difference characteristics related to meanness (e.g., dispositional empathy, psychopathy) are selectively associated with amplitude of LPP to pain photos, but not N110 or N240, when participants are instructed to focus on the experience of the person depicted in the photo (Decety et al., 2015). These findings suggest that meanness should be associated with amplitude of LPP response to images of others in pain.

The Current Study

The current study takes a multi-modal approach to understanding individual differences in pain processing through examining associations with two key dispositional traits – boldness and meanness – that may help to account for the well-documented association between pain responding and antisocial behavior. Only one study to date, by Miller et al. (2014), has examined the role of either trait in the relationship between pain processing and antisocial behavior — finding evidence for mediating roles of callousness, antagonism, and narcissism. The authors proposed that high pain tolerance may create a context for the development of callousness, which in turn increases propensity toward antisocial behavior. However, this study relied solely on pain tolerance to index pain processing.

The current study extended this prior work by using pain measures from three different modalities — experiential report, behavioral response (tolerance), and ERPs – and assessing for variations in boldness and meanness to clarify the basis of associations between pain processing and antisocial behavior. We examined both traits together to understand their unique versus interdependent effects, given that both are theorized to develop from temperamental fearlessness (Patrick et al., 2009) and that they covary to a small but consistent degree (r = .16; Sleep et al., 2019). With regard to

measurement modalities, a major innovative feature of the current work was its inclusion of ERP measures of pain processing, which have not been used in prior studies of this type (Brislin et al., 2016; Miller et al., 2014).

Based on prior research findings and conceptual points as described above, we advanced the following hypotheses: (1) Higher scores on Boldness would relate to (a) heightened pain tolerance — though perhaps not independently of Meanness (Brislin et al., 2016); (b) lower ratings of the painfulness of pictured pain scenarios in relation to oneself (self-perspective ratings), and (c) smaller early ERP responses (N110 and N240) to pictured pain scenarios. (2) Higher scores on Meanness would relate to (a) higher tolerance for pressure pain, (b) lower other-perspective ratings of the painfulness of pictured pain scenarios, and (c) smaller LPP response to pictured pain scenarios. (3) Associations between pain processing variables and antisocial behavior would mirror those for Meanness. Specifically, higher levels of antisocial behavior would be associated (a) higher tolerance for pressure pain, (b), lower other-perspective ratings of the painfulness of pictured pain scenarios, and (c) smaller LPP response to pictured pain scenarios. (4) Meanness, rather than Boldness, would mediate associations between the pain indices and antisocial behavior. This prediction was based on prior work suggesting that the association between heightened pain tolerance and antisocial behavior is attributable to low empathic concern (Miller et al., 2014).

Method

Participants

A total of 118 participants were recruited from the undergraduate student population of [MASKED] via an online screening survey administered to all introductory psychology classes. The sample was 49.2% female and had a mean age of 19.5 years (*SD* = 3.8 range = 17 to 56). Seventy-eight percent of the sample was white, 8.5% of the sample was African American, 3.4% of the sample was Asian, and 69.5% of the sample was non-Hispanic. All study participants were either currently

enrolled in college or had completed at least one year of college. Study participants were compensated $10 per hour or with class credit for their voluntary participation. All study procedures were approved by [MASKED] Institutional Review Board, and all participants provided written informed consent prior to commencement of data collection.

Questionnaire Measures

The Triarchic Psychopathy Measure (TriPM; Patrick, 2010) is a 58-item questionnaire that assesses trait constructs of boldness, (Patrick et al., 2019b), and meanness (Palumbo et al., 2020) — along with a third trait reflecting variations in inhibitory control capacity (i.e., disinhibition). The Boldness and Meanness scales (each 19 items) of the TriPM have been extensively validated in relation to physiological and behavioral as well as report-based criterion measures (for reviews, see: Patrick, 2018; Patrick et al., 2019; Patrick & Drislane, 2015). These scales were scored by taking the mean of items, rated 0-3, and then dividing by 3 resulting in scores with a possible range from 0-1. These two TriPM scales demonstrated high internal consistency reliability in the current sample (Cronbach's αs = .82 and .90 for Boldness and Meanness, respectively).

Participants also completed an abbreviated version of the Crime and Analogous Behavior scale (CAB; Miller & Lynam, 2003) containing scales covering aggressive and non-aggressive antisocial behavior (CAB-AB; 9 items). In the current sample, this brief CAB-AB scale demonstrated acceptable reliability (Cronbach's α = .76).

Stimuli and Procedure

Algometer Testing

Two different pressure algometers were used for different portions of the study sample, a hand-operated instrument and an automated one.

Hand-Operated Algometer. For 34 participants, pain tolerance was assessed using the hand-operated pressure algometer (AlgoMed Algometer FPIX 50; Medoc USA, Durham, NC). This device

was used to induce pressure on the dorsal side of the participant's dominant hand (medial placement between knuckles of pointer finger and middle finger). The experimenter applied progressively increasing pressure at an approximate rate of 50 kPa/s to the hand until the participant said "stop," indicating that the level reached was the maximum amount of pain they could stand. This measurement was performed a total of five times per participant, and the average of the maximum pressure endured was used as a measure of individual pain tolerance. These measurements were separated by 30-second pauses to allow pressure sensation to return to baseline. Reliability for the five different measurements with this instrument was excellent (Cronbach's α = .96), in line with prior literature (Pollatos et al., 2012).

Automated Algometer. Pain tolerance for the other 63 participants was assessed using an automated algometer consisting of a computer-controlled mechanical device designed for purposes of this study. The pressure tip was modeled after that of the manual algometer described above. All other specifications remained identical, including the five measurements separated by 30 s each and the rate of pressure increase (50 kPa/s). As with the hand-operated algometer, reliability of the different measurements with the automatic algometer was excellent (Cronbach's α = .98).

Data from an additional 21 participants were excluded from the analyses ($n_{hand\text{-}operated}$ = 19, $n_{automated}$ = 2). This due either to experimenter error in administration of the hand-operated algometer (i.e., pressure applied to a different part of the hand; n = 19) or to discontinuation after an anomalously low number of pressure trials (i.e., fewer than 5; n = 2). The type of algometer used had no influence on pain tolerance ($t_{(87.27)}$ = .08, p = .94), and thus data for the two algometer types were collapsed for purposes of our main reported analyses.

Pain Task

The pain task consisted of two parts, with participants first passively viewing painful and non-painful images with recording of ERP responses, and then viewing and rating the same images under

both self- and other-perspective instructions. Picture stimuli were presented using the E-Prime 3.0 software package (Psychology Software Tools, Pittsburgh, PA). These two parts of the task are described below.

Pain Task: Passive Viewing. Participants viewed a series of 128 color pictures, each depicting either the right hand or right foot of people in various painful and non-painful situations (Jackson et al., 2005). The situations were everyday or close-to-everyday ones (e.g., working in the garden with a shovel), presented in painful and non-painful (neutral) variants (e.g., garden shovel hitting bare foot, vs. positioned at a safe distance from foot). The painful variants depicted noxious stimulation of differing types (mechanical, thermal, pressure) and degree of injury that would be inflicted (e.g., varying from a finger being hammered to a foot being run over by a car). Participants first passively viewed each of the pictures once, during which time EEG data were collected. Each picture was presented for 1400 to 1700 ms, with an inter-stimulus interval of 300 to 600 ms. Together, these jittered periods contributed to a variable inter-trial interval, averting the possibility that alpha-wave activity would become time-locked to the stimulus (Luck, 2014; Woodman, 2010). The duration of this portion of the task was approximately 5 minutes. The limb pictured (hand or foot) had no influence on any of the study results, as reported in Supplemental Tables 3 and 4; thus, data for the two limbs were collapsed for purposes of our main reported analyses.

Pain Task: Behavioral Ratings. Following the passive viewing portion of the task, participants viewed the same pictures again and rated the severity of pain depicted in each scene on a 4-point Likert scale ranging from “no pain” to “worst possible pain.” Rating responses were recorded using the E-Prime 3.0 software package (Psychology Software Tools, Pittsburgh, PA). In this part of the procedure, each pictured scene was viewed and rated twice. As the aim was to assess the perceived painfulness of each stimuli under both self- and other-perspective situations, the instructional conditions were blocked, such that 8 consecutive images always had the same instruction (“yourself”

or “someone else”) before switching to the other instruction. Each block also included a single category of image (painful or non-painful hand or foot), and the different blocks were presented in a pseudorandom order with the restriction that no block of a specific picture category under the same instructional condition was presented consecutively. An average rating was calculated for each instructional condition (self, someone else) within each scene type (painful, non-painful), resulting in four average rating scores for each participant; again, hand and foot ratings were collapsed given the strong convergence of these ratings (see Supplemental Tables 3 and 4). Each picture was presented for a duration of 1400 to 1700 ms, with a varying inter-stimulus interval of 200 to 400 ms. Participants were allowed the same length of time as that trial’s picture presentation to enter a rating (i.e., 1400 to 1700 ms). The duration of this portion of the task was approximately 15 minutes.

EEG Data Processing and Reduction. Neural reactivity to painful and non-painful scenes was measured during the passive viewing phase using 128 scalp electrodes embedded in a NeuroScan Quik-Cap, positioned according to Neuroscan’s nonstandard layout (NSL) configuration. Additional electrodes were placed above and below the left eye, and adjacent to the outer canthi of the left and right eyes, in order to record vertical and horizontal electrooculographic (EOG) activity, respectively. Impedances for all electrodes were kept below 10 KΩ. The raw EEG signal was continuously recorded at a rate of 1000 Hz and bandpass filtered online at 0.05-200 Hz using a Neuroscan Synamps system, referenced online to electrode 64 (analogous to CPz in the standard 10-20 layout). Offline, EEG data were arithmetically re-referenced to the average of left and right mastoid electrodes. The filtered continuous EEG recording was epoched from -1000 ms before stimulus onset to 2000 ms after stimulus onset, and corrected for eye movements using the algorithm developed by Semlitsch et al. (1986), implemented within the EDIT version 4.5 software package (Neuroscan, Inc.). The data were then imported into Matlab (Mathworks, Inc., Natick, MA) for further processing using the EEGLAB (Delorme & Makeig, 2004) and ERPLAB (Lopez-Calderon & Luck, 2014) Toolboxes. EEG data were

first downsampled to 128 Hz with application of an anti-aliasing filter. Trial epochs on which signal activity exceeded a ±75 μV threshold were omitted from further processing (*M* = 6.33% SD = 7.99). Data from bad electrodes (those with more than 25% of trial epochs rejected) were interpolated using the EEGLAB spherical spline interpolation function. Accepted epochs were averaged across foot and hand trials within condition (painful image, non-painful image).

ERP Quantification. The average epoched signal was baseline corrected by subtracting the mean EEG amplitude across a 200 ms pre-stimulus interval from each aggregate time point. Electrodes and time windows for quantifying the ERPs of interest were determined based on the scalp distribution and timing of the current data (see Figure S1 for grand average waveforms and scalp topographies) and prior ERP research on pain empathy indicating maximal activity at frontocentral scalp sites for the N110 and N240 components, and a centroparietal maximum for the LPP component (Coll, 2018). Given evidence for superior reliability of ERP measurements when quantified across multiple electrodes (Huffmeijer et al., 2014), electrodes spanning from Fz to Cz (NSL electrode numbers: 60, 61, 62 and 63) were pooled to quantify N110 and N240 amplitudes, defined as the peak negativity evident in the ERP waveform between 120-180 ms and 220-280 ms, respectively (e.g., Fan & Han, 2008; Meng et al., 2013). LPP response was defined as mean activity during a subsequent window of 400-1000 ms, pooled across 5 electrodes spanning from Cz to POz (NSL electrode numbers: 63, 64, 65, 66, 67), consistent with prior research on pain empathy ERPs and psychopathic traits (cf. Decety et al., 2015). Reliabilities for ERP measures were computed using split-half (odd-even method) correlations, adjusted for attenuation using the Spearman-Brown prophecy formula (see Supplemental Table 1).

Analytic Approach

All statistical analyses were performed using version 24 of the SPSS Statistics package (IBM Corporation, 2016). Pearson correlations were used to quantify simple bivariate relations of TriPM

Meanness, TriPM Boldness, and CAB-AB scale scores with pain tolerance, ERP amplitudes, and self- and other-perspective pain ratings. In addition, hierarchical regression analyses were conducted to test for unique associations of TriPM Boldness and Meanness with these three types of dependent measures, when accounting for overlap between the two scales. For the pain tolerance variable, participant sex was entered as a predictor at Step 1, given evidence for sex effects on pain tolerance (Fillingim et al., 2009), followed by TriPM Boldness and Meanness scale scores at Step 2.[1] For pain ratings, separate regression analyses were conducted for the self- and other-pain variables; in each of these analyses, ratings for the corresponding no-pain condition were entered at Step 1, followed by scores for the Boldness and Meanness scales at Step 2. For ERP response to painful picture stimuli, separate regression analyses were conducted for each ERP component measure; in each of these analyses, the corresponding ERP response to non-painful stimuli was entered at Step 1, followed by TriPM Boldness and Meanness scale scores at Step 2.

Finally, given prior work suggesting that affiliative capacity accounts for associations between pain responsivity and antisocial behavior (Miller et al., 2014), we performed a series of mediation analyses[2], wherein we examined the indirect effect of affiliative capacity (operationalized via TriPM Meanness scale score) on the association between antisocial behavior and indicators of pain processing from each measurement modality. *Post hoc* bias-corrected bootstrapped indirect effect analyses were conducted using the SPSS PROCESS macro, model 4 (Hayes, 2017) to evaluate the indirect effect of TriPM Meanness in the observed associations between pain processing variables (i.e., pain tolerance, self- and other-perspective pain ratings, LPP amplitude to pain and non-pain images) and CAB-AB

[1] A supplemental analysis was performed with algometer type included as an additional predictor at Step 1. Consistent with the null findings for independent t-tests, no predictive association was evident for this variable at Step 1, and associations for the other predictors at Steps 1 and 2 were highly comparable regardless of its inclusion.

[2] While the analytic approach that we used is commonly referred to as a mediation model, our goal was to test the indirect effect of the Meanness scale on associations between pain processing and antisocial behavior. None of these analyses were performed with the goal of determining causality as all data are cross sectional. Therefore, the terminology used in this paper (e.g., referring to the Meanness scale as a mediator) should not be taken to imply that these analyses are meant to support claims of causality.

scores. In separate models (see Figure 1), pain tolerance, self- and other-perspective pain ratings, and LPP amplitude to pain and non-pain images were the independent variables, TriPM Meanness was the mediator, and CAB-AB was the dependent variable. Bootstrapping (5,000 resamples) was performed to determine bias-corrected 95% confidence intervals (Cis; Preacher & Hayes, 2004).

Results

Descriptive statistics and reliability coefficients for all study variables are presented in Supplemental Table 1. Intercorrelations among all study variables are shown in Supplemental Table 2.

Pain Tolerance. Associations of TriPM Boldness and Meanness scales with pain tolerance, measured via algometer, were examined using Pearson correlations and a hierarchical regression analysis (Table 1). TriPM Boldness and Meanness each showed positive bivariate *r*s with algometer pain tolerance. When sex was entered as the predictor of pain tolerance at Step 1 of a hierarchical regression model, the addition of Boldness and Meanness as predictors at Step 2 resulted in a significant increase in R^2 over the baseline model, but neither trait demonstrated a unique predictive association.

The CAB-AB showed a significant positive correlation with pain tolerance at the bivariate level ($r = .21$, $p = .04$). However, the association for this antisocial behavior scale with pain tolerance fell below significance ($\beta = .16$, $p = .10$) when it was entered at the second step of a hierarchical regression model following the entry of sex at Step 1.

Pain Ratings. Table 2 shows correlations (*r*s) for TriPM Boldness and Meanness scale scores with ratings of pain intensity for depictions of painful and non-painful situations under instructions to imagine oneself ("self-perspective") or someone else ("other-perspective") in that situation. At the bivariate level, Boldness and Meanness scale scores were not related to ratings of non-painful scenes (either perspective), nor other-perspective painful scenes. However, a negative association was evident for TriPM Meanness with ratings of self-perspective painful scenes ($r = -.27$, $p = .01$) and other-

perspective scenes (r = -.20, p = .04). Hierarchical regression analyses examining concurrent predictive relations of TriPM Boldness and Meanness with ratings of pain scenes at Step 2, after entering ratings for no-pain scenes at Step 1, revealed unique negative associations for only Meanness with ratings of both self- and other-perspective painful situations (β = -.24, p = .02 and β = -.23, p = .03, respectively; see Table 2).[3]

CAB-AB scores were negatively associated with self-perspective (r = -.26, p = .01) and other-perspective (r = -.20, p = .04) ratings of painful, but not non-painful, situations. In hierarchical regression models controlling for counterpart no-pain ratings at Step 1, these significant associations were maintained for both self- and other-perspective ratings (β = -.26, p = .009 and β = -.20, p = .04, respectively).

Electrocortical Response. Associations of the TriPM Boldness and Meanness scales with ERP components of interest — N110, N240, and LPP, for painful and non-painful scenes separately — were quantified using bivariate correlations and hierarchical regression analyses (see Table 3). At the bivariate level, TriPM Boldness was positively associated with N110 and N240, (i.e., higher Boldness was related to weaker negative-going response in each case; Figure 1) for both painful and non-painful scenes, and TriPM Meanness was negatively related to LPP (i.e., higher Meanness was related to weaker positive-going response; Figure 2) for painful scenes specifically.

Separate hierarchical regression models were conducted for each component of ERP response to painful scenes, with the counterpart ERP response to non-painful scenes entered at Step 1, and the TriPM Boldness and Meanness scale scores entered at Step 2. Despite significant bivariate correlations with early ERP components to pain images, Boldness was not significantly associated with N110 and N240 components to pain after controlling for the corresponding no-pain condition. Meanness alone showed a unique association in the model for LPP response (β = -.15, p = .02). The change in R^2 at

[3] See Supplemental Table 4 for highly similar results for ratings of hand and foot stimuli separately.

Step 2 was not significant for any of the models, indicating that the addition of TriPM Boldness and Meanness scales did not contribute significantly to pain-scene ERP response, over and above counterpart ERP response to non-pain scenes.[4]

In addition, LPPs to both pain and non-pain stimuli were negatively related to CAB-AB (r = -.18, p = .05 and r = -.23, p = .02, respectively), although the association with LPP to pain falls just short of significance. In a regression model where LPP scores for stimuli of the two types were included as concurrent predictors of CAB-AB score, neither one emerged as significant (LPP Pain β = -.02, p = .89; LPP No Pain β = -.21, p = .14), although the overall regression model was significant (R = .25, p = .03).

Mediating Role of Meanness in Relations between Pain Measures and Antisocial Behavior. There was a significant indirect effect of TriPM Meanness on the association between pain tolerance and CAB-AB (standardized indirect effect coefficient = .12, 95% CI: [.03, .24]; Figure 3A). This indicates that TriPM Meanness scores accounted for the bivariate association between pain tolerance and antisocial behavior. However, when controlling for sex as a covariate in the model, the indirect effect was not significant (standardized coefficient = .10, 95% CI: [-.01, 21]). Paralleling the earlier regression analysis examining joint effects of Boldness and Meanness on pain tolerance, a follow-up analysis was conducted evaluating roles for the two traits, as concurrent mediators. This model revealed a significant total indirect effect for the two traits (standardized coefficient = .15, 95% CI: [.06, .26]), with the indirect effect for Meanness emerging as significant (standardized coefficient = .12, 95% CI: [.02, .24]), but not the indirect effect for Boldness (standardized coefficient = .03, 95% CI: [-.03, .13]).

A significant indirect effect of TriPM Meanness was also found for the association between self-perspective pain ratings and CAB-AB (standardized coefficient = -.12, 95% CI: [-.23, -.02]; Figure

[4] See Supplemental Table 3 for highly similar results for ERPs to hand and foot stimuli separately.

3B), indicating that Meanness scores accounted for the observed association between low ratings of one's own pain and increased antisocial behavior. By contrast, the indirect effect of Meanness on the association between other-perspective pain ratings and CAB-AB was non-significant (standardized indirect effect coefficient = -.08, 95% CI: [-.19, .00]).

There was also a significant indirect effect of TriPM Meanness on the association between LPP to pain images and CAB-AB (standardized coefficient = -.10, 95% CI: [-.19, -.02]).[5] That is, TriPM Meanness scores accounted for the association between blunted LPP to painful images and reported engagement in antisocial behavior. However, no mediating effect of Meanness was found for the association between LPP to non-pain images and CAB-AB scores (standardized indirect effect coefficient = -.05, 95% CI: [-.14, .03]), indicating that Meanness accounted only for variance in CAB-AB scores that overlapped with LPP response to pain images.

Discussion

The current study examined how indices of pain processing from different assessment modalities relate to traits of boldness and meanness (operationalized using the TriPM), and whether these traits might account for associations between pain responding and antisocial behavior. Findings from this work demonstrate associations for boldness and meanness with different aspects of pain processing and provide evidence that meanness uniquely accounts for the relationship between blunted pain responding and risk for antisocial behavior.

As noted at the outset, a particularly innovative feature of the current work was its inclusion of ERP measures of pain processing. Consistent with hypotheses, boldness was significantly associated with early ERPs (N110, N240) to visual pain images. These results are the first to connect these early ERP responses to pain-related images with individual differences in threat sensitivity. Contrary to our

[5] The indirect effect of TriPM Meanness was consistent when controlling for LPP to non-pain as a covariate with a significant indirect effect of Meanness (standardized indirect effect = -.15, 95% CI: [-.34. -.12].

hypotheses, we found that TriPM-assessed boldness was also associated negatively with amplitude of N110 and N240 response to non-painful images. This result can be interpreted in relation to evidence from a recent meta-analytic study suggesting that these two ERP components do not reliably differentiate between painful and non-painful scenes when the two are intermingled (Coll, 2018). The implication of this finding is that these early visual ERPs are broadly influenced by affective context, leading to enhanced early-ERP responding to all images within the series. Current study results indicate that individuals higher in boldness show less of this effect. This accords with prior research showing that high-bold individuals are less sensitive to the presence of threat cues during performance of a cognitive-attentional task (Dvorak-Bertsch et al., 2009; Yancey et al., 2019).

Contrary to our hypotheses, boldness as indexed by the TriPM did not significantly predict reduced ratings of perceived pain in the self-perspective condition. The observed association was negative (r = -.15) as predicted, but the associated p-value (p = .13) did not achieve significance given the N of 104 for this analysis. Of note, a similar-magnitude correlation (r = -.18), also falling below significance, was reported by Brislin et al. (2016; N = 95) between boldness and ratings of experienced pain collected following an algometer test procedure. Statistical power to detect these effects is discussed in the limitations section below.

At the bivariate level, both boldness and meanness were significantly associated with pain tolerance, such that individuals reporting higher levels of boldness and meanness also withstood higher levels of algometer pressure. This finding accords with prior work showing that scale measures relevant to each trait were related to higher pressure-pain tolerance (Miller et al., 2014). In the current study, when controlling for sex and the moderate overlap between scores for the two traits (r = .31), neither boldness nor meanness maintained a unique association with pain tolerance. Nonetheless, their inclusion in the model resulted in a significant increase in R^2. This finding indicates that the shared variance between these two traits contributed importantly to bivariate relations of each with pressure

pain tolerance. Conceptually, individual differences in boldness and meanness in adulthood are each believed to emerge in part from a temperamental dimension of fear/fearlessness (Patrick et al., 2009). This common substrate could be what links threat sensitivity and affiliative capacity to pain tolerance. Interestingly, the only other study that has directly compared the two traits found that pain tolerance was associated more strongly with meanness than with boldness (Brislin et al., 2016). Further work is needed to clarify these contrasting findings. One explanation may be that Brislin et al. (2016) did not examine or control for sex differences, despite evidence for such differences in measures of pain tolerance (Fillingim et al., 2009) and the two traits of interest (Drislane & Patrick, 2017). Besides evaluating the replicability of our finding of a shared association for boldness and meanness with pressure pain tolerance, future research should examine whether this association generalizes to other forms of pain (e.g., shock- or heat-induced pain).

As hypothesized, meanness as indexed by the TriPM was associated with reduced brain-LPP response to scenes of pain infliction under simple (passive) viewing conditions. This finding coincides with results from prior pain-ERP research (Decety et al., 2015) and indicates that high-callous individuals are less responsive to the pain of others at a basic neuro-affective level. Given evidence that reactivity at this basic level promotes prosocial action in the form of comforting or helping behavior (Decety, 2012), its relative absence suggests a mechanism for the exploitative disregard exhibited by individuals high in dispositional meanness. These findings, considered alongside research demonstrating individuals high in meanness also show a blunted LPP response to facial expressions of fear and sadness (Brislin & Patrick, 2019), suggest that meanness reflects a blunted processing of distress cues more broadly (Blair, 1995), rather than being limited to expressions of pain.

Complementing the findings for ERP response, our use of behavioral ratings in the current study provides information regarding how meanness relates to perceptions of pain in scenes of noxious stimulation or injury. As hypothesized, individuals scoring high in meanness rated scenes of this type

as less painful when viewing them under the "other" (happening to someone else) instruction. However, we also found that high-meanness individuals rated noxious/injurious scenes as less painful when viewing them under the "self" (happening to yourself) instruction. One potential explanation for this unexpected finding is that reduced sensitivity to pain in others is related, in part, to a lowered perception of the pain of noxious stimulation to oneself (i.e., "What doesn't bother me shouldn't bother you.").

As hypothesized, the pattern of associations between pain measures and antisocial behavior largely mirrored their associations with dispositional meanness. Higher pain tolerance was associated with greater CAB-AB scores, although only at the bivariate level. When sex was included as a covariate in the analysis, the association was no longer significant. Males demonstrated significantly higher levels of pain tolerance and scored significantly higher on the CAB-AB scale than females (r between CAB-AB and algometer tolerance in males = .25, p = .09; for females, r = .11, p = .47). In addition, higher CAB-AB scores were associated with smaller LPP amplitude to the painful as well as the non-painful images, although neither was uniquely associated with antisocial behavior in the regression model. Antisocial behavior is associated with impulsive-disinhibitory personality traits along with low affiliative capacity, which could have adversely affected attentional processing of images in general, regardless of content. Higher levels of antisocial behavior were also associated with lower ratings of self- and other-perspective pain, similar to the results for affiliative capacity.

Based on current results together with findings from a previous study that evaluated low affiliative capacity as a mediator of the association between pain tolerance and antisocial behavior (Miller et al., 2014), we performed mediation analyses to determine whether TriPM-assessed meanness might account for observed associations between pain processing variables and antisocial behavior. Analyses revealed that meanness scores accounted for the associations of pain tolerance, LPP response to pain images, and self-perspective ratings of pain images with antisocial behavior. These results are

consistent with a model advanced by Niel and colleagues' (2007) to characterize relations among high pain tolerance, deficits in pain-related social cognition, and antisocial behavior, which posits that low affiliative capacity accounts for shared variance across these phenomena. Future work replicating these findings in larger samples and using etiologically informative (e.g., longitudinal, twin) datasets is needed to better understand the nature and bases of relations among atypical pain processing, low affiliative capacity, and increased antisocial behavior.

The current study is the first to use data from multiple measurement modalities — behavioral tolerance, experiential ratings, and brain response — to examine how pain processing relates to clinically-relevant biobehavioral traits and antisocial behavior. A novel finding emerging from this work is that although different measures were generally correlated *within* modality (e.g., N110 and N240 to pain images correlated $r = .68$), divergence was evident *across* modalities. In particular, none of the ERP measures was significantly related to either pain tolerance or pain ratings. These findings suggest that each measure captures distinct facets of pain processing and highlight the need for a multi-modal approach to operationalizing pain in studies examining how pain processing relates to clinical phenomena such as antisocial behavior and associated trait characteristics.

Some limitations of the current study warrant mention. One is that our sample consisted primarily of college students, 78% of whom were White, and no data was collected on culture and geographic background. Follow-up studies employing more diverse samples in terms of age, education level, cultural background, and race/ethnicity are needed to establish the generalizability of our findings. In addition, though the range of scores on the TriPM Boldness and Meanness scales indicated sufficient representation of individuals across the range of each target trait, most participants reported low levels of antisocial behavior. Results from the current study need to be replicated in samples exhibiting higher rates of antisocial behavior such as correctional or forensic hospital samples, to affirm their robustness, using measures that distinguish between aggressive and non-aggressive forms of antisocial behavior.

Our study had a relatively small sample, which limited our power to detect small effects as well as our ability to perform more computationally nuanced analyses (e.g., formally modeling variance shared across pain measures). A sensitivity power analysis conducted using G*Power v3.1 (Faul et al., 2007) revealed that, at an alpha level of .05 and with desired power of .80, the minimal detectable effects (in terms of bivariate associations, two-tailed tests) that our study could reliably detect were effects of |.29| for pain tolerance (N = 92), |.27| for pain ratings (N = 104), and |.26| for pain ERPs (N = 113). In addition, the majority of our findings (only two out of 13 hypothesized tests) would survive the Benjamini-Hochberg false discovery rate correction. While further work with larger samples is needed to more conclusively test for associations between boldness, meanness, and multimodal measures of pain processing, our findings are of similar magnitude and consistent with those reported in previous studies (e.g., Decety et al., 2015; Miller et al., 2014)

Despite these limitations, the current study is the first to examine relations between multi-modal indices of pain processing and antisocial behavior and explore the roles of boldness and meanness in these relations. The study provides evidence that boldness and meanness are differentially associated with indices of pain from particular modalities, and that it is meanness — not boldness — that accounts for relations of facets of pain processing with antisocial behavior. Our study also contributes to basic understanding of pain by showing that different measures of pain processing index distinct affective processes, highlighting the need to account for this complexity in future research to reconcile and integrate contrasting findings. The current work also contributes to conceptual understanding of antisocial behavior and sets the stage for future work examining meanness as an attribute contributing to deficits in recognizing, sympathizing with, and responding to the pain of others.

References

Berke, D. S., Reidy, D. E., Miller, J. D., & Zeichner, A. (2016). Take it like a man: Gender-threatened men's experience of gender role discrepancy, emotion activation, and pain tolerance. *Psychology of Men & Masculinity*, *18*(1), 62. https://doi.org/10.1037/men0000036

Berkowitz, L. (2003). Affect, aggression, and antisocial behavior. In R. J. Davidson, K. R. Scherer, & H. H. Goldsmith (Eds.), *Handbook of Affective Sciences* (pp. 804–823). Oxford University Press.

Bertoldi, B. M., Perkins, E. R., Tuvblad, C., Oskarsson, S., Kramer, M. D., Latzman, R. D., Baker, L. A., Raine, A., & Patrick, C. J. (2021). Pursuing the developmental aims of the triarchic model of psychopathy: Creation and validation of triarchic scales for use in the USC: RFAB longitudinal twin project. *Development and Psychopathology*, 1–16.

Blair, R. (1995). A cognitive developmental approach to morality: Investigating the psychopath. *Cognition*, *57*(1), 1–29. https://doi.org/10.1016/0010-0277(95)00676-P

Brislin, S. J., Buchman-Schmitt, J. M., Joiner, T. E., & Patrick, C. J. (2016). "Do unto others"? Distinct psychopathy facets predict reduced perception and tolerance of pain. *Personality Disorders: Theory, Research, and Treatment*, *7*(3), 240. https://doi.org/10.1037/per0000180

Brislin, S. J., & Patrick, C. J. (2019). Callousness and affective face processing: Clarifying the neural basis of behavioral-recognition deficits through the use of brain event-related potentials. *Clinical Psychological Science*, *7*(6), 1389–1402. https://doi.org/10.1177/2167702619856342

Brislin, S. J., Yancey, J. R., Perkins, E. R., Palumbo, I. M., Drislane, L. E., Salekin, R. T., Fanti, K. A., Kimonis, E. R., Frick, P. J., Blair R., J. R., & Patrick, C. J. (2018). Callousness and affective face processing in adults: Behavioral and brain-potential indicators. *Personality Disorders*, *9*(2), 122–132. https://doi.org/10.1037/per0000235

Coll, M.P. (2018). Meta-analysis of ERP investigations of pain empathy underlines methodological issues in ERP research. *Social Cognitive and Affective Neuroscience*, *13*(10), 1003–1017.

Cui, F., Zhu, X., Duan, F., & Luo, Y. (2016). Instructions of cooperation and competition influence the neural responses to others' pain: An ERP study. *Social Neuroscience*, *11*(3), 289–296. https://doi.org/10.1080/17470919.2015.1078258

Decety, J. (2012). Putting together phylogenetic and ontogenetic perspectives on empathy. *Developmental Cognitive Neuroscience*, 24.

Decety, J., Lewis, K. L., & Cowell, J. M. (2015). Specific electrophysiological components disentangle affective sharing and empathic concern in psychopathy. *Journal of Neurophysiology*, *114*(1), 493–504. https://doi.org/10.1152/jn.00253.2015

Delorme, A., & Makeig, S. (2004). EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, *134*(1), 9–21.

Drislane, L. E., & Patrick, C. J. (2017). Integrating Alternative Conceptions of Psychopathic Personality: A Latent Variable Model of Triarchic Psychopathy Constructs. *Journal of Personality Disorders*, *31*(1), 110–132. https://doi.org/10.1521/pedi_2016_30_240

Drislane, L. E., Patrick, C. J., & Arsal, G. (2014). Clarifying the content coverage of differing psychopathy inventories through reference to the Triarchic Psychopathy Measure. *Psychological Assessment*, *26*(2), 350.

Drislane, L. E., Patrick, C. J., Sourander, A., Sillanmäki, L., Aggen, S. H., Elonheimo, H., Parkkola, K., Multimäki, P., & Kendler, K. S. (2014b). Distinct variants of extreme psychopathic individuals in society at large: Evidence from a population-based sample. *Personality Disorders: Theory, Research, and Treatment*, *5*(2), 154–163. https://doi.org/10.1037/per0000060

Durand, G., & Plata, E. M. (2017). The effects of psychopathic traits on fear of pain, anxiety, and stress. *Personality and Individual Differences*, *119*, 198–203. https://doi.org/10.1016/j.paid.2017.07.024

Fan, Y., & Han, S. (2008). Temporal dynamic of neural mechanisms involved in empathy for pain: An event-related brain potential study. *Neuropsychologia*, *46*(1), 160–173. https://doi.org/10.1016/j.neuropsychologia.2007.07.023

Fillingim, R. B., King, C. D., Ribeiro-Dasilva, M. C., Rahim-Williams, B., & Riley, J. L. (2009). Sex, Gender, and Pain: A Review of Recent Clinical and Experimental Findings. *The Journal of Pain*, *10*(5), 447–485. https://doi.org/10.1016/j.jpain.2008.12.001

Gottfried, E. D., Harrop, T. M., Anestis, J. C., Venables, N. C., & Sellbom, M. (2019). An examination of triarchic psychopathy constructs in female offenders. *Journal of Personality Assessment*, *101*(5), 455–467. https://doi.org/10.1080/00223891.2018.1502193

Hajcak, G., & Foti, D. (2020). Significance?... Significance! Empirical, methodological, and theoretical connections between the late positive potential and P300 as neural responses to stimulus significance: An integrative review. *Psychophysiology*, *57*(7), e13570.

Hayes, A. F. (2017). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd ed.). The Guilford Press.

Huffmeijer, R., Bakermans-Kranenburg, M. J., Alink, L. R., & Van IJzendoorn, M. H. (2014). Reliability of event-related potentials: The influence of number of trials and electrodes. *Physiology & Behavior*, *130*, 13–22.

Jackson, P.L., Meltzoff, A.N. & Decety, J. (2005). How do we perceive the pain of others? A window into the neural processes involved in empathy. *NeuroImage, 24*(3), 771-779.

Jackson, P. L., Rainville, P., & Decety, J. (2006). To what extent do we share the pain of others? Insight from the neural bases of pain empathy: *Pain*, *125*(1), 5–9. https://doi.org/10.1016/j.pain.2006.09.013

Lamm, C., Batson, C. D., & Decety, J. (2007). The neural substrate of human empathy: Effects of perspective-taking and cognitive appraisal. *Journal of Cognitive Neuroscience*, *19*(1), 42–58.

Li, W., & Han, S. (2010). Perspective taking modulates event-related potentials to perceived pain. *Neuroscience Letters*, *469*(3), 328–332. https://doi.org/10.1016/j.neulet.2009.12.021

Lopez-Calderon, J., & Luck, S. J. (2014). ERPLAB: an open-source toolbox for the analysis of event-related potentials. *Frontiers in Human Neuroscience*, *8*, 213.

Luck, S. J. (2014). *An introduction to the event-related potential technique* (2nd ed.). MIT Press.

Meng, J., Jackson, T., Chen, H., Hu, L., Yang, Z., Su, Y., & Huang, X. (2013). Pain perception in the self and observation of others: An ERP investigation. *Neuroimage*, *72*, 164–173.

Miller, J. D., & Lynam, D. R. (2003). Psychopathy and the five-factor model of personality: A replication and extension. *Journal of Personality Assessment*, *81*(2), 168–178.

Miller, J. D., Rausher, S., Hyatt, C. S., Maples, J., & Zeichner, A. (2014). Examining the relations among pain tolerance, psychopathic traits, and violent and nonviolent antisocial behavior. *Journal of Abnormal Psychology*, *123*(1), 205–213. https://doi.org/10.1037/a0035072

Niel, K. A., Hunnicutt-Ferguson, K., Reidy, D. E., Martinez, M. A., & Zeichner, A. (2007). Relationship of Pain Tolerance with Human Aggression. *Psychological Reports*, *101*(1), 141–144. https://doi.org/10.2466/pr0.101.1.141-144

Palumbo, I. M., Perkins, E. R., Yancey, J. R., Brislin, S. J., Patrick, C. J., & Latzman, R. D. (2020). Toward a multimodal measurement model for the neurobehavioral trait of affiliative capacity. *Personality Neuroscience*, *3*. https://doi.org/10.1017/pen.2020.9

Patrick, C. (2010). Triarchic psychopathy measure (TriPM). *PhenX Toolkit Online Assessment Catalog*, *813*, 814.

Patrick, C. J., & Drislane, L. E. (2015). Triarchic Model of Psychopathy: Origins, Operationalizations, and Observed Linkages with Personality and General Psychopathology: Triarchic Model of Psychopathy. *Journal of Personality*, *83*(6), 627–643. https://doi.org/10.1111/jopy.12119

Patrick, C. J., Fowles, D. C., & Krueger, R. F. (2009). Triarchic conceptualization of psychopathy: Developmental origins of disinhibition, boldness, and meanness. *Development and Psychopathology*, *21*(3), 913–938. https://doi.org/10.1017/S0954579409000492

Patrick, C. J., Iacono, W. G., & Venables, N. C. (2019a). Incorporating neurophysiological measures into clinical assessments: Fundamental challenges and a strategy for addressing them. *Psychological Assessment, 31*(12), 1512–1529.

Patrick, C. J., Kramer, M. D., Vaidyanathan, U., Benning, S. D., Hicks, B. M., & Lilienfeld, S. O. (2019). Formulation of a measurement model for the boldness construct of psychopathy. *Psychological Assessment*, *31*(5), 643.

Perkins, E. R., Yancey, J. R., Drislane, L. E., Venables, N. C., Balsis, S., & Patrick, C. J. (2017). Methodological issues in the use of individual brain measures to index trait liabilities: The example of noise-probe P3. *International Journal of Psychophysiology*, *111*, 145–155.

Pollatos, O., Füstös, J., & Critchley, H. D. (2012). On the generalised embodiment of pain: How interoceptive sensitivity modulates cutaneous pain perception. *Pain, 153*(8), 1680–1686.

Preacher, K. J., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments, & Computers, 36*(4), 717–731. https://doi.org/10.3758/BF03206553

Reidy, D. E., Dimmick, K., MacDonald, K., & Zeichner, A. (2009). The relationship between pain tolerance and trait aggression: Effects of sex and gender role. *Aggressive Behavior*, *35*(5), 422-429.

Séguin, J. R., Pihl, R. O., Boulerice, B., Tremblay, R. E., & Harden, P. W. (1996). Pain Sensitivity and Stability of Physical Aggression in Boys. *Journal of Child Psychology and Psychiatry*, *37*(7), 823–834. https://doi.org/10.1111/j.1469-7610.1996.tb01478.x

Semlitsch, H. V., Anderer, P., Schuster, P., & Presslich, O. (1986). A Solution for Reliable and Valid Reduction of Ocular Artifacts, Applied to the P300 ERP. Psychophysiology, 23(6), 695–703.

Skevington, S. M. (1995). *Psychology of pain* (pp. xi, 348). John Wiley & Sons.

Sleep, C. E., Weiss, B., Lynam, D. R., & Miller, J. D. (2019). An examination of the Triarchic Model of psychopathy's nomological network: A meta-analytic review. *Clinical psychology review*, *71*, 1-26.

Somma, A., Borroni, S., Drislane, L. E., & Fossati, A. (2015). Assessing the triarchic model of psychopathy in adolescence: Reliability and validity of the Triarchic Psychopathy Measure (TriPM) in three samples of Italian community-dwelling adolescents. *Psychological Assessment*, *28*(4), e36. https://doi.org/10.1037/pas0000184

Vaidyanathan, U., Patrick, C. J., & Bernat, E. M. (2009). Startle reflex potentiation during aversive picture viewing as an indicator of trait fear. *Psychophysiology*, *46*(1), 75–85. https://doi.org/10.1111/j.1469-8986.2008.00751.x

Vervoort, T., & Trost, Z. (2017). Examining Affective-Motivational Dynamics and Behavioral Implications Within The Interpersonal Context of Pain. *The Journal of Pain*, *18*(10), 1174–1183. https://doi.org/10.1016/j.jpain.2017.03.010

Waller, R., & Wagner, N. (2019). The Sensitivity to Threat and Affiliative Reward (STAR) model

and the development of callous-unemotional traits. *Neuroscience & Biobehavioral Reviews*, *107*, 656-671.

Wise, E. A., Price, D. D., Myers, C. D., Heft, M. W., & Robinson, M. E. (2002). Gender role expectations of pain: Relationship to experimental pain perception. *Pain*, *96*(3), 335–342.

Woodman, G. F. (2010). A Brief Introduction to the Use of Event-Related Potentials (ERPs) in Studies of Perception and Attention. *Attention, Perception & Psychophysics*, *72*(8).

Yancey, J. R., Bowyer, C. B., Foell, J., Boot, W. R., & Patrick, C. J. (2019). Boldness moderates the effects of external threat on performance within a task-switching paradigm. *Journal of Experimental Psychology: Human Perception and Performance*, *45*(6), 758.

Table 1. Associations of TriPM Boldness and Meanness scales with pressure pain tolerance.

		Pain Tolerance		**Model *R***
	r	*β (Step 1)*	*β (Step 2)*	**(R^2 change)**
Step 1				.34**
Sex	-.34**	-.34**	-.26*	
Step 2				.43** (.07*)
Boldness	.32**		.21	
Meanness	.25*		.13	

Note. $N = 92$. Standardized beta weights from a hierarchical regression model predicting algometer pressure-pain tolerance, with participant sex entered as a predictor at Step 1 and TriPM Boldness and Meanness scores entered at Step 2. Model *R* refers to the omnibus regression coefficient for the full model including both steps; R^2 change refers to the contribution of the TriPM scales (Boldness, Meanness) to the model at Step 2.
*$p < .05$, **$p < .01$.

Table 2. Associations of TriPM Boldness and Meanness with pain picture ratings.

	Boldness *r (β)*	**Meanness** *r (β)*	**Model *R*** (R^2 change)
Self			
Pain	-.15 (-.07)	-.27**(-.24*)	.31 (.07*)
No Pain	.00	-.05	
Other			
Pain	.04 (.11)	-.20* (-.23*)	.26 (.05)
No Pain	-.01	-.03	

Notes. $N = 104$. βs are standardized beta weights from a hierarchical regression model predicting pain rating under "self" or "other" instructions, with corresponding self/other no-pain rating entered at Step 1, and TriPM Boldness and Meanness scores entered at Step 2. Model *R* refers to the omnibus regression coefficient for the full model including both steps; R^2 change refers to the contribution of the TriPM scales (Boldness, Meanness) to the model at Step 2.
*$p < .05$, **$p < .01$

Table 3. Associations of TriPM Boldness and Meanness with ERP responses to pain pictures.

	Boldness *r (β)*	**Meanness** *r (β)*	**Model *R*** (R^2 change)
N110			
Pain	.23* (.10)	-.09 (-.09)	.84** (.01)
No Pain	.20*	-.03	
N240			
Pain	.27** (.05)	-.03 (-.06)	.82** (.01)
No Pain	.30**	.02	
LPP			
Pain	.02 (.05)	-.21* (-.15*)	.77** (.02)
No Pain	.02	-.10	

Note. $N = 113$. βs are standardized beta weights from a hierarchical regression model predicting amplitude of ERP response to pain pictures, with ERP amplitude for no pain pictures entered at Step 1, and TriPM Boldness and Meanness scores entered at Step 2. Model *R* refers to the omnibus regression coefficient for the full model including both steps; R^2 change refers to the contribution of the TriPM scales (Boldness, Meanness) to the model at Step 2.
*$p < .05$, **$p < .01$

Figure 1. (a) Grand average ERP waveforms for pain (solid lines) and no pain (dotted lines) conditions at the fronto-central electrode cluster (pooling of NSL electrodes: 60, 61, 62, 63) for participants scoring in the top (blue) and bottom (black) terciles on the TriPM Boldness scale. The gray area depicts the time windows used for scoring the N110 (120-180 ms) and N240 (220-280 ms) components. (b) Scatter plot illustrating the association between TriPM Boldness scores and N110 amplitudes for pain (black dots) and no pain (gray dots) conditions. (c) Scatter plot illustrating the association between TriPM Boldness scores and N240 amplitudes for pain (black dots) and no pain (gray dots) conditions.

Figure 2. (a) Grand average ERP waveforms for pain (solid lines) and no pain (dotted lines) conditions at the centro-parietal electrode cluster (pooling of NSL electrodes: 63, 64, 65, 66, 67) for participants scoring in the top (red) and bottom (black) terciles on the TriPM Meanness scale. The gray area depicts the time window used for scoring the LPP (400-1000 ms) component. (b) Scatter plot illustrating the association between TriPM Meanness scores and LPP amplitudes for pain (black dots) and no pain (gray dots) conditions.

Figure 3. Significant indirect effect models. (a) Standardized beta coefficients denoting the direct and indirect effect of TriPM Meanness on associations between pain tolerance measured via algometer and CAB-AB scale. (b) Standardized beta coefficients denoting the direct and indirect effect of TriPM Meanness on associations between self-perspective pain ratings and CAB-AB scale. (c) Standardized beta coefficients denoting the direct and indirect effect of TriPM Meanness on associations between LPP amplitude to pain and CAB-AB scale. CAB-AB = Crime and Analogous Behavior-Antisocial Behavior scale. *$p < .05$, **$p < .01$

Figure 1.

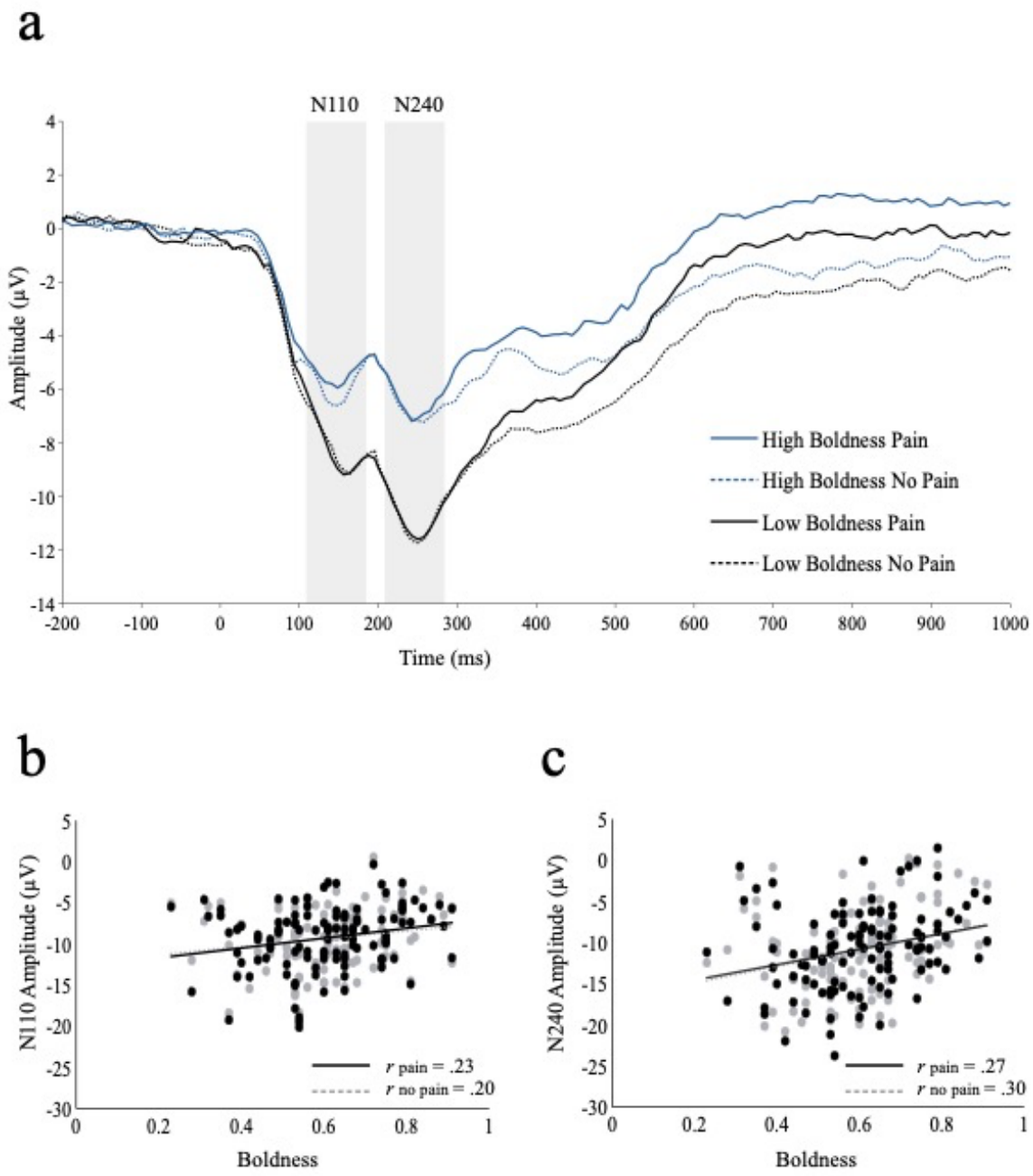

a
N110
N240
Amplitude (μV)
Time (ms)
High Boldness Pain
High Boldness No Pain
Low Boldness Pain
Low Boldness No Pain
b
N110 Amplitude (μV)
r pain = .23
r no pain = .20
Boldness
c
N240 Amplitude (μV)
r pain = .27
r no pain = .30
Boldness

Figure 2.

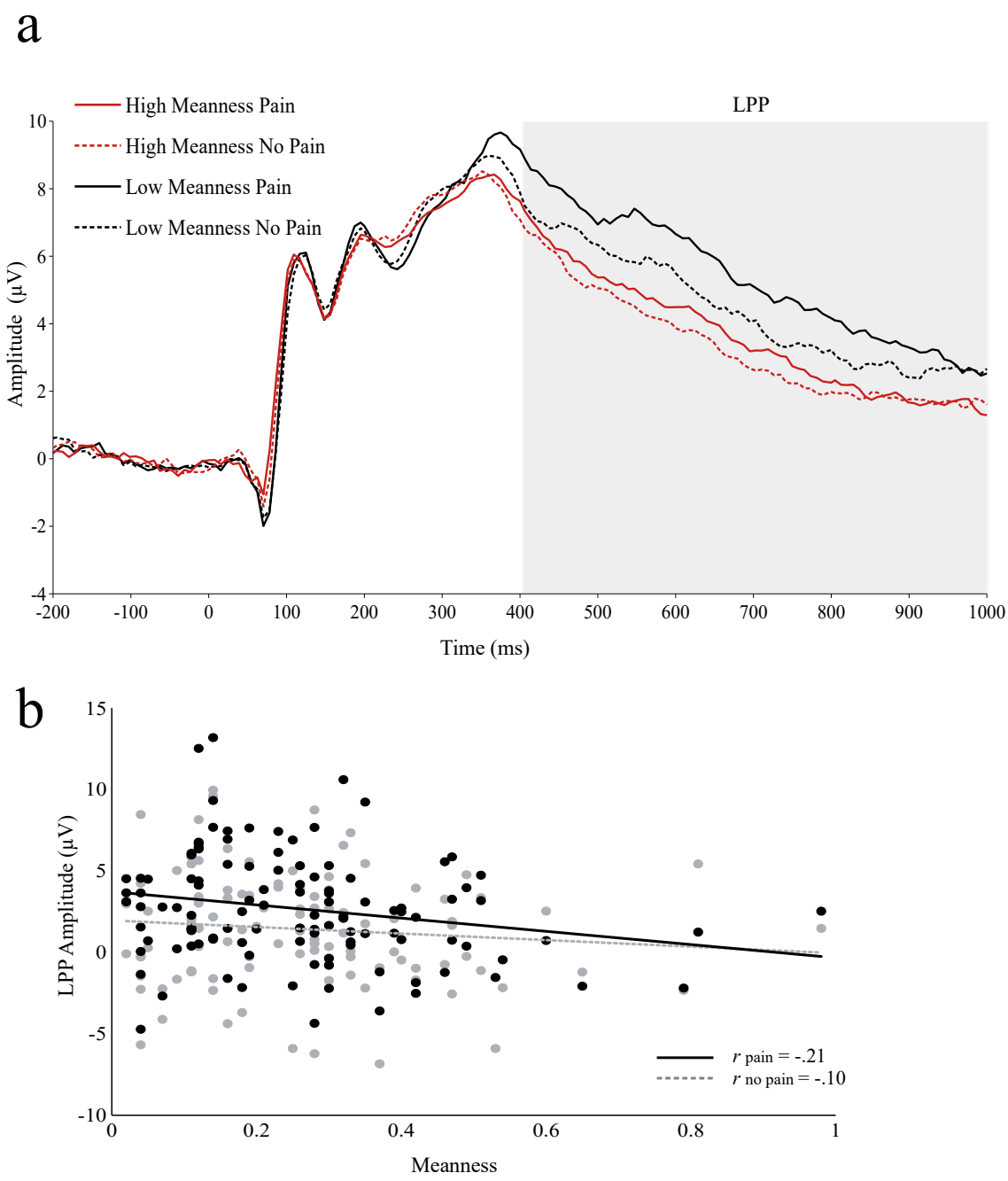
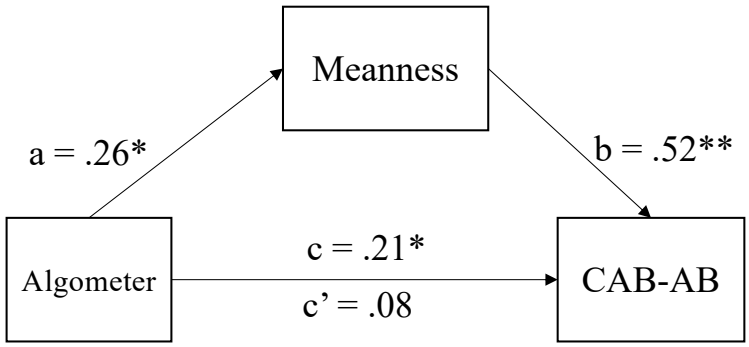

a
High Meanness Pain
High Meanness No Pain
Low Meanness Pain
Low Meanness No Pain
LPP
Amplitude (μV)
Time (ms)
b
LPP Amplitude (μV)
Meanness
r pain = -.21
r no pain = -.10

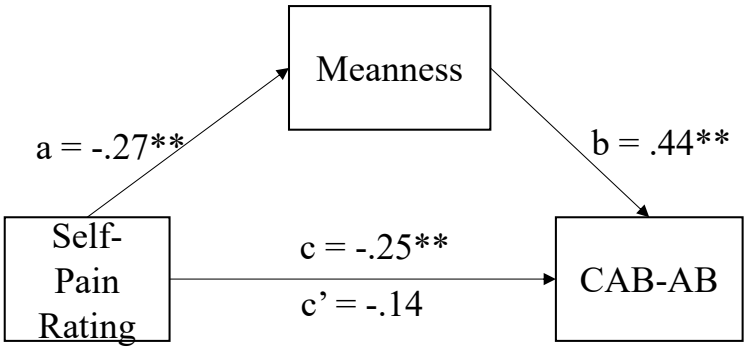
Figure 3.

a.



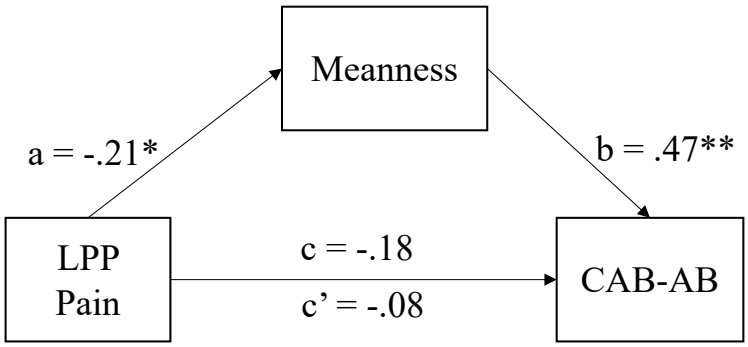
Standardized Indirect Effect: .12; 95% CI: .03; .24

b.



Standardized Indirect Effect: -.12; 95% CI: -.23, -.02

c.



Standardized Indirect Effect: -.10; 95% CI: -.19; -.02