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TITLE:

Electrophysiological study of the Violence Inhibition Mechanism in relation to callous-unemotional and aggressive traits

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Highlights:

- Uncaring traits were associated with poorer face processing (N170)
- Physical aggression was associated with poorer motor extinction (Stop-P300)
- Anger-specific N170 augmentation might be a function of task priming

ABSTRACT

The violence inhibition mechanism (VIM) proposes that observing another's distress inhibits responses that can lead to violent behaviour. Dysfunction of this system is associated with disorders characterised by aggressive and callous-unemotional traits, such as psychopathy. This study examines electrophysiological indices of face processing and motor extinction, in the context of aggressive and callous-unemotional traits. Fifty-four participants completed the inventory of callous and unemotional traits, the aggression questionnaire, and a Facial Affect Stop-Go task whereby facial distress was used as stop signals. Uncaring traits inversely associated with N170 amplitude across all facial expressions and aggressive traits inversely associated with Stop-P300 amplitude to facial distress. The N170 and Stop-P300 might provide useful electrophysiological markers for deficits across face processing and motor extinction stages of the VIM, respectively.

Keywords: distress processing; healthy adults; motor extinction; electrophysiology; aggression; callous-unemotional traits

1 INTRODUCTION

Robert Stelmack's work has improved understanding of the biological bases of personality, and how individual variation might be reliably indexed through electrophysiology. Noteworthy, is his work evidencing differences in cortical activity between introverts and extroverts (Stelmack, 1990); a personality spectrum associated with both pro- and anti-social behaviours. The current investigation delineates electrophysiological variation as a function of aggression and psychopathy-related traits.

The ability to suppress a planned or ongoing motor response in reaction to socially relevant information is important for adaptive behaviour (Huster et al., 2014). The violence inhibition mechanism (VIM) (Blair, 1995, 2001) comprises at least two stages of affect perception (including empathy) and motor extinction, whereby organisms typically learn to modulate aggression through perceiving expressions of distress in others. Dysfunction of this system is implicated in the development of psychopathy, and reflected through callous, unemotional, and uncaring (CU) traits (Blair, 1995, 2001).

CU and aggressive traits are associated with atypical categorisation of, and responses to, facial distress (Marsh & Blair, 2008; Seidel et al., 2013; Wilson et al., 2011). Although inconsistent findings exist (Eisenbarth et al., 2008; Glass & Newman, 2006), meta-analysis supports the presence of face processing deficits in affective psychopathy not specific to expressions of distress nor explained fully by aggressive behaviour (Dawel et al., 2012).

In regards to motor extinction proficiency, deficits in VIM-related executive function (e.g. error monitoring, response inhibition) have been reported in violent offenders (Vilà-Balló et al. 2014) and in association with trait aggression (Pawliczek et al. 2013). However, to our knowledge, no investigation has used facial affect as an inhibitory stimulus. Such research is important to better understand the motor extinction stage of the VIM.

To establish processing deficits across the aforementioned stages of the VIM, precise temporal measurements are required. Electroencephalography (EEG) reflects gross post-synaptic cortical activity of neuronal clusters with high temporal resolution, and offers a useful tool for distinguishing the time-course of neurological responses elicited during face processing (Gow et al., 2013) and motor extinction (Sumich et al., 2008). Time-locked EEG, to stimulus presentation or behavioural response, is termed the event-related potential (ERP).

Face stimuli elicit several well-documented ERPs including the N170 (150-200 ms post-stimulus) and P300 (300-500 ms post-stimulus). The N170 is best observed over temporo-parietal sites and is typically larger over the right hemisphere (Hinojosa et al., 2015). The N170 purportedly represents the conjoined processing of face identity and expression, and larger N170 amplitudes have been observed to angry and fearful (but not sad) faces, possibly as a function of their biological significance and representation of potential threat (Hinojosa et al., 2015).

N170 *attenuation* (lower amplitudes) has been observed in non-clinical cohorts presenting low emotional expressivity (Meaux et al., 2014) and high fearless dominance (Almeida et al., 2014); arguably linked to uncaring traits and a lack of concern for oneself and others (Kimonis et al., 2013). In contrast, N170 *augmentation* (larger amplitudes) has been related to cold-heartedness, possibly indicating a need for greater cortical effort when processing facial affect (Almeida et al., 2014). Cold-heartedness is associated with callousness (i.e. disregard for the feelings of others) and unemotional (i.e. blunted affect) traits (Patrick, 2010). Thus, qualitatively different CU traits might differentially modulate the N170. Whilst no difference in N170 amplitude has been reported in antisocial personality disorder (Eisenbarth et al., 2013; Pfabigan et al., 2012), measurement of the N170 in these studies was from atypical electrode sites and so direct comparison with findings of other studies is limited. Accordingly, the relationship between N170 responses to facial affect and individual differences in aggression (investigated in regards to face processing but not on an electrophysiological level) and CU traits remains unclear.

The P300 is associated with attention orientation and stimulus evaluation (Polich, 2007). Lower P300 amplitudes are considered a common characteristic across externalising behaviours (e.g. alcohol and drug dependence, antisocial behaviour; Hicks et al., 2007), and have been associated with reactive aggression in offender (Barratt et al., 1997; Bernat et al., 2007) and non-offender (Bartholow et al., 2006; Gerstle et al., 1998) cohorts.

During tasks that require inhibiting a motor response, the P300 is characterised by an anterior topography thought to reflect inhibitory control and motor extinction efficiency (Kok et al., 2004). Lower P300 amplitudes evoked during response inhibition have been reported in relation to delinquency (Meier et al., 2012) and in individuals with psychopathic traits (Kim & Jung, 2014). However, one investigation reported *larger* inhibitory P300 amplitude in violent offenders (Munro et al., 2007), a finding in line with intact (Patrick, 2008) or even augmented (Carlson & Thái, 2010; Flor et al., 2002) P300 responses, evoked to non-inhibitory stimuli, in relation to CU traits.

The current study investigates face processing and motor extinction stages of the VIM using a distress-cued motor extinction task in relation to CU traits and physical aggression. Specifically, N170 responses to facial stimuli and P300 responses to stop signals cued by facial expressions of distress (fear, sadness) were investigated. N170 amplitude was hypothesised to be [1] larger to fearful and angry, but not sad and neutral facial stimuli, and show [2] a positive association with callous and unemotional traits, but [3] an inverse relationship with uncaring and aggressive traits. Stop-P300 amplitude was hypothesised to be [4] inversely associated with aggressive and CU traits.

2 METHODS

2.1 Participants

Fifty-four psychology students (aged 19.06 ± 1.25 years, 61% female) provided written informed consent. No participants reported psychiatric disorders or medication that might affect electrophysiology. Participants were compensated for their time with research credits.

2.2 Measures

2.2.1 Aggression

The Aggression Questionnaire version 2 (AQ-2) (Buss & Warren, 2000) measures the propensity to aggress and comprises five subscales: physical aggression, verbal aggression, anger, hostility, and indirect aggression. The current investigation reports on physical aggression (Cronbach's $\alpha = .80$). Following standard scoring procedures, scores were transformed according to age and sex. Higher scores indicate greater aggression.

2.2.2 CU traits

The Inventory of Callous–Unemotional Traits (ICU) (Frick, 2003) measures the occurrence and intensity of CU traits and comprises three subscales: callousness, uncaring, and unemotional. Higher scores indicate greater CU traits.

2.2.3 The Facial Affect Stop-Go Task (FAST)

The FAST (Figure 1) was created by the researchers and presented in two blocks using OpenSesame v3.0 (Mathôt et al., 2012). Stimuli consisted of neutral, angry, sad, fearful, and surprised expressions (open mouths) from 17 identities (IDs 01, 03, 05, 06, 07, 08, 09, 10, 20, 21, 23, 25, 26, 32, 34, 35, 36; MacBrain NimStim Face Stimulus Set [Tottenham et al., 2009]). Each block began with a 4000 ms lead-in, followed by 136 trials. Each trial involved the presentation of a pair of facial stimuli (800 ms; 100 ms jitter) separated by black screen (160 ms; 40 ms jitter), with a red fixation cross presented between trials (1800 ms; 200 ms jitter) (see Figure 1). Facial stimuli pairings were divided across Background (Fear-Fear; Sad-Sad; Neutral-Sad; Neutral-Fear), Go (Anger-Anger; Anger-Surprise), and Stop (Anger-Fear; Anger-Sad) conditions, with each pairing presented 17 times per block. Participants were instructed to move their right index finger from a red key to an adjacent green in response to go stimuli (angry faces [stimulus 1]); but to interrupt their response and return their finger to the red key, following stop stimuli (i.e. sad/fearful faces [stimulus 2]). No response was required if stimulus one was not an angry face. Twenty practice trials were delivered using two additional identities (IDs 13, 38).

2.3 Electrophysiological acquisition, signal processing and analysis

EEG was recorded using an active-electrode, 64-channel Active-Two acquisition system and ActiView v.6.05 software (BioSemi, Amsterdam, Netherlands), sampled at 2048 Hz and digitised at 24-bits. An average reference was calculated online. Impedance was maintained below 5 kΩ.

Vertical and horizontal electrooculography artefacts were corrected (Jung et al., 2000). A band-pass filter of .01–35 Hz and a notch filter of 50 Hz were applied. Trials were baseline corrected before averaging (-200 ms). The N170 was average-referenced to avoid ERP attenuation at temporo-parietal sites (Joyce & Rossion, 2005) and the P300 was re-referenced to linked mastoids to minimise spatial distortion (Luck, 2005). Average temporo-parietal (left: P7, PO7, O1, PO3 – right: P8, PO8, O2, PO4) N170 responses (130 to 200 ms) were recorded for each emotion (background stimuli). Average bilateral and midline anterior (F5, Fz, F6) P300 responses (300 to 450 ms) were measured to stop stimuli (successful trials only). Following artefact rejection, the average number of accepted stop trials was 22 and 26 for fearful and sad stimuli, respectively.

Analyses of variance (ANOVA) were computed for the N170 and P300 using *emotion* (N170 [anger, fear, sadness, neutral]; P300 [fear, sadness]) and *hemisphere* (N170 [left, right]; P300 [left, midline, right]) as within-subjects factors. Hemisphere was included to better characterise the ERP across emotion. Interaction effects were computed. *Post hoc t*-tests delineated statistically significant interactions. Pearson correlations were computed between ERP amplitude (across emotion and hemisphere) and trait scores (callousness, uncaring, unemotional, physical aggression). Hochberg correction accounted for multiple comparisons. Additive inverse values were used for the N170.

3 RESULTS

Means and standard deviations for psychometric measures were: *physical aggression* (52.98 [*t*-transformed] ± 8.61), *callousness* (5.98 ± 2.97), *uncaring* (8.00 ± 3.33), and *unemotional* (8.16 ± 3.06).

3.1 Behavioural Analysis

Motor extinction success (successfully extinguishing a go response following a stop signal) was greater for sad (77.29 ± 15.94 %) than fearful (64.87 ± 16.48 %) stimuli (t [53] = 6.37, $p < .001$, *padj* < .001), and stop reaction times were shorter to sad (763.29 ± 203.10 ms) than fearful (822.13 ± 230.08 ms) stimuli (t [53] = 4.20, $p < .001$, *padj* < .001).

Uncaring traits negatively associated with successful motor extinction to fearful faces (r = -.341, p = .012, *padj* = .18) and positively associated with stop reaction times to fearful (r = .281, p = .039, *padj* = .507) and sad (r = .365, p = .007, *padj* = .112) faces. No correlation survived multiple comparison correction.

3.2 ANOVA

3.2.1 N170

N170 amplitude (2.10 ± 3.16 μV) varied with *emotion* after correcting degrees of freedom using Greenhouse-Geisser sphericity estimates (ε = .74, *F* [2.23, 118.03] = 5.76, p = .003, η_p^2 = .10). N170 amplitudes were larger to angry (1.69 ± 2.79 μV) than fearful (2.11 ± 2.81 μV; *t* [53] = 2.51, p = .02), sad (2.21 ± 2.92 μV; *t* [53] = 3.00, p < .01), and neutral stimuli (2.40 ± 2.55 μV; *t* [53] = 5.76, p < .001). N170 amplitude did not vary between fearful and sad, fearful and neutral, or sad and neutral stimuli. Although the N170 appeared larger over the right hemisphere (Figure 2), neither a main effect of *hemisphere* nor interaction between *hemisphere* and *emotion* was observed.

3.2.2 P300

Four participants were excluded from P300 analysis as they failed to stop on more than 50% of trials ([fear: 28.68 ± 6.06 %]; [sad: 41.91 ± 16.35 %]).

P300 amplitude varied with *hemisphere* after correcting degrees of freedom using Greenhouse-Geisser sphericity estimates (ε = .86, *F* [1.71, 83.97] = 11.64, p < .01, η_p^2 = .19). P300 amplitudes were larger over the midline (1.42 ± 2.33 μV) than left (-.91 ± 2.97 μV; *t* [49] = 4.33, p < .001) or right (-.93 ± 3.12 μV; *t* [49] = 5.05, p < .001) hemispheres (Figure 3). P300 amplitude varied with *emotion* (*F* [1, 49] = 10.21, p = .002, η_p^2 = .17), with larger amplitudes to sad (.43 ± 1.74 μV) than fearful stimuli (-.72 ± 2.39 μV; *t* [49] = 3.21, p < .01). There was no interaction between *hemisphere* and *emotion* (*F* [1, 49] = 1.49, p = .24, η_p^2 = .06).

3.3 Pearson Correlations: ERP

The left N170 response to sad (r = -.47, p < .001, *padj* < .001) and neutral (r = -.37, p = .007, *padj* = .049) expressions exhibited negative, moderately strong correlations with *uncaring* traits (Figure 4). Similar correlations were observed to fearful (r = -.28, p = .038, *padj* = .19) and angry expressions (r = -.29, p = .032, *padj* = .19) but did not survive multiple comparison correction. Partial correlations confirmed an inverse association between the left N170 response to sad (r = -.43, p = .002) and neutral (r = -.33, p = .02) expressions and uncaring scores after controlling for age, sex, and aggressive, callousness, and unemotional traits.

Physical aggression shared a moderately strong, negative correlation with P300 responses to facial distress at anterior midline sites (fear [r = -.54, p < .001, *padj* = .001], sad [r = -.58, p < .001, *padj* < .001]) (Figure 5). Partial correlations confirmed these associations (fear [r = -.56, p < .001] sad [r = -.62, p < .001]) after controlling for age, sex, and CU traits. No CU traits correlated with Stop-P300 responses.

4 DISCUSSION

Electrophysiological indices of affect perception and motor extinction stages of the VIM were investigated in relation to CU traits and physical aggression. N170 amplitude was largest to angry expressions. Stop-P300 amplitude was larger in response to sad, relative to fearful, expressions. Uncaring traits were associated with lower left N170 amplitude, especially to sad and neutral expressions. Physical aggression was associated with lower Stop-P300 amplitude to fearful and sad expressions.

4.1 Relationships between ERPs and personality traits

Inverse relationships between uncaring traits and left N170 amplitude across emotion concurs with deficient face processing in individuals characterised by affective malfunction after controlling for aggressive traits (Dawel et al., 2012). Furthermore, it corresponds with inverse associations reported between N170 amplitude and poor emotional sensitivity/expressivity (Meaux et al., 2014) and fearless dominance (Almeida et al., 2014). Whilst these traits relate to uncaring and/or unemotional facets (Kimonis et al., 2013), we are first to show a specific association between uncaring traits and the N170.

Neither unemotional nor callous traits associated with N170 amplitude. Previously, positive associations have been evidenced between cold-heartedness (akin to callousness) and N170 responses to angry expressions (Almeida et al., 2014). In this investigation, participants attended to facial affect, yet participants in Almeida et al. responded to non-face targets. Thus, inconsistent findings might reflect task-specific voluntary attention (Holmes et al., 2003).

Although previous investigations document comparable P300 responses between individuals with and without CU traits (Patrick, 2008), P300 attenuation has been observed during inhibitory tasks (Kim & Jung, 2014). However, no CU trait associated with Stop-P300 amplitude in this investigation. Disparity could be explained by variation in task (NoGo vs. Stop-Go), stimuli (geometric shapes vs. faces), and/or assay of CU traits.

As expected, Stop-P300 responses to facial distress inversely associated with physical aggression. Therefore, when prompted by facial distress, individuals reporting higher trait physical aggression might exhibit executive functioning and inhibitory control deficits and be less efficient at engaging motor extinction mechanisms (Kok et al., 2004). Results are in line with VIM theory and findings of attenuated anterior P300 responses to target (Bartholow et al., 2006; Bernat et al., 2007; Gerstle et al., 1998) and NoGo stimuli (Krakowski et al., 2016; Vilà-Balló et al., 2014). Though findings were not supported by behavioural data, this might be a function of recruiting a non-clinical sample and requires further investigation. Nevertheless, our study contributes to understanding of the impact of aggression on the P300 across task modality and population.

4.2 Electrophysiological responses to facial affect

Anger-specific N170 augmentation is consistent with larger N170 responses to schematic angry faces (Eger et al., 2003; Krombholz et al., 2007), but contrasts fear-evoked N170 augmentation reported elsewhere (Batty & Taylor, 2003; Blau et al., 2007; Shannon et al., 2013). Fear and anger are thought to communicate important social information requiring an immediate reaction (Hinojosa et al., 2015), for example threat and so N170 augmentation likely reflects orientation of attention towards such stimuli.

As the FAST requires responses to angry expressions, anger-specific N170 augmentation might reflect response priming and anger-directed attention (Holmes et al., 2003). Previously, N170 augmentation to anger has been observed in investigations where priming was used (Eger et al., 2003; Krombholz et al., 2007), but not in those where it was not (Boucsein et al., 2001; Holmes et al., 2003). To better understand the effect of emotion-specific task instructions on the N170, current findings should be compared with those evoked to [1] comparable stimuli during passive tasks, and [2] a FAST whereby go and stop facial stimuli are varied.

With regard to motor extinction, this is the first investigation to characterise the facial-distress-cued Stop-P300. Here, Stop-P300 responses to distress were shown to be larger over the anterior midline - consistent with similar tasks using non-facial stimuli (Baumeister et al., 2014; Fallgatter et al., 2005; Kok et al., 2004). Moreover, Stop-P300 responses were larger to sad than fearful expressions, which are typically thought to share similar processing networks (Adolphs & Tranel, 2004). Combined with shorter reaction times to sad expressions, attenuated P300 responses to fearful expressions may reflect ambiguity and increased difficulty during fear processing (Elfenbein & Ambady, 2002; Stockdale et al., 2015).

4.3 Study limitations and future directions

Although angry and distressed facial stimuli were chosen to best index the VIM, it is necessary to compare P300 responses to non-distress expressions. To regard the FAST as a valid index of the VIM; P300 responses to facial distress should be greater than that to other expressions. Second, the FAST currently only presents facial distress, and not distress signalled through auditory signals or body postures. Characterising VIM-relevant electrophysiological responses as a function of stimulus modality would increase utility of the FAST. Third, this experiment sampled students, restricting variability of trait responses. Access to clinical samples would facilitate comparison of high- and low-scoring subgroups in order to negate the limitations of correlational analysis (i.e. inability to infer causation, between-subject variation). Finally, as a consideration of statistical power, this investigation only indexed aggressive traits through physical aggression due to its relationship with reactive aggression (Buss & Warren, 2000). Future investigations should investigate relationships between other manifestations of aggression (e.g. verbal, indirect aggression) and associated traits (e.g. anger, hostility) and electrophysiological indices of the VIM.

5 CONCLUSION

In conclusion, findings support the importance of distinguishing between CU and aggressive traits when testing the VIM and extend this knowledge by showing associations between uncaring traits and vulnerability for poor responses to distress-related social cues, and aggressive traits with deficits in distress-cued motor extinction. Moreover, findings are in line with Stelmack’s idea that psychophysiological measurement of cortical activity can provide a useful tool for better understanding individual differences in personality, with variation in electrophysiology as a function of aggression and psychopathy-related traits observed here. Future studies should seek to validate the FAST as an index of the

VIM and compare findings observed here to those observed in populations characterised by extreme physical aggression/CU traits. Reported results have importance for using electrophysiological indices as a potential marker of face processing and motor extinction efficacy.

Conflict of Interest

None declared.

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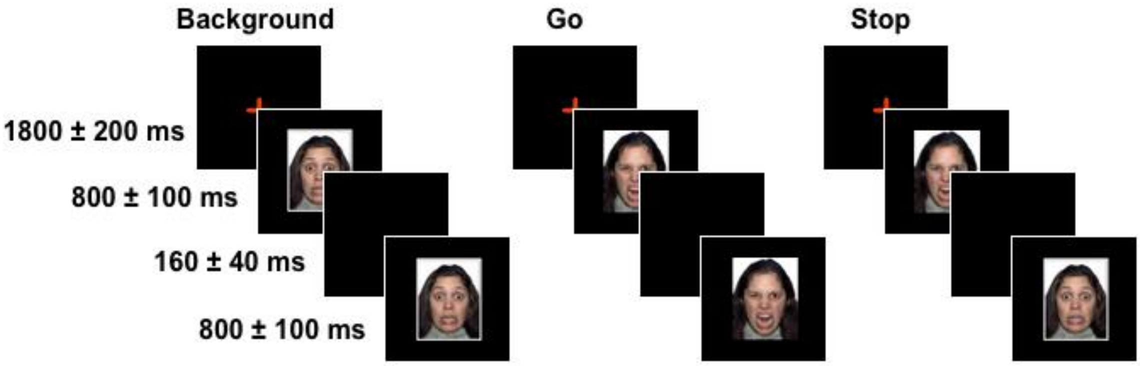
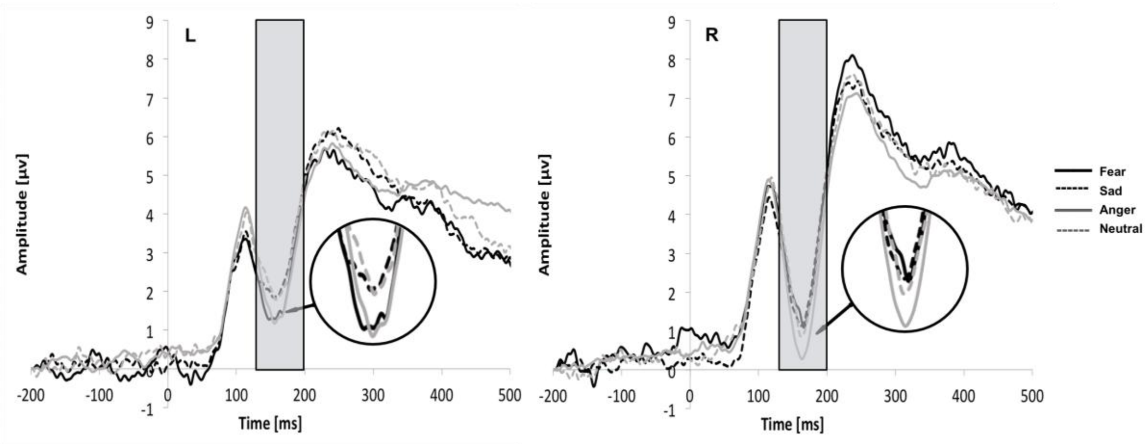
Figures

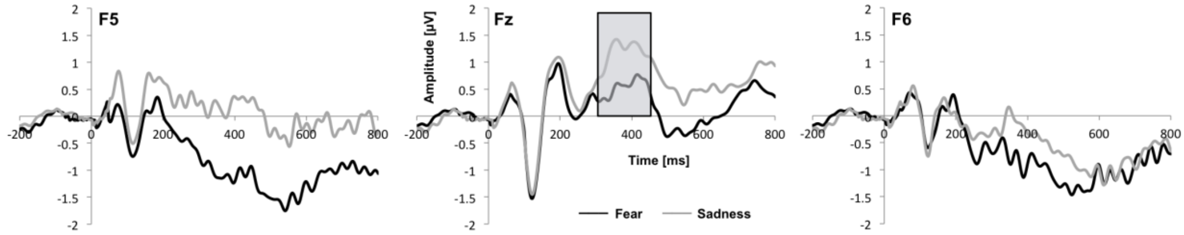
[1]


Background
Go
Stop
1800 ± 200 ms
800 ± 100 ms
160 ± 40 ms
800 ± 100 ms

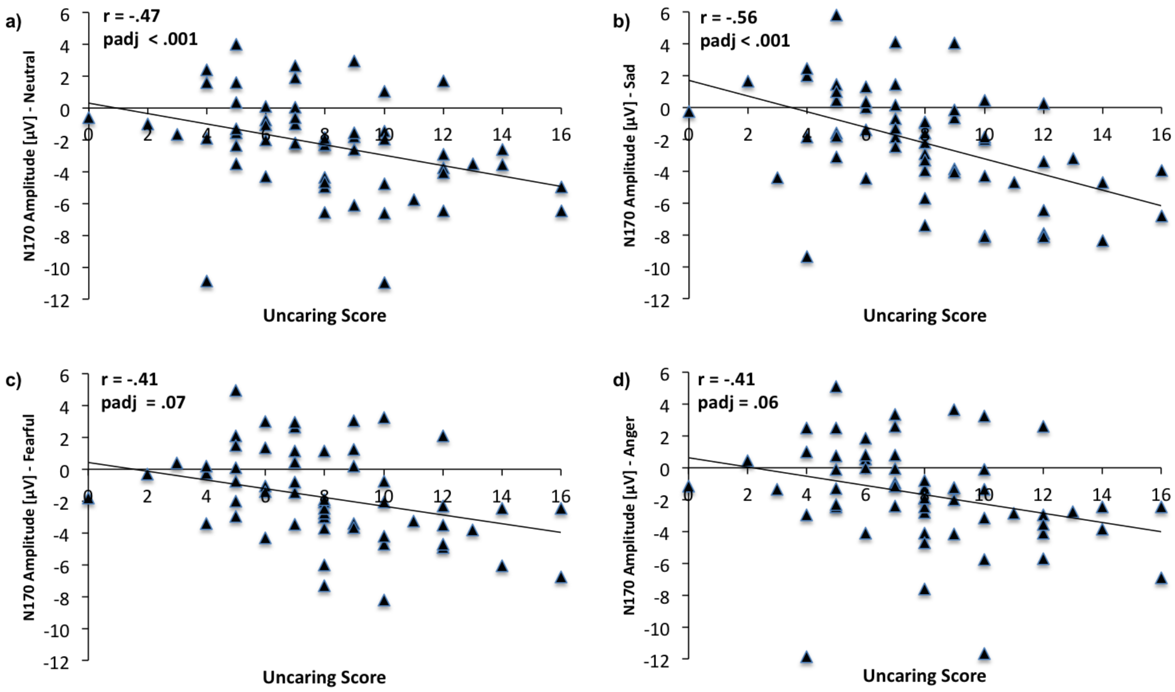
[2]


L
R
Amplitude [µv]
Time [ms]
Fear
Sad
Anger
Neutral

[3]


F5
Fz
F6
Amplitude [µV]
Time [ms]
Fear
Sadness

[4]



[5]

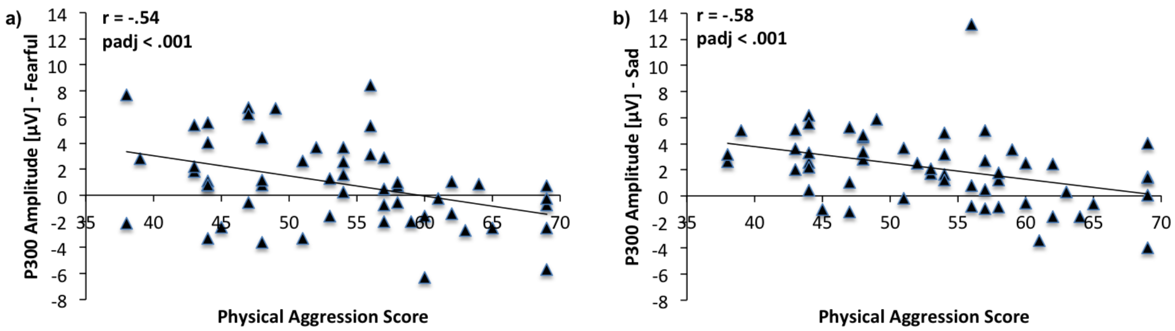


Figure Legends

Figure 1

Facial Affect Stop-Go task (FAST). Participants responded to infrequent go (angry) stimuli among frequent background (neutral, fearful, or sad) stimuli (800 ± 100 ms) by moving their finger from a red to a green button after the go stimulus had expired. Facial stimuli were followed by a black screen lasting 120 to 200 ms. Afterwards, participants were either presented with an [1] angry or surprised facial stimulus, indicating the go response should be completed, or a [2] fearful or sad facial stimulus, indicating the go response should be extinguished by returning their finger to the red button without pressing the green button.

Figure 2

Grand average ERPs to angry (target) and fearful, sad, and neutral (background) facial stimuli with N170 enlarged. Left ERP is an average of P07, P7, O1, and T7 electrodes. Right ERP is an average of P08, P8, O2, and T8 electrodes. ERPs are representative of EEG signal referenced to averaged electrodes. Shaded area denotes 130 to 200 ms time window where mean N170 amplitude was measured.

Figure 3

Grand average ERPs to fearful and sad (stop) facial stimuli from three electrodes (F5, Fz, and F6). ERPs are representative of EEG signal referenced to averaged mastoids. Shaded area denotes 300 to 450 ms time window where mean midline P300 amplitude was measured.

Figure 4

Scatter plots of left hemispheric N170 amplitude (μV) to a) neutral, b) sad, c) fearful, and d) angry facial expressions against uncaring trait scores. Pearson correlations.

Figure 5

Scatter plot of anterior midline P300 amplitude (μV) to a) fearful and b) sad facial expressions against physical aggression trait scores. Pearson correlations.

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