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Callous-unemotional traits and neural responses to emotional faces in a community sample of young adults☆

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ABSTRACT

Former studies suggest that the core features of psychopathy, namely the callous-unemotional (CU) traits are associated with emotional dysfunction characterized by atypical processing of other people's distress. Using a dimensional approach to CU traits, the current study aims to test neural activity during performance of a facial expression recognition task in a community sample of young adults. Forty-one participants (25 females, *M* age = 25.44, *SD* = 4.03) completed the Inventory of Callous-Unemotional Traits. Functional magnetic resonance imaging data were collected to measure neural responses to fearful, happy and sad faces as compared with neutral facial expressions. Region-of-interest analyses revealed that during exposure to fearful face expressions, blood oxygenation level-dependent responses were negatively associated with CU traits in the right anterior cingulate gyrus (ACCg), but not in the amygdala. These findings support that CU traits are related to a unique neural response to fearful faces in noncriminal population as well. It also highlights the importance of taking into account other regions outside the amygdala, in particular the ACC, when testing the relation between CU traits and fear response.

1. Introduction

During the past several decades, research on the nature of psychopathy has been dominated by theories that recognize deficient or abnormal emotional experience as a hallmark of psychopathy (Blair, 2003; Patrick, 1994). Much attention has been paid to the affective personality features of psychopathic disorder that has been labelled as callous–unemotional (CU) traits. CU traits include characteristics such as lack of remorse and guilt, shallow and deficient emotions, and lack of empathy, which are considered to be the core features of psychopathy (Cleckley, 1941; Hare, 1993). A significant amount of study has demonstrated that adults and children with CU traits have selective impairments in experiencing and recognizing distress in others, but show normal response to other emotional expressions such as happiness (see Brook, Brieman, & Kosson, 2013; Herpers, Scheepers, Bons, Buitelaar, & Rommelse, 2014, for a review).

The neurological basis for this impairment is considered to be related to the limbic system. More specifically, dysfunction of the amygdala is believed to be critical for deficits in processing distress based social cues. Consistent with the integrated emotion systems model (Blair, 2005), studies using functional magnetic resonance imaging (fMRI) have demonstrated that children and adults with CU traits show lower amygdala response to fearful expressions (Decety, Skelly, Yoder, & Kiehl, 2014; Dolan & Fullam, 2009; Gordon, Baird, & End, 2004; Jones, Laurens, Herba, Barker, & Viding, 2009; Marsh et al., 2008; Viding et al., 2012). Furthermore, amygdala lesions were also found to be related to impaired recognition of fearful emotional faces (Adolphs et al., 1999; Davis & Whalen, 2001).

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According to Kiehl's neurobiological model (Kiehl, 2006), psychopathy is a disorder connected to the paralimbic system, and the anterior cingulate cortex (ACC) also contributes to the impairments observed in psychopathy. Reduced ACC activation has been reported in both children and adults with psychopathic traits during emotion related tasks such as affective memory (Kiehl et al., 2001), fear conditioning (Birbaumer et al., 2005; Veit et al., 2002), viewing negative emotional pictures (Müller et al., 2003) and pictures of others in pain (Lockwood et al., 2013; Marsh et al., 2013). Besides fMRI studies, reduced activity of the ACC (indexed by error-related negativity, ERN) in response to fearful expressions has also been observed in psychopaths in an electroencephalography (EEG) study (Munro et al., 2007). However, it is unclear whether these results indicate the dysfunction of ACC itself. In a contrasting view, the integrated emotion systems model states that these findings may reflect deficient input from associated regions, such as the amygdala and the orbitofrontal cortex (OFC), rather than the direct dysfunction of the ACC (Blair, 2005, 2013). Although reduced activity in the OFC has also been associated with psychopathy, this deficit seems to be more pronounced in criminal psychopaths (e.g., Gao & Raine, 2010; Koenigs, 2012).

The majority of neuroimaging research investigating neural correlates of adult psychopathic features focused on clinical or incarcerated populations using the Psychopathy-Checklist Revised (PCL-R, Hare, 1991) to assess psychopathic traits (particularly the core affective component). However, several researchers have argued that personality traits associated with psychopathy should be viewed as dimensions existing along a continuum (Edens, Marcus, Lilienfeld, & Poythress, 2006; Feilhauer & Cima, 2013; Guay, Ruscio, Knight, & Hare, 2007; Lynam, 2002; Marcus, John, & Edens, 2004; Murrie et al., 2007). So it may be more efficient to measure CU traits as a dimensional rather than a categorical (or taxonic) construct.

Evidence suggests that even in the general population psychopathic traits are associated with decreased responses in amygdala during processing of facial expressions (Gordon et al., 2004) and during rating one's own empathic response to others' emotional expressions (i.e., affective resonance) (Seara-Cardoso, Sebastian, Viding, & Roiser, 2016). Although, these studies focused on male subjects only. Using a dimensional approach to CU traits, the aim of the present study is to investigate neural activity during an implicit facial expression recognition task in healthy subjects. In the current study, fMRI blood-oxygen-level-dependent (BOLD) responses to fearful, happy and sad expressions compared to neutral faces were assessed. On the basis of prior research and theory, it was hypothesized that the affective features of psychopathy (i.e., CU traits) would be associated with reduced amygdala and anterior cingulate cortex activity to distress-related cues (i.e., fearful and sad expressions). To the best of our knowledge, this the first fMRI study assessing whether CU traits are accompanied with reduced activity in these two particular structures in a community sample of young adults (males and females).

2. Materials and methods

2.1. Participants

This study reports data from forty-one healthy adult volunteers (25 females, age range 21–37 years, $M = 25.44$, $SD = 4.03$). Participants were recruited via university advertisements and a newspaper article. All participants were right-handed, had normal or corrected-to-normal vision, and no history of medical, neurological or psychiatric disease. Right handedness was confirmed using a standardized handedness questionnaire (Edinburgh Handedness Inventory; Oldfield, 1971). Diagnostic assessments were conducted by senior neurologist and psychiatrist researchers to rule out the presence of psychiatric disorders (Mini-International Neuropsychiatric Interview; M.I.N.I.; Sheehan et al., 1998). One participant was excluded because of excessive head movements during scanning (motion outliers > 15%).

All participants gave written informed consent for participation prior to the study, which was conducted in accordance with the Declaration of Helsinki. The study was approved by the Scientific and Research Ethics Committee of the Medical Research Council (Hungary).

2.2. Experimental task

Emotional processing was measured by an implicit facial expression recognition task. Stimuli comprised six adult faces (three male and three female individuals) making three emotional (fearful, happy, sad) and neutral expressions. Participants were shown grey-scale images of hair-cropped faces displayed on a black background. Face stimuli were derived from a standard set of pictures of facial affect (Ekman & Friesen, 1976) and presented in a block design. Stimulus presentations were delivered by E-Prime 2.0 (Psychology Software Tools, Inc., Pittsburgh, USA).

Participants viewed blocks of face stimuli separated by three rest blocks where a fixation cross was displayed at the centre of the screen for 20 s. Emotional blocks (three blocks of each emotion) were presented in a pseudo-random order and interspersed with twelve neutral blocks (see Fig. 1). Each block consisted of six faces presented for 3000 ms with interstimulus intervals of 333 ms and 334 ms. Therefore, each block lasted 20 s and the total running time for the task was 8 min.

To ensure that participants were attending to the stimuli, they were required to categorize the sex of each face stimulus using two response buttons. Accuracy and reaction times were recorded throughout the task. Visual stimuli were projected on a screen and viewed through a mirror attached to the head coil. Finger-press (index finger and thumb) responses were recorded by a two-button MRI-compatible response grip, using the right hand. Before entering the scanner room, participants completed a brief practice session on a laptop computer showing four neutral faces.

2.3. Demographic questions

Participants completed basic demographic questions regarding age, sex, ethnicity, employment status, subjective financial status, educational level, family and personal psychiatric history.

2.4. Callous-unemotional traits

CU traits were measured by the Inventory of Callous-Unemotional Traits (ICU; Frick, 2003; Pataky et al., 2011). The ICU includes 24 items that are rated on a four-point Likert scale ranging from 0 (*not at all true*) to 3 (*definitely true*) and has three subscales: callousness, uncaring, and unemotional (Byrd, Kahn, & Pardini, 2013; Essau, Sasagawa, & Frick, 2006). The ICU has been validated in adult samples (Byrd et al., 2013). In the present study, the total ICU score demonstrated adequate internal consistency ($\alpha = 0.76$).

2.5. fMRI acquisition

Functional MRI data acquisition was performed on a 3T MRI scanner (Achieva 3T, Philips Medical System) using a BOLD-sensitive T2*-weighted echo-planar imaging sequence (repetition time [TR] = 2500 ms, echo time [TE] = 30 ms, field of view [FOV] = $240 \times 240\ mm^2$) with 3 mm × 3 mm in-plane resolution and contiguous 3-mm slices providing whole brain coverage. A series of high-resolution anatomical images were also acquired during the first functional imaging session using a T1-weighted 3D TFE sequence with $1 \times 1 \times 1$ mm resolution.

2.6. Data analysis

For the statistical analyses of the self-reported and behavioural data, SPSS version 23.0 software was used (SPSS, Inc., Chicago, IL, USA). After

Fig. 1. Experimental design. N, Neutral blocks; H, Happy blocks; S, Sad blocks; F, Fear block; R, Rest blocks.

Pearson correlations were performed among the main study variables, independent *t*-tests were also conducted to examine the differences in accuracy, reaction times, and ICU scores between male and female participants. The reliability of the ICU measure was assessed using Cronbach's alpha coefficient.

2.7. fMRI analysis

Imaging data were analysed using Statistical Parametrical Mapping (SPM12) analysis software package (Wellcome Department of Imaging Neuroscience, Institute of Neurology, London, UK; http://www.fil.ion.ucl.ac.uk/spm12/) implemented in Matlab 2015b (Math Works, Natick, MA). Preprocessing followed a standard sequence. Functional images were realigned and the mean functional image was co-registered to the structural image. Co-registered structural image was than segmented. Finally, functional images were normalized into Montreal Neurological Institute (MNI) space and smoothed using 8 mm full-width-at-half-maximum (FWHM) Gaussian kernel.

In addition, normalized data were examined using Artifact Detection Tools (ART; http://www.nitrc.org/projects/artifact_detect/) to identify and exclude motion outliers in the global mean image time series and movement parameters using an outlier threshold of global signal >3 *SD* and motion >1 mm. The motion outliers were used as regressors of no interest in the fMRI model.

First-level analysis was performed on each participant focusing on the significant BOLD signal responses to emotional expressions based on three types of contrast: fear – neutral, happy – neutral, sad – neutral. Contrast images were entered into group analyses using one-sample *t*-test to investigate the main effects of the experimental task. Based on a large meta-analysis of 105 fMRI studies of emotional face expressions (Fusar-Poli et al., 2009; see Table S1 in the supplemental material), region-of-interest (ROI) analyses were performed using small volume corrections (SVCs) with anatomical masks derived from the automated anatomical labelling atlas (aal; Tzourio-Mazoyer et al., 2002) in the Wake Forest University Pick-Atlas software program (WFU Pick-Atlas, version 2.5.2, Wake Forest University School of Medicine; Winston-Salem, NC, USA, http://fmri.wfubmc.edu/software/PickAtlas). For the fear-neutral contrast, ROI analyses were conducted on the bilateral amygdala, bilateral fusiform gyrus and right medial frontal gyrus; for the happy-neutral contrast on the bilateral amygdala, right anterior cingulate cortex and left fusiform gyrus; and for the sad-neutral contrast on the right amygdala and left lingual gyrus. For all regions of interest, an initial threshold of $p < 0.001$ uncorrected for multiple comparison with a cluster size of five voxels ($k \geq 5$) was applied and results survived SVC family-wise error correction at a voxel-level threshold of $p_{FWE} < 0.05$ were reported.

In the second-level analysis, multiple regression method was used to examine the relationship between BOLD responses during the three emotional conditions and ICU scores, with sex and CU traits serving as covariates. Sex was entered as a control variable because men generally score higher on all psychopathic dimensions, including the CU traits than women in both criminal and noncriminal populations (e.g., Forth, Brown, Hart, & Hare, 1996; Vitale & Newman, 2001). As the amygdala and anterior cingulate cortex were the a priori regions of interest, separate ROI analysis was conducted in these two particular regions using an initial threshold of $p < 0.001$, $k \geq 5$ uncorrected, with a SVC voxel-level correction at $p_{FWE} < 0.05$ in each case. For the a priori specified brain area of interest that exhibited a significant association with CU scores, the BOLD signal change observed during the emotional conditions was extracted from SPM and used in Pearson correlational analysis (SPSS version 23.0). To assess brain activity outside the amygdala and anterior cingulate, whole brain analysis was also performed. Again, results were thresholded at $p_{FWE} < 0.05$ cluster-level using an initial threshold of $p < 0.001$ uncorrected and activations with a cluster size of ten voxel ($k \geq 5$) were used.

3. Results

3.1. Behavioural results

Participants showed high accuracy on the sex identification task. The mean accuracy level across conditions was 99.31% ($SD = 1.01$). There were no significant differences between male and female subjects in accuracy ($t(39) = 1.34$, $p = 0.187$) and reaction times (neutral: $t(39) = 0.38$, $p = 0.703$; fear: $t(39) = 1.22$, $p = 0.229$; happy: $t(39) = 1.19$, $p = 0.241$; sad: $t(39) = 0.25$, $p = 0.803$). There were no significant correlations between reaction time data and ICU scores (neutral: $r = 0.161$, $p = 0.314$; fear: $r = 0.193$, $p = 0.228$; happy: $r = 0.144$, $p = 0.371$; sad: $r = 0.235$ $p = 0.139$), but there was a significant difference regarding CU traits between male ($M = 21.44$, $SD = 6.16$) and female participants ($M = 16.08$, $SD = 5.15$; $t(39) = 3.01$, $p = 0.005$, Cohen's $d = 0.92$).

3.2. Neural correlates

3.2.1. Main effects of the task

Region of interest analyses revealed that exposure to fearful faces compared to neutral expressions evoked significant BOLD signal increases in the bilateral amygdala and bilateral fusiform gyrus. Happy-neutral contrast showed significant BOLD responses in the left fusiform gyrus. During exposure to facial expression of sad faces, significant activations were observed in the left lingual gyrus (see Table 1).

3.2.2. Effect of callous-unemotional traits

After controlling for sex, ROI analyses revealed that during exposure to fearful face expressions (relative to neutral faces), BOLD responses were negatively associated with CU traits in the right anterior cingulate gyrus ($r = -0.47$, $p = 0.002$), but not in the amygdala (see Table 2, Fig. 2). Furthermore, ROI analyses did not identify significant associations between BOLD signal and CU traits for happy and sad emotions.

Whole brain analysis at a cluster-level threshold of $p_{FWE} < 0.05$ showed no other regions besides the anterior cingulate gyrus of significant activations during emotional compared to neutral face processing.

Table 1
Main effects of the task in all participants.

Cluster size	Region	Side	FWE	Peak coordinates			Peak T
				x	y	z	
Fear							
44	Amygdala	Right	0.000	24	−4	−16	5.87
16	Amygdala	Left	0.002	−21	−4	−16	4.38
287	Fusiform gyrus	Left	0.000	−21	−85	−13	7.48
236	Fusiform gyrus	Right	0.000	30	−76	−16	6.95
Happy							
245	Fusiform gyrus	Left	0.000	−36	−76	−13	5.39
Sad							
215	Lingual gyrus	Left	0.000	−3	−79	−10	5.73

Note. Voxels are significant at $p_{FWE} = 0.05$, with small volume and peak-level correction for multiple comparison. Coordinates are in Montreal Institute (MNI) space.

Table 2
Results of the region of interest analyses in the relation of callous-unemotional traits during responses to fearful expressions.

Cluster size	Region	Side	FWE	Peak coordinates			Peak T
				x	y	z	
Fear							
13	Anterior cingulate gyrus	Right	0.032	3	23	20	3.86

Note. Result is significant at $p_{FWE} = 0.05$, with small volume and peak-level correction for multiple comparison. Coordinates are in Montreal Institute (MNI) space.

4. Discussion

The current study investigated the link between callous-unemotional traits and neural responses to facial expressions in a community sample of young adults. Facial processing was measured by a widely used emotional faces paradigm and the main neural effects of the task was in line with previous findings (Fusar-Poli et al., 2009). Bilateral amygdala and bilateral fusiform gyrus activated more strongly to fearful than to neutral faces. In addition, there was a significant activation in the left fusiform gyrus during exposure to happy faces, and in the left lingual gyrus in the sad – neutral contrast. Increased amygdala activity was not observed in the case of happy and sad facial expressions which supports the traditional view that amygdala plays a key role in detecting fearful expressions (Adolphs et al., 1999; Blair, Peschardt, Budhani, Mitchell, & Pine, 2006). Since there are no established cut-off scores for CU traits and research supports that psychopathy is a dimensional trait rather than a categorical (or taxonomic) construct, a dimensional approach was preferred to measure the core features of psychopathy. Contrary to our expectations, CU traits were not associated with decreased amygdala response to distress-related cues (i.e., fearful and sad expressions). However, in line with our hypothesis, CU traits were related to lower anterior cingulate cortex activation in response to fearful faces.

To our knowledge, this is the first imaging study to demonstrate that CU traits are associated with reduced right anterior cingulate responsiveness during exposure to fearful expressions in a noncriminal sample. More specifically, reduced activity of the anterior cingulate gyrus (ACCg) was found to be related to CU traits. This finding is in accordance with recent anatomical and functional evidence suggesting that the ACCg plays a crucial role in processing information about others (Apps, Rushworth, & Chang, 2016; Lockwood, 2016; Lockwood, Apps, Roiser, & Viding, 2015). Our finding is also in line with Lockwood et al. (2013), who found that activity in ACCg was negatively associated with callous traits among children with conduct problems during viewing pictures of others in pain. It seems that the gyral and not the sulcal portion of the ACC (ACCs; often called as the dorsal ACC, dACC) is compromised in psychopathy (Lockwood, 2016).

Crucially, decreased right ACCg response was found to fearful, but not to sad emotional faces. In line with this, research points toward the conclusion that processing fearful expressions is uniquely implicated in youth and adults with CU traits. Studies quite consistently show impaired facial fear response, but the findings on impaired processing of sad faces are less often (Brook et al., 2013; Herpers et al., 2014; Marsh, 2013). However, it is important to consider why CU traits were not associated with decreased amygdala response to fearful expressions, which is in contrast with fMRI studies demonstrating abnormal amygdala activation in children and adults with CU traits (Decety et al., 2014; Dolan & Fullam, 2009; Gordon et al., 2004; Jones et al., 2009; Marsh et al., 2008; Seara-Cardoso et al., 2016; Viding et al., 2012). These studies differ from the current one in a number of important

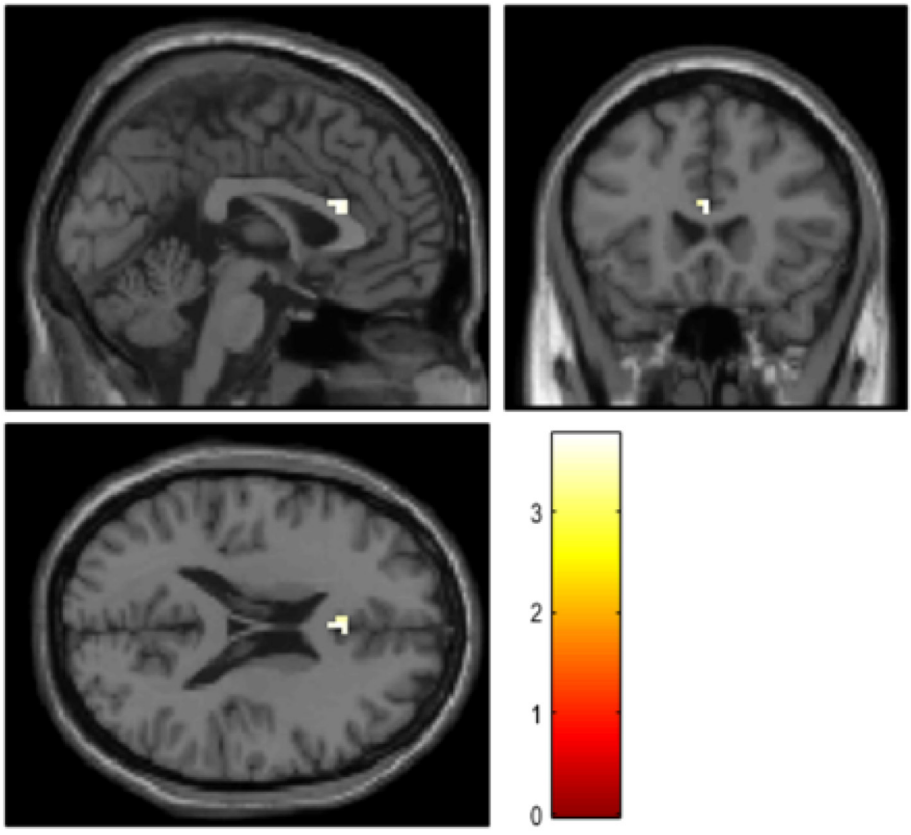

Fig. 2. Reduced activity in anterior cingulate gyrus (Montreal Institute coordinates: $x = 3, y = 23, z = 20$). Region-of-interest analysis was performed in bilateral anterior cingulate cortex using a mask derived from the automated anatomical labelling atlas. The images are thresholded at $p_{FWE} = 0.05$, $k \geq 5$, with small volume and peak-level correction for multiple comparison. Scale represents the T score.

respects. Firstly, previous studies used different kinds of paradigms to measure processing of facial expressions (e.g., affective resonance, dynamic facial expressions). Secondly, most of them focused on children or incarcerated adult samples. From the two studies that have examined healthy male adults, Gordon et al. (2004) found a significant connection between affective psychopathic features and decreased right amygdala response to fear by using a rather liberal threshold uncorrected for multiple comparisons. In addition, in the study of Seara-Cardoso et al. (2016), activation in the amygdala was negatively associated with psychopathic traits in an affective resonance task in response to all emotional faces (relative to baseline). Thirdly, our study used continuous measure to evaluate CU traits. Although classifying participants can lead to a questionable homogeneity of the created groups, the method of using arbitrary cut-off scores (e.g., median score or deviation from the sample mean) to categorize participants into low and high psychopathy groups is quite common (e.g., Dolan & Fullam, 2009; Gordon et al., 2004; Marsh et al., 2008).

As a consequence, although previous work has demonstrated impaired amygdala function in community population, this deficit may not be as pronounced (Raine & Glenn, 2014). There is evidence to suggest that amygdala functioning is deficient in noncriminal samples to a lesser extent than seen in criminal samples (Yang, Raine, Colletti, Toga, & Narr, 2010). It is also important to highlight that CU traits were not associated with impaired behavioural reaction to negative emotional stimuli, which is consistent with Gordon et al.'s (2004) findings, so it may also reflect the nonclinical nature of the current sample.

In light of the present results, reduced activity in the anterior cingulate gyrus might not be due to lack of input from the amygdala. It might reflect a deficit within the ACC itself or reduced input from other core regions implicated in psychopathy (e.g., orbitofrontal cortex). Although the idea that reduced ACC activation contributes to psychopathic traits supports the paralimbic hypothesis (Kiehl, 2006), further studies are needed to clarify whether ACC is dependent on input from other associated regions.

The results should be evaluated in the context of certain study limitations, including the use of self-report measure of callous-unemotional traits. However, although CU traits are often associated with manipulative and deceitful interpersonal style (Hare, Hart, & Harpur, 1991), research has found that self-report measures can be used to reliably assess psychopathic personality traits (Miller, Jones, & Lynam, 2011; Ray et al., 2013). In addition, due to the format of the facial expression recognition task, the rest condition could not be used as an additional baseline condition. Furthermore, the present study did not measure the gaze patterns of participants during emotional processing. It has been recently demonstrated that the impairments in emotional facial recognition associated with psychopathic traits may reflect reduced attention to the eye region of human faces in healthy adults (Gillespie, Rotshtein, Wells, Beech, & Mitchell, 2015). Similarly, reduced attention to the eyes has been found among children with conduct problems and CU traits (Dadds, El Masry, Wimalaweera, & Guastella, 2008; Dadds et al., 2006). It seems that fear-recognition deficits can be attenuated by focusing attention on emotionally significant aspects of the face, which may result in normalized amygdala reactivity. From this perspective, the lack of significant connection between CU traits and reduced amygdala response in the present sample may be due to the increased attention to the eye region. Finally, it is also important to recognize that although two regions of interest (the amygdala and ACC) were defined in the present study, they are not the only structures implicated in psychopathy.

Despite these limitations, our results suggest the importance of considering other regions of the limbic system outside the amygdala, particularly the anterior cingulate cortex, when investigating the association between callous characteristics and fear response. Although reduced amygdala response, believed to be one of the neural bases of psychopathy, was not observed in the current study, our findings give further support that the core affective features of psychopathy are associated with a unique neural signature in the normal population as well, and shed more light on similarities and differences in the neural mechanism underlying CU traits between criminal and noncriminal individuals.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.paid.2017.02.026.

Ethical statement

All participants gave written informed consent for participation prior to the study, which was conducted in accordance with the Declaration of Helsinki. The study was approved by the Scientific and Research Ethics Committee of the Medical Research Council (Hungary).

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