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Brain structure correlates of emotion-based rash impulsivity

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ABSTRACT

Negative urgency (the tendency to engage in rash, ill-considered action in response to intense negative emotions), is a personality trait that has been linked to problematic involvement in several risky and impulsive behaviours, and to various forms of disinhibitory psychopathology, but its neurobiological correlates are poorly understood. Here, we explored whether inter-individual variation in levels of trait negative urgency was associated with inter-individual variation in regional grey matter volumes. Using voxel-based morphometry (VBM) in a sample (n = 152) of healthy participants, we found that smaller volumes of the dorsomedial prefrontal cortex and right temporal pole, regions previously linked to emotion appraisal, emotion regulation and emotion-based decision-making, were associated with higher levels of trait negative urgency. When controlling for other impulsivity linked personality traits (sensation seeking, lack of planning/perseverance) and negative emotionality per se (neuroticism), these associations remained, and an additional relationship was found between higher levels of trait negative urgency and smaller volumes of the left ventral striatum. This latter finding mirrors recent VBM findings in an animal model of impulsivity. Our findings offer novel insight into the brain structure correlates of one key source of inter-individual differences in impulsivity.

Introduction

The personality trait of "impulsivity" has long been implicated as an important risk and maintaining factor across a diverse range of risky behaviours and mental health problems (DeYoung et al., 2010; Dalley et al., 2011). It is increasingly apparent, however, that there is no single impulsivity trait. Rather, there are separate personality traits underlying various forms of impulsive behaviour (Birkley and Smith, 2011; Sharma et al., 2013). According to one influential model, the UPPS model (Whiteside and Lynam, 2001), the construct of impulsivity encompasses four largely distinct "impulsigenic" (Sharma et al., 2013) traits or dispositions: sensation seeking (the tendency to seek excitement), lack of planning (the tendency not to plan or think ahead), lack of perseverance (the inability to sustain attention and motivation on boring tasks) and urgency (the tendency to act rashly when distressed). Subsequent revisions to this model (Birkley and Smith, 2011; Cyders and Smith, 2008; Sharma et al., 2013) have revealed that urgency has two facets (negative and positive urgency, referring to the tendency to act rashly when experiencing intensively negative or positive mood states, respectively) and that lack of planning and lack of perseverance represent two facets of a lack of conscientiousness.

A notable feature of the UPPS model is that it has drawn attention to emotion-related impulsigenic traits that were largely neglected previously. In particular, one facet of impulsivity, negative urgency, refers specifically to the disposition to act rashly in the context of intense negative emotional states (Whiteside and Lynam, 2001; Cyders and Smith, 2008). After controlling for the other impulsivity-related traits (sensation-seeking, lack of planning/ perseverance) and for the tendency to experience negative emotions per se, negative urgency has been shown, across multiple populations, including adolescent, undergraduate, adult community and clinical samples, to be a uniquely important cross-sectional and prospective predictor of problematic involvement in several maladaptive and risky behaviours, including susceptibility to negative peer influence, risky sexual behaviour, reckless driving, intimate partner violence, smoking, alcohol problems and illegal drug use (Cyders and Coskunpinar, 2010; Dir et al., 2013; Settles et al., 2012; Stautz and Cooper, 2014). Additionally, negative urgency is the impulsigenic trait most strongly linked to the severity of psychopathology in clinical psychiatric disorders such as binge eating disorder (Racine et al., 2013), pathological gambling (Michalczuk et al., 2011) and borderline personality disorder (Whiteside et al., 2005). In particular, negative urgency is an important personality contributor across the spectrum of so-called externalizing or disinhibitory disorders (e.g. alcohol dependence, drug use, aggression and conduct disorders) (Settles et al., 2012), and may represent the personality "core" of the externalizing disorders (Clark, 2005). A critical issue for impulsivity neuroscience, then, is to determine the neurobiological underpinnings of the negative urgency trait.

Recent structural magnetic resonance imaging (MRI) studies have found that inter-individual variation in a number of behavioural traits – including personality traits – can be predicted from the local structure of grey matter as assessed by voxel-based morphometry (VBM) (Kanai and Rees, 2011). Here, we used VBM to examine the relationship

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between trait negative urgency and local grey matter volumes in a sample of healthy individuals. Negative urgency can be considered to represent a personality process by which subjective distress leads to disagreeable, ill-considered rash action, and shares variance with the 'big five' personality traits of high neuroticism, low conscientiousness and low agreeableness (Cyders and Smith, 2008; Settles et al., 2012). DeYoung et al. (2010), using brain structure morphometry, found that lower local volumes of medial/superior frontal gyrus (dorsomedial prefrontal cortex) were linked to high neuroticism, but also to low agreeableness and to low conscientiousness. Relatedly, negative urgency is thought to reflect, in part, underlying problems with emotion regulation (Carver et al., 2008; Cyders and Smith, 2008) and activity in the dorsomedial prefrontal cortex (dmPFC) is associated with both instructed and spontaneous emotion regulation (Ochsner et al., 2004; Silvers et al., 2014a). Indeed, the dmPFC has been shown in a recent fMRI meta-analysis to be the region most consistently active across 48 studies of emotion regulation (Buhle et al., 2013). Hence, we predicted that, across individuals, higher levels of trait negative urgency would be associated with smaller local grey matter volume in the dmPFC. In addition, individuals with co-occurring cocaine dependence and personality disorder, characterised by very high levels of trait negative urgency, have recently been shown to have smaller grey matter volume of the right temporal pole (Albein-Urios et al., 2013). We therefore also examined potential associations between higher levels of negative urgency and smaller grey matter volumes in right temporal polar regions. To examine the unique variance explained by negative urgency, we additionally controlled for individual differences in the other impulsivity-related traits of the UPPS model (sensation seeking, lack of planning/perseverance) and negative emotionality per se (i.e. trait neuroticism). Our findings provide novel insight into the neurobiological variations that reflect inter-individual differences in tendencies towards rash, impulsive behaviours in the context of heightened negative emotions.

Methods

Sample

One-hundred and fifty-two healthy right-handed participants, primarily undergraduate and graduate university students (109 females; mean age: 23.6 years [standard deviation: 5.4 years]), underwent structural magnetic resonance imaging (MRI) after providing written informed consent and screening for MRI contra-indications, including a history of neurological or psychiatric disorders. The study was approved by the Cardiff University School of Psychology Research Ethics Committee.

Negative urgency

Trait negative urgency was measured using the UPPS Impulsive Behaviour Scale (Whiteside and Lynam, 2001), a 45-item scale formed from a factor analysis of a wide-range of self-report impulsivity scales, and designed to assess urgency, lack of planning, lack of perseverance and sensation seeking. The 12-item negative urgency subscale contains questions such as "I am always able to keep my feelings under control" and uses a 4-point Likert-type scale ranging from 1 (*agree strongly*) to 4 (*disagree strongly*). Higher mean scores reflect higher levels of impulsivity. It has excellent internal consistency, with Cronbach's alpha level typically exceeding 0.8 (in this study, Cronbach's alpha was 0.79). An extensive body of evidence supports the validity of the negative urgency scale. The scale has repeatedly emerged as uni-dimensional, scores converge across self-report and interview assessment methods (Smith et al., 2007), and the scale is gender invariant (i.e. measures the same trait in women and men) (Cyders, 2013). Further, trait negative urgency has excellent discriminant validity in comparison to measures of the other UPPS traits, and correlates with criterion variables as predicted by theory (for a review, see Birkley and Smith, 2011; Cyders and Smith, 2008).

Here, mean scores (out of a maximum possible score of four) for negative urgency were calculated and used in all analyses. The other traits from the UPPS (lack of planning, lack of perseveration and sensation-seeking) were also scored and used as covariates.

Negative emotionality (neuroticism)

Trait neuroticism (the tendency to experience negative emotions) was measured using the neuroticism scale of the Big Five Inventory (BFI) 44-item version (John et al., 2008). This self-report personality scale was completed by a subset of 139 of the 152 participants described above (109 female, mean age: 23.2 years, standard deviation: 5.3). The neuroticism scale was not acquired in 13 subjects for logistical reasons. The BFI-44 neuroticism scale features eight short-phrase items, such as "I see myself as someone who is depressed, blue", rated on a 5-point Likert-type scale ranging from 1 (*disagree strongly*) to 5 (*agree strongly*). In this study, Cronbach's alpha for Neuroticism was 0.85, indicating excellent internal consistency.

MRI data-acquisition and pre-processing

MRI scans were obtained on a 3 T GE HDx signa MRI scanner at the Cardiff University Brain Research Imaging Centre (CUBRIC) fitted with an 8-channel head coil. High resolution T1-weighted fast spoiled gradient (FSPGR) coronal scans (TR = 7.9 ms, TE = 3 ms, inversion time = 450 ms, flip angle = 20^0, 1 mm isotropic resolution) were acquired with 168 or 172 slices depending on head size.

Images were segmented using SPM8 (Wellcome Trust Centre for Neuroimaging, London) into grey matter, white matter and cerebrospinal fluid tissue classes using unified segmentation. Grey matter images were then normalised to a grey matter population template, generated from the complete image set using the diffeomorphic anatomical registration using exponentiated lie-algebra (DARTEL) registration method (Ashburner, 2007). This nonlinear warping technique minimises between-subject structural variations. All images were checked following segmentation and normalisation to ensure the accuracy of these steps. The final voxel resolution was $1 \times 1 \times 1$ mm^3. Spatially normalised images were modulated by the Jacobian determinants so that intensities represent the amount of deformation needed to normalise the images, and then smoothed with an 8-mm full-width at half-maximum Gaussian kernel.

Voxel based morphometry: statistical analysis

Voxel-based multiple regression analysis (based on the general linear model: GLM) was carried out using SPM8 with voxel-wise grey matter volume (GMV) as the dependent variable. Age and gender (known predictors of brain volume) were added as nuisance covariates to the GLM (Barnes et al., 2010). Negative urgency mean score was used as the predictor. Total intracranial volumes were calculated by summing the values of the native space tissue segmentations (grey matter, white matter and cerebrospinal fluid) using the 'get_totals' function in SPM8 and added as a global measure for proportional global scaling (Peelle et al., 2012). Resulting SPM t-maps were superimposed on the MNI single subject brain and labelling was carried out using the AAL atlas (Tzourio-Mazoyer et al., 2002) included in the MRIcron software package (http://www.mccauslandcenter.sc.edu/mricro/mricron/). Results were visualized using NeuroElf (www.neuroelf.net).

Statistical analysis was then carried out in the following stages.

1. Correlations between negative urgency scores and grey matter volumes were assessed using a region of interest (ROI) based approach, with ROIs sampled using 10 mm diameter spheres (drawn using the