Archival Report

Biological Psychiatry: CNNI

Impulsive-Antisocial Dimension of Psychopathy Linked to Enlargement and Abnormal Functional Connectivity of the Striatum

Cole Korponay, Maia Pujara, Philip Deming, Carissa Philippi, Jean Decety, David S. Kosson, Kent A. Kiehl, and Michael Koenigs

ABSTRACT

BACKGROUND: Psychopathy is a mental health disorder characterized by callous and impulsive antisocial behavior, and it is associated with a high incidence of violent crime, substance abuse, and recidivism. Recent studies suggest that the striatum may be a key component of the neurobiological basis for the disorder, although structural findings have been mixed, and functional connectivity of the striatum in psychopathy has yet to be fully examined.

METHODS: We performed a multimodal neuroimaging study of striatum volume and functional connectivity in psychopathy using a large sample of adult male prison inmates ($N = 124$). We conducted volumetric analyses in striatal subnuclei and subsequently assessed resting-state functional connectivity in areas where volume was related to psychopathy severity.

RESULTS: Total Psychopathy Checklist–Revised and factor 2 scores (which index the impulsive-antisocial traits of psychopathy) were associated with larger striatal subnuclei volumes and increased volume in focal areas throughout the striatum, particularly in the nucleus accumbens and putamen bilaterally. Furthermore, at many of the striatal areas where volume was positively associated with factor 2 scores, psychopathy severity was also associated with abnormal functional connectivity with other brain regions, including dorsolateral prefrontal cortex, ventral midbrain, and other areas of the striatum. The results were not attributable to age, race, IQ, substance use history, or intracranial volume.

CONCLUSIONS: These findings associate the impulsive-antisocial dimension of psychopathy with enlarged striatal subnuclei and aberrant functional connectivity between the striatum and other brain regions. Furthermore, the colocalization of volumetric and functional connectivity findings suggests that these neural abnormalities may be pathophysiologically linked.

Keywords: Functional connectivity, Nucleus accumbens, Psychopathy, Putamen, Reward, Striatum

http://dx.doi.org/10.1016/j.bpsc.2016.07.004

Psychopathy is a mental health disorder characterized by callous and impulsive antisocial behavior. Present in roughly a quarter of adult prison inmates, psychopathy is associated with a disproportionately high incidence of violent crime, substance abuse, and recidivism (1,2). Identifying the psychological and neurobiological mechanisms underlying this disorder could thus have profound implications for the clinical and legal management of psychopathic criminals, as well as for the basic understanding of human social behavior. Based on the personality and behavioral characteristics of the disorder, such as impulsivity and deficits in passive avoidance (3), reversal learning (4), and perseverative responding to reward (5), it has long been postulated that psychopathy may be linked to abnormalities in processing reward and punishment (3,6–9). Over several decades, a host of behavioral and psychophysiological studies has offered support for this theory (3,4,10,11). More recently, brain imaging has been used to address this hypothesis at the neural systems level. A number of these studies have focused on the ventral striatum, a subcortical target of mesolimbic dopamine neurons that responds to rewarding or pleasurable stimuli, as well as to abstract stimuli predicting their occurrence (3,12,13). While functional imaging studies in community samples have associated impulsive-antisocial psychopathic traits with heightened ventral striatum activity during the anticipation of monetary gain (14,15), structural imaging studies have offered more mixed results. Some studies have associated psychopathy with increased ventral striatum volumes (16,17), others have reported decreased ventral striatum volumes (18), and others have found volume increases (19) and decreases (20) in more dorsal and lateral regions of the striatum. The mixed findings among volumetric studies may be attributable to differences in subject populations (e.g., prison inmates vs. community samples), psychopathy severity, sample sizes, and substance use history.

SEE COMMENTARY ON PAGE 111

ISSN: 2451-9022

In the present study, we used a unique mobile scanner to collect multimodal magnetic resonance imaging (MRI) from a large (N = 124) sample of adult male prison inmates with a broad range of psychopathy severity to determine whether volumes of striatal subregions were linked to assessments of overall psychopathy severity as well as to assessments of distinct components of psychopathic traits (factor 1: affective and interpersonal traits; factor 2: antisocial and lifestyle traits). Furthermore, we analyzed resting-state functional MRI (fMRI) data from the same participants to determine whether the observed striatal structural abnormalities were accompanied by alterations in striatal functional connectivity. This combination of analyses comprises the most comprehensive study of striatum structure and functional connectivity in psychopathy to date.

METHODS AND MATERIALS

Participants

Adult male inmates (N = 124), recruited from a medium-security Wisconsin correctional facility, participated in the present study. Informed consent was obtained both orally and in writing. Participants were selected based on the following inclusion criteria: 1) younger than 45 years; 2) IQ greater than 70; 3) no history of psychosis or bipolar disorder; 4) no history of significant head injury or postconcussion symptoms; 5) no current use of psychotropic medications, and 6) completed interview assessments for psychopathy and substance use disorder (see below). Of these 124 subjects, resting-state functional connectivity (RSFC) data were obtained for 115 subjects; 8 of the subjects were excluded due to excessive motion in the scanner, leaving a total of 107 subjects for RSFC analysis.

Psychopathy was assessed with the Psychopathy Checklist–Revised (PCL-R) by trained research assistants (2). The PCL-R is a 20-item scale completed based on a semistructured interview and file review. Each item was scored as 0, 1, or 2 based on the severity of each trait. Total scores ≥30 (n = 41) indicate psychopathy; scores >20 and <30 (n = 48) are considered intermediate, and scores ≤20 (n = 35) are nonpsychopathic (2). Interrater reliability (intraclass correlation) for total PCL-R score was 0.98 based on 10 dual ratings. Total PCL-R, factor 1 (interpersonal/affective traits), and factor 2 (lifestyle/antisocial traits) scores were used for separate regression analyses (21).

Substance use disorder was assessed with the Structured Clinical Interview for DSM-IV Axis I disorders (22). This measure classifies whether a subject meets criteria for lifetime history of substance abuse or substance dependence for each of the following substances: alcohol, cannabis, cocaine, opioids, stimulants, sedatives, and hallucinogens. Participant characteristics are summarized in Table 1.

MRI Acquisition

MRI data were acquired using the Mind Research Network's Siemens 1.5T Avanto Mobile MRI System equipped with a 12-element head coil. All participants underwent scanning on correctional facility grounds. A high-resolution T1-weighted structural image was acquired for each subject using a four-echo magnetization-prepared rapid gradient-echo sequence (repetition time = 2530 ms; echo time = 1.64, 3.5, 5.36, and 7.22 ms; flip angle = 7°; field of view = 256 × 256 mm^2; matrix = 128 × 128; slice thickness = 1.33 mm; no gap; voxel size = 1 × 1 × 1.33 mm^3; 128 interleaved sagittal slices). All four echoes were averaged into a single high-resolution image (23). Resting-state functional images (T2*-weighted gradient-echo functional echo planar images [EPIs]) were collected while subjects lay still and awake, passively viewing a fixation cross for 5.5 minuntes (158 volumes) (24) and were acquired with the following parameters: repetition time = 2000 ms;

Table 1. Participant Characteristics

	All (N = 124)		Nonpsychopathic (n = 35)		Intermediate (n = 48)		Psychopathic (n = 41)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	p^a
Age, Years	31.6	7.3	31.3	7.9	31.8	6.7	31.5	7.7	.93
IQ	98.1	11.5	97.3	12.0	95.3	11.6	101.5	10.3	.19
Total PCL-R Score	24.8	7.1	15.3	3.4	25.6	2.3	32.1	1.6	<.001
Factor 1 Score	9.2	3.3	5.5	2.1	9.3	2.3	12.3	1.8	<.001
Factor 2 Score	13.6	3.9	8.6	2.8	14.3	1.9	17	1.5	<.001
	%	n	%	n	%	n	%	n	
SUD: Abuse	24.2	30	22.9	8	25	12	24.4	10	.88
SUD: Dependence	55.6	69	40	14	56	27	68.3	28	.01
Race									
Caucasian	56.6	70	60	21	45.8	22	65.6	27	.52
African American	41.1	51	34.3	12	52.1	25	34.1	14	.52
Hispanic	1.6	2	2.9	1	2.1	1	0	0	NA
Native American	0.8	1	2.9	1	0	0	0	0	NA

Participant demographic and neuropsychological information is presented by group for nonpsychopathic (PCL-R ≤20), intermediate (PCL-R >20 and <30), and psychopathic (PCL-R ≥30) inmates.

NA, not applicable; PCL-R, Psychopathy Checklist–Revised; SUD, substance use disorder.

[a]Reported for two-sample t tests (for age, IQ, and psychopathy scores), Fisher's exact test (for race), and Pearson chi-squared test (for substance abuse and dependence) comparing psychopathic and nonpsychopathic inmates.