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Abnormal brain structure in youth who commit homicide

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ABSTRACT

Background: Violence that leads to homicide results in an extreme financial and emotional burden on society. Juveniles who commit homicide are often tried in adult court and typically spend the majority of their lives in prison. Despite the enormous costs associated with homicidal behavior, there have been no serious neuroscientific studies examining youth who commit homicide.

Methods: Here we use neuroimaging and voxel-based morphometry to examine brain gray matter in incarcerated male adolescents who committed homicide ($n = 20$) compared with incarcerated offenders who did not commit homicide ($n = 135$). Two additional control groups were used to understand further the nature of gray matter differences: incarcerated offenders who did not commit homicide matched on important demographic and psychometric variables ($n = 20$) and healthy participants from the community ($n = 21$).

Results: Compared with incarcerated adolescents who did not commit homicide ($n = 135$), incarcerated homicide offenders had reduced gray matter volumes in the medial and lateral temporal lobes, including the hippocampus and posterior insula. Feature selection and support vector machine learning classified offenders into the homicide and non-homicide groups with 81% overall accuracy.

Conclusions: Our results indicate that brain structural differences may help identify those at the highest risk for committing serious violent offenses.

1. Introduction

Estimates of the financial burden of homicide exceed $17 million per offense, including costs associated with policing, prosecution, incarceration, and lost productivity (DeLisi et al., 2010). With approximately 15,000 homicides committed each year (Murphy et al., 2013), the fiscal cost of homicide in the U.S. was over $250 billion in 2011 alone. And whereas the financial burden of homicide is staggering, these figures do not capture the emotional toll on the 9.3% of U.S. adults who have been directly affected by homicide experience (Armour and Umbreit, 2007).

Adolescence is a time of significant biological, cognitive, and neural changes (Sweeten et al., 2013), and is sometimes associated with reckless, irresponsible, delinquent, and at times, violent behavior. Most adolescents age out of this type of behavior, but a small percentage of youth continue this antisociality into adulthood and are referred to as being on the "life-course persistent" trajectory (Moffitt, 1993). Research that attempts to identify youth at the highest risk of committing serious and violent crimes as adolescents and/or adults could be particularly valuable for prevention and treatment efforts (Hawkins et al., 2000; Davidson et al., 2000).

Callous and unemotional (CU) traits and poor behavioral control (i.e., conduct disorder) are risk factors for youth who might be on the life course persistent trajectory of antisocial behavior and lifelong personality problems (Corrado et al., 2004). Recent neuroimaging research has shown that youth who demonstrate such problematic behavior have reduced gray matter in critical cognitive control and emotional brain regions. For instance, one study found that male youth with conduct disorder (CD; $n = 12$) displayed reduced gray matter volumes in the left amygdala and anterior insula bilaterally compared to healthy controls ($n = 12$), and that these reductions were specifically related to aggressive behavior (Sterzer et al., 2007). In another recent study, adolescent males with CD ($n = 23$) had reduced

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gray matter volumes in the left orbitofrontal cortex and bilateral temporal lobes, as well as the left amygdala and hippocampus. Overall, the CD group had 6% less gray matter volume than healthy controls (Huebner et al., 2008). In a large sample of incarcerated adolescent males ($n = 191$), Ermer et al. (2013) found gray matter reductions related to high CU/CD traits in the orbitofrontal cortex, posterior cingulate, parahippocampal cortex, and temporal poles. Similar research in adults has identified gray matter reductions primarily in the orbitofrontal cortex (de Oliveira-Souza et al., 2008; Ermer et al., 2012; Tiihonen et al., 2008), temporal cortex (de Oliveira-Souza et al., 2008; Ermer et al., 2012), and limbic areas (Ermer et al., 2012) related to callous and unemotional traits and impulsive behaviors (i.e., psychopathic traits).

Despite these recent advancements, no studies have sought to examine whether youth who commit homicide have any unique gray matter abnormalities relative to comparison youth. To begin to address this issue we analyzed structural magnetic resonance imaging (MRI) data to examine brain gray matter differences in incarcerated adolescent males who committed homicide ($n = 20$) versus incarcerated adolescent males who did not ($n = 135$). We also compared the homicide offenders ($n = 20$) to a subsample of matched non-homicide offenders ($n = 20$) as well as to a group of non-incarcerated healthy adolescent controls. The non-homicide offenders ($n = 20$) were matched with the homicide offenders ($n = 20$) on the following variables: IQ, age at scan, number of traumatic brain injuries with loss of consciousness, Hare Psychopathy Checklist: Youth Version Total, Factor 1, and Factor 2 scores, substance dependence, years of regular substance use, psychiatric diagnoses, and violent, non-violent, drug, and total number of convictions. We hypothesized that youth who commit homicide represent youth with more profound callous and unemotional traits and poor behavioral controls and thus we expected these youth to show gray matter abnormalities in paralimbic regions.

2. Materials and methods

2.1. Participants

These data were drawn from the National Institute of Mental Health (NIMH)-funded SouthWest Advanced Neuroimaging Cohort, Youth Sample (SWANC-Y), collected between June 2007 and March 2011, from ongoing research studies at a maximum-security youth detention facility in New Mexico. The present study reports on a subsample of the participants from Ermer et al. (2013) (all males; $n = 155$) for whom official criminal records and self-report criminal activity were available (mean age = 17.5 years, SD = 1.14; 78.1% Hispanic, 14.2% white; 89.0% right-handed). Within this sample, individuals whose official state criminal records included a murder conviction ($n = 4$) or who self-reported killing another person without being convicted during confidential research interviews ($n = 16$) were classified as homicide offenders ($n = 20$); all others were classified as non-homicide offenders ($n = 135$). Non-homicide offenders included those who had committed serious violent crimes such as rape and assault, and non-violent crimes such as burglary, theft, fraud, and drug possession/distribution. In addition, we report data from $n = 21$ male healthy adolescent non-offender controls drawn from the community (mean age = 16.4 years, SD = 2.07; 38.6% Hispanic, 47.6% white; 90.5% right-handed).

This research was approved by the University of New Mexico Health Sciences Center Human Research Review Committee and all individuals volunteered to participate after providing written informed consent (if ≥18 years of age) or after providing written informed assent and parent/guardian written informed consent (if <18 years of age). Participation did not affect institutional status (e.g., security level, privileges, parole or release date). Participants were excluded from participation if they had a history of seizures, epilepsy, psychosis, traumatic brain injury, other major medical problems, or failed to show fluency in English at or above a grade four reading level.

2.2. Assessments

2.2.1. Psychopathy

All offenders were assessed for psychopathy (i.e., callous and unemotional traits and impulsive/antisocial behaviors) using the expert-rater Hare Psychopathy Checklist: Youth Version (Forth et al., 2003). The PCL:YV assessment includes a review of institutional records and a semi-structured interview that reviews individuals' school, family, work, and criminal histories, and their interpersonal and emotional skills. Individuals are scored on 20 items that measure personality traits and behaviors characteristic of psychopathy. Scores range from 0 to 40. For adults, the accepted diagnostic cutoff for psychopathy is 30 and above (Hare, 2003). Psychopathy includes interpersonal and affective traits, such as glibness, shallow affect, callousness, and lacking guilt and remorse (Factor 1) and lifestyle and antisocial traits, such as impulsivity, irresponsibility, and poor behavioral controls (Factor 2). The PCL:YV was not administered in the healthy sample.

2.2.2. Substance use

We calculated the total number of substances (alcohol and drug) for which an individual met the lifetime dependence diagnostic criteria from the Kiddie Schedule for Affective Disorders and Schizophrenia (KSADS) (Kaufman et al., 1997) ("substance dependence"). A modified version of the Addiction Severity Index (McLellan et al., 1992) was also administered. Years of regular use were summed for each substance (alcohol and drug) that the participant reported using regularly (i.e., three or more times per week for a minimum period of 1 month) ("regular substance use"). Healthy control participants from the community were excluded if they self-reported any substance use.

2.2.3. Other measures

Median household income for each participant's home zip code was used as a proxy for socioeconomic status (SES). Full-scale IQ was estimated from the Vocabulary and Matrix Reasoning subtests of the Wechsler Adult Intelligence Scale (Wechsler, 1997; Ryan et al., 1999) for participants older than 16 years of age and from the Wechsler Intelligence Scale for Children—Fourth Edition (Wechsler, 2003; Sattler and Dumont, 2004) for participants younger than 16 years of age. Means and standard deviations are given in Table 1. IQ estimates were unavailable for $n = 7$ in the non-homicide offender group and $n = 1$ in the healthy group.

Trained researchers administered a post-head injury symptoms questionnaire (King et al., 1995) to evaluate history of traumatic brain injury (TBI). Number of TBIs with loss of consciousness (LOC) is reported. The Inventory of Callous-Unemotional Traits (Youth Self-Report Version; ICU, (Essau et al., 2006)) and Barratt's Impulsiveness Scale (BIS-11, (Patton et al., 1995)) were also administered to the incarcerated samples.

From the KSADS, offenders with a history of psychosis or bipolar disorders were excluded from further participation. Among non-homicide offenders, 3% met KSADS criteria for a past anxiety disorder and 3.7% met the criteria for a current anxiety disorder, 11.1% met the criteria for a past depressive disorder and 3.7% met the criteria for a current depressive disorder, 9.6% met the criteria for past attention deficit-hyperactivity disorder (ADHD) and 3.7% met the criteria for current ADHD, 88.1% met the criteria for past oppositional defiant (ODD) or conduct disorders (CD) and 8.9% met the criteria for current ODD/CD, and 1.5% met the criteria for past post-traumatic stress disorder (PTSD) and 5.2% met the criteria for current PTSD. Among