Morphological Alterations in the Prefrontal Cortex and the Amygdala in Unsuccessful Psychopaths

Yaling Yang
David Geffen School of Medicine at the University of California, Los Angeles

Adrian Raine
University of Pennsylvania

Patrick Colletti
University of Southern California School of Medicine

Arthur W. Toga and Katherine L. Narr
David Geffen School of Medicine at the University of California, Los Angeles

Although deficits in several cortical and subcortical structures have been found in psychopaths, it remains unclear whether the neuropathology differs between subgroups of psychopaths (i.e., unsuccessful and successful). Using both traditional and novel image analyses methods, this study aims to reveal gross and subtle morphological changes in the prefrontal cortex and the amygdala in unsuccessful and successful psychopaths. Volumetric segmentation, cortical pattern matching, and surface-based mesh modeling methods were used to examine prefrontal and amygdala structures in 16 unsuccessful psychopaths, 10 successful psychopaths, and 27 controls. Significant reduced gray matter volume and cortical thickness/surface shape in the middle frontal, orbitofrontal cortex and the amygdala were found in unsuccessful psychopaths but not successful psychopaths, compared with controls. This study provides the first evidence of greater prefrontal and amygdala structural deficits in unsuccessful psychopaths, which may predispose them to poor behavioral control and impaired decision-making, thus making them more prone to convictions.

Keywords: MRI, psychopathy, amygdala, prefrontal, temporal

Psychopathy, originally termed “sociopathic personality” by Patridge (1930), is a condition composed of complex symptoms including antisocial behavior, interpersonal dysfunction, and emotional impairments. There have been numerous hypotheses proposing that the deficits in the prefrontal cortex and the amygdala may contribute to the emotional and behavioral disturbances in psychopaths (Blair, 2003, 2008; Kiehl, 2006; Yang & Yang, 2006; Yang, Glenn, & Raine, 2008); however, findings from structural brain imaging studies conducted to date have been less than conclusive. For example, reduced prefrontal gray matter volume in the prefrontal cortex has been found in individuals with antisocial personality disorder and high psychopathy scores (Raine, Lencz, Bihrle, LaCasse, & Colletti, 2000). In addition, increased psychopathy score has been correlated with reduced prefrontal gray matter volume and cortical thickness (Yang, Raine, Colletti, Toga, & Narr, 2009; Yang et al., 2005). However, some studies failed to find such effects for psychopaths and alcoholics with antisocial personality disorder (Dolan, Deakin, Roberts, & Anderson, 2002; Lakko et al., 2002).

The inconsistent findings concerning the neuroanatomical correlates of psychopathy raise the question of whether the structural impairments are associated only with criminal psychopaths (“unsuccessful” psychopaths) but not “successful” psychopaths who manage to avoid any criminal conviction (Widom, 1978). Several studies have demonstrated neurobiological differences between successful psychopaths and their unsuccessful counterparts. One initial study by Raine et al. (2004) found an exaggerated hippocampal asymmetry (right > left) in unsuccessful psychopaths but not in successful psychopaths, reflecting an underlying neurodevelopmental abnormality that disrupts hippocampal-prefrontal circuitry in unsuccessful psychopaths. In a later study, Yang et al. (2005) revealed a significant 18–23% reduction in the prefrontal gray matter volume in unsuccessful psychopaths compared with both successful psychopaths and controls. These findings suggest that the structural deficits in prefrontal and temporal regions may...
render unsuccessful psychopaths less sensitive to environmental cues signaling danger and capture, making them more prone to conviction. However, it remains uncertain whether the prefrontal abnormality in unsuccessful psychopaths is restricted to particular prefrontal subregions. Furthermore, it is also unclear whether other structural characteristics (i.e., cortical thickness) of the prefrontal cortex are also altered in unsuccessful psychopaths.

In addition to the prefrontal cortex, previous hypotheses have linked deficits in the amygdala to psychopathic personality and behavior (Blair, 2003, 2008; Kiehl, 2006; Raine & Yang, 2006; Yang et al., 2008). The amygdala is crucial for fear conditioning and emotion recognition (Adolphs et al., 1994); thus, deficits in this structure have been linked to the most well-replicated findings of impaired fear conditioning and poor facial emotion recognition in psychopaths (Blair, 2008; Kiehl, 2006; Raine & Yang, 2006; Yang et al., 2008). Furthermore, the amygdala has been found to be associated with social judgment and moral emotion (Adolphs, Tranel, & Damasio, 1998; Blair, 2007); thus, deficits to this structure may further contribute to social dysfunction and impaired moral decision-making found in psychopaths, particularly unsuccessful psychopaths. Because successful and unsuccessful psychopaths both suffer emotion dysfunction, such as shallow affect and lack of remorse, it is plausible that any amygdala deficits found in unsuccessful psychopaths will be prominent compared to controls but indistinguishable compared with successful psychopaths. However, there has been no study to date that examined the structural integrity of the amygdala in unsuccessful and successful psychopaths.

In this study, we employed sensitive image-analysis methods to address these research questions using an overlapping group of subjects included in prior studies (Raine et al., 2000; Yang et al., 2005). The traditional volumetric analysis and more recently developed cortical pattern matching analysis methods were applied to identify disturbances in both regional gray matter volume and cortical thickness in the prefrontal cortex in unsuccessful and successful psychopaths. Regarding the amygdala, volumetric analysis was used to examine the gross structural integrity, whereas a surface-based mesh modeling method was employed to identify the regions of surface deformations in unsuccessful and successful psychopaths. It was hypothesized that unsuccessful psychopaths, but not successful psychopaths, would show prominent volumetric and morphological reductions in the orbitofrontal cortex, dorsolateral prefrontal cortex, and the amygdala compared with controls.

Method

Participants

All subjects were from a total sample of 87 male and female community volunteers drawn from five temporary employment agencies in Los Angeles, California (Raine et al., 2000) who received a structural MRI scan. Diagnostic, physical, and psychosocial characteristics of the subjects were assessed, including handedness, intelligence, substance dependence, alcohol used in the past month, and socioeconomic status (Raine et al., 2000; Yang et al., 2005, 2009). Written informed consent was obtained from all subjects, and the study was approved by the University of Southern California Institutional Review Board (IRB).

Psychopathy and Crime Assessment

Psychopathy was assessed using the Psychopathy Checklist—Revised (PCL–R) (Hare, 2003) with 6 sources of collateral data including the Interpersonal Measure of Psychopathy, self-reported crime and violence, criminal history transcripts obtained from the Department of Justice, data derived from and behavioral observations made during the Structured Clinical Interview for DSM Disorders I and II (First, Spitzer, Gibbon, & Williams, 1994; First, Spitzer, Gibbon, Williams, & Benjamin, 1994), and independent Interpersonal Measure of Psychopathy ratings made by two different laboratory assistants during separate phases of testing (Raine et al., 2000).

In line with previous reports on this sample, psychopaths were further classified into successful and unsuccessful psychopaths on the basis of their history of criminal convictions derived from statewide court records and lifetime self-reports (Raine et al., 2000; Yang et al., 2005). “Unsuccessful psychopaths” were defined as those with high PCL–R total scores (23 and above) who were prosecuted for their criminal acts, whereas “successful psychopaths” were those with high PCL–R total scores but who had escaped detection for their crimes. Despite the difference in their history of criminal convictions, the average number of self-reported crimes committed by unsuccessful psychopaths (9.88) was identical to that of their successful counterparts (9.37). It is worth mentioning that “successful” here only refers to their ability in avoiding criminal conviction for their crimes and does not suggest that they are “successful” in other aspects of cognitive or social functioning. In fact, in this sample, unsuccessful psychopaths had higher mean socioeconomic status than did successful psychopaths, although the difference was not statistically significant (p = .06). Those who had a total PCL–R score lower than 14 and no criminal conviction were classified as nonpsychopathic controls. The final samples of 53 consisted of 16 unsuccessful psychopaths, 10 successful psychopaths, and 27 controls.

MRI Acquisition and Data Processing

One hundred twenty-eight three-dimensional T1-weighted gradient-echo coronal images (TR 34 ms, TE 12.4 ms, flip angle 35°, 1.7 mm thickness, 256 × 256 matrix, FOV = 23 cm) were obtained from each participant on a Philips (S15/ACS) 1.5 Tesla scanner (Raine et al., 2000). Before manual delineation of the regions of interest (ROIs), all images were processed with a series of preparatory steps including tissue classification and the generation of a three-dimensional object model (Yang, Raine, Colletti, et al., 2009; Yang, Raine, Narr, Colletti, & Toga, 2009; Yang et al., 2007). For the amygdala, each image volume was further resampled into a 1-mm thickness to improve the visibility of anatomical details of the structure by using the Chirp-z interpolation to change the voxel size. Because this is a Fourier-based method, there is no loss of information or degradation of image quality with the change in thickness, and it does not introduce artifact into the data set.

The delineation of the ROIs was conducted by two independent technicians blind to group membership, who received extensive training on the delineation protocols under the supervision of Yaling Yang (see Yang, Raine, Narr, et al., 2009; Yang et al., 2007, for detail). For each hemisphere, the prefrontal lobe was
segmented into five subregions (i.e., superior frontal cortex, middle frontal cortex [MFC], inferior frontal cortex, orbitofrontal cortex [OFC], and rectal gyrus [RG]), following the methods detailed in the Appendix of Ballmaier et al. (2004), and the amygdala was traced following a protocol adopted from previously validated methods (Bartzokis et al., 1993; Narr et al., 2001; Yang, Raine, Narr, et al., 2009). All anatomical delineations were conducted on the coronal brain images of each individual while simultaneously displayed in the sagittal and transverse planes to facilitate a more accurate identification of the anatomical boundaries. For interrater reliability, intraclass correlation coefficients ranged between .90 and .97 for gray matter and white matter volume estimates obtained for the five frontal subregional and amygdala volumes (Yang, Raine, Narr, et al., 2009; Yang et al., 2007). In addition, whole brain volume inclusive of cerebral gray and white matter but excluding the ventricles, pons, and cerebellum was estimated for each individual (Yang et al., 2007) and retained for use in subsequent statistical analyses to control for individual brain size differences.

For the prefrontal cortex, previously validated cortical pattern-matching methods were applied to investigate extremely local cortical thickness changes (Narayan et al., 2007; Narr et al., 2005; Sowell et al., 2004; Yang, Raine, Colletti, et al., 2009) by matching homogenous regions of the cortex across the sample and allowing group comparisons of cortical thickness to be made at each cortical surface point (Yang, Raine, Colletti, et al., 2009). For the amygdala, previously validated surface-based mesh modeling and subsequent skeletonizing methods were used to approximate regional morphological changes of the amygdala (Narr et al., 2004; Yang, Raine, Narr, et al., 2009).

Statistical Analyses

Analyses of ROI volume measures were conducted using SPSS (SPSS, Inc., Chicago, IL) using the general linear model. Multivariate analyses of variance (ANOVAs) were conducted for the prefrontal subregional and amygdala volume (mm³) with group (unsuccessful psychopaths, successful psychopaths, and controls) as a between-subjects factor and whole brain volume as a covariate. Significant omnibus effects of group were followed up by lower order ANOVAs for pairwise comparisons to examine differences between successful and unsuccessful psychopaths and between each psychopath group and controls separately. For significant findings, socioeconomic status and substance dependence, for which groups differed significantly (see Table 1), were included as additional covariates to examine the cumulative effects of these potential confounds. Significance was established based on a two-tailed alpha level of .05 for all tests.

The same statistical models described above were implemented using the statistical program R (www.r-project.org) to identify regional changes in cortical thickness and amygdala surface anatomy between groups. Uncorrected two-tailed probability values obtained from statistical tests conducted for each cortical and amygdala surface point were color coded and displayed on the averaged cortical and amygdala surface representations of the entire group to allow initial visualization of group differences. Permutation tests with a threshold of $p < .05$ were applied to control for multiple spatially correlated comparisons to ensure that the overall pattern of effects in the uncorrected statistical maps could not have been observed by chance alone (Narayan et al., 2007; Yang et al., 2007). Given the hypotheses of this study, a ROI mask of the prefrontal cortex was made with a probabilistic atlas to be applied in the permutation tests across each hemisphere for the cortical thickness analyses (Bullmore et al., 1999; Narayan et al., 2007; Yang et al., 2007). Findings outside of the prefrontal cortex were treated as exploratory, because the goal of the cortical thickness analyses was to clarify existing prefrontal findings.

Results

Prefrontal Cortex

Volumetric findings. Multivariate ANOVAs showed a significant effect for the group, $F(20, 84) = 1.73, p = .044$, while controlling for whole brain volume. Specifically, the gray matter volumes of the right MFC, $F(2, 51) = 3.51, p = .037$; right and left OFC, $F(2, 51) = 6.96, p = .002$, and $F(2, 51) = 10.76, p < .001$, respectively; and the right RG, $F(2, 51) = 5.55, p = .007$, differed between three groups when we controlled for whole brain volume. Follow-up ANOVAs revealed that unsuccessful psychopaths exhibited significant gray matter volume reductions in the right MFC ($p = .039$), right and left OFC ($p = .001$ and $p < .001$, respectively), and the right RG ($p = .002$) compared with controls when we covaried for whole brain volume (see Figure 1). In addition, unsuccessful psychopaths showed volume reductions in the right MFC ($p = .03$) and right and left OFC ($p = .016$ and $p = .009$, respectively) compared with successful psychopaths (see Figure 1). However, only findings for reduced bilateral OFC volume in unsuccessful psychopaths remained significant after controlling additionally for socioeconomic status, substance dependence, and PCL–R Facet 1 and 4 scores compared with successful psychopaths and controls (all $p < .038$). No significant difference was found in any of the five prefrontal subregions in successful psychopaths compared with controls (all $p > .2$; see Figure 1). Regarding prefrontal white matter volumes, no significant group difference was found (all $p > .2$).

Cortical thickness findings. Consistent with the volumetric findings, unsuccessful psychopaths were found to show significant reductions in cortical gray matter thickness compared to controls across the entire hemispheres (left permutation corrected $p = .022$; right corrected $p = .01$; see Figure 2). Specifically, unsuccessful psychopaths showed cortical thinning in the right MFC, bilateral OFC, temporal cortex, and posterior cingulate cortex compared with controls (see Figure 2). ROI permutation tests confirmed findings for the right prefrontal cortical thinning in unsuccessful psychopaths compared to controls when we controlled for whole brain volume ($p < .042$), and the effects remained significant after we controlled for socioeconomic status and substance dependence ($p < .037$). In contrast, successful psychopaths showed no significant overall cortical thinning effects compared with controls (all $p > .1$). However, the uncorrected probability maps also showed cortical thinning in the right MFC in successful psychopaths compared to controls (see Figure 2), but this result did not survive permutation correction ($p = .07$). Compared with successful psychopaths, the uncorrected probability maps revealed that unsuccessful psychopaths showed reduced cortical thickness in the left posterior cingulate cortex and orbitofrontal cortex and increased cortical thickness in right superior frontal cortex (see Figure 2);
Table 1
Demographic, Cognitive, and Diagnostic Measures on Unsuccessful Psychopaths, Successful Psychopaths, and Controls

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Unsuccessful psychopaths (UP) (N = 16)</th>
<th>Successful psychopaths (SP) (N = 10)</th>
<th>Controls (C) (N = 27)</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>Range</td>
<td>n</td>
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<tr>
<td>Demographic</td>
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<tr>
<td>Age</td>
<td>33.62</td>
<td>6.94</td>
<td>30.20</td>
<td>6.39</td>
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<tr>
<td>Socioeconomic status</td>
<td>31.81</td>
<td>7.40</td>
<td>26.60</td>
<td>6.65</td>
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</tr>
<tr>
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<td>5</td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>11</td>
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<td>4</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
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<td></td>
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<td></td>
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<tr>
<td>Male</td>
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<td></td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Female</td>
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<td></td>
<td>1</td>
<td></td>
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<tr>
<td>Handedness</td>
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<tr>
<td>Right</td>
<td>13</td>
<td></td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>3</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Cognitive</td>
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<tr>
<td>Full IQ</td>
<td>96.00</td>
<td>14.87</td>
<td>102.10</td>
<td>13.35</td>
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<td>Diagnostic</td>
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<tr>
<td>Psychopathy</td>
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<tr>
<td>Total PCL–R score</td>
<td>30.06</td>
<td>5.34</td>
<td>23–40</td>
<td></td>
</tr>
<tr>
<td>Facet 1 (Interpersonal)</td>
<td>5.88</td>
<td>1.54</td>
<td>3–8</td>
<td></td>
</tr>
<tr>
<td>Facet 2 (Affective)</td>
<td>5.19</td>
<td>2.04</td>
<td>2–8</td>
<td></td>
</tr>
<tr>
<td>Facet 3 (Lifestyle)</td>
<td>7.56</td>
<td>2.19</td>
<td>3–10</td>
<td></td>
</tr>
<tr>
<td>Facet 4 (Antisocial)</td>
<td>7.81</td>
<td>1.80</td>
<td>4–10</td>
<td></td>
</tr>
<tr>
<td>Substance dependence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>14</td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>2</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Times drink alcohol per month</td>
<td>5.56</td>
<td>6.45</td>
<td>8.80</td>
<td>8.56</td>
</tr>
</tbody>
</table>

Note. PCL–R = Psychopathy Checklist—Revised (Hare, 2003).
however, the thickness difference between these two psychopathy subgroups was not significant after we corrected for multiple comparisons (all \( p > .091 \)).

**Amygdala**

**Volumetric findings.** Multivariate ANOVAs showed a significant effect for the group, \( F(4, 104) = 3.96, p = .005 \), when we controlled for whole brain volume. Specifically, three groups differed in both the right and left amygdala volume, \( F(2, 46) = 4.1, p = .012 \), and \( F(2, 46) = 4.9, p = .023 \), respectively, when we controlled for whole brain volume. Follow-up ANOVAs showed significant volumetric reduction in the right and left amygdala in unsuccessful psychopaths compared with controls (\( p = .009 \) and \( p = .022 \), respectively). As illustrated in Figure 3, unsuccessful psychopaths showed a 26% volume reduction in the left amygdala, and a 20% volume reduction in the right amygdala compared with controls. Volume reductions in the right and left amygdala in unsuccessful psychopaths remained significant after correcting for socioeconomic status and substance dependence compared with controls (\( p = .004 \) and \( p = .006 \), respectively). Successful psychopaths also showed a 9.3% volume reduction in the left amygdala and a 12.7% volume reduction in the right amygdala compared with controls. However, neither left nor right amygdala volume of successful psychopaths differed significantly compared with unsuccessful psychopaths (\( p = .35 \) and \( p = .21 \), respectively) or controls (\( p = .32 \) and \( p = .33 \), respectively).

**Regional amygdala findings.** Bilateral shape differences in the amygdala were found in unsuccessful psychopaths compared with controls (left permutation corrected \( p = .014 \); right \( p < .001 \); see Figure 4), where results remain significant after controlling for substance dependence and socioeconomic status (all \( p < .023 \)). Regarding the localization of amygdala surface alterations, the uncorrected surface probability maps revealed that unsuccessful psychopaths showed prominent deformations in the vicinity of the superficial (superior view) and basolateral nuclei group (superior and inferior view) of the amygdala bilaterally compared with controls (see Figure 4). Consistent with the volumetric findings, successful psychopaths showed no significant amygdala deformation compared to unsuccessful psychopaths and controls (all \( p > .12 \)).

**Discussion**

This is the first study to show regional volumetric and morphological abnormalities in the prefrontal cortex and the amygdala in unsuccessful psychopaths. Specifically, unsuccessful psychopaths showed significant gray matter volume and thickness reduction in the MFC and OFC compared with controls. Focused analysis of the amygdala further showed significant bilateral volume reduc-
tions of the amygdala in unsuccessful psychopaths compared with controls, where amygdala surface deformations were most prominent in regions corresponding to the basolateral and superficial nuclei group. Successful psychopaths did not exhibit prefrontal and amygdala deficits compared with controls. Follow-up analyses revealed little evidence that findings could be attributed to group differences in substance dependence and socioeconomic status. Results are in line with prior investigations suggesting that unsuccessful psychopaths suffer a greater degree of structural deficits in the prefrontal cortex and the amygdala that may differentiate this subgroup of psychopaths from their successful counterparts and nonpsychopaths.

Findings of gray matter volume reduction within the prefrontal cortex in unsuccessful psychopaths are consistent with prior results (Yang et al., 2005) and further indicate a preferential involvement of the right MFC, bilateral OFC, and right RG. Subtle structural

![Uncorrected statistical mapping results of the cortical thickness differences between groups.](image)

![Comparisons of right and left amygdala volumes between groups, with total brain volume as a covariate. The vertical lines represent the standard errors of the means.](image)
alterations of reduced cortical gray matter thickness were found in similar subregions of the prefrontal cortex in unsuccessful psychopaths, confirming that structural deficits in the MFC and OFC may predispose one to increased psychopathy and risky behavior. The findings are consistent with recent studies that found decreased gray matter volume in the dorsolateral prefrontal cortex (DLPFC), OFC, and RG in psychopaths (de Oliveira-Souza et al., 2008; Müller et al., 2008). The findings are also supported by lesion studies of patients with damage to the OFC and DLPFC who show disturbed personality and increased antisocial behavior, such as inappropriate social conduct, poor decision-making, and response perseveration (Tranel, Bechara, & Denburg, 2002), all symptoms similar to features of psychopathy (Hare, 2003). Findings of this study suggest that reduced gray matter volume and thickness in these prefrontal regions may predispose unsuccessful psychopaths to impulsive and risky behaviors and deprive them the ability to detect cues signaling arrests. The absence of prominent neuroanatomical pathology in the prefrontal regions of successful psychopaths is consistent with prior findings (Yang et al., 2005) and suggests that relatively intact prefrontal volume may function as a protective factor that preserves the ability to either express psychopathic personality tendencies in more adaptive ways or conceal crimes more effectively to avoid arrests and/or convictions.

In addition to the prefrontal cortical thinning, our exploratory findings showed that unsuccessful psychopaths have reduced cortical thickness in the medial and superior temporal cortex and the posterior cingulate cortex compared with controls. These exploratory results are in line with previous studies that reported reduced gray matter volume in the temporal and cingulate cortices in psychopaths (de Oliveira-Souza et al., 2008; Müller et al., 2008) and children with conduct disorders (Kruesi, Casanova, Mannheim, & Johnson-Bilder, 2004). These findings are supported by previous hypotheses that impairments in the paralimbic system may be associated with psychopathy (Kiehl, 2006; Raine & Yang, 2006; Yang et al., 2008), mostly through the mediation of semantic and social conceptual processing. The possibility arises that the involvement of the temporal cortex in decoding social cues may contribute to the inability of unsuccessful psychopaths to recognize alarming signals that could lead to capture. Although they are preliminary, these findings suggest a more complex neuropathology in the fronto-temporal circuit of psychopaths, particularly those with criminal convictions, where different degrees of structural deficits in discrete regions of this circuit may explain differences in the symptom manifestations of the psychopathy subgroups.

Another key finding of this study is the significant bilateral amygdala volume reductions observed in unsuccessful psychopaths compared with controls. The findings are consistent with several previous hypotheses (Blair, 2003, 2008; Kiehl, 2006; Raine & Yang, 2006; Yang et al., 2008) that deficits in the amygdala may disrupt moral development and socialization and eventually lead to psychopathy. The findings also reveal that the amygdala deficits in unsuccessful psychopaths were more pronounced in the basolateral and superficial nuclei groups of the amygdala compared with controls. The basolateral nuclei group of the amygdala, which includes the lateral, basolateral, and basomedial nuclei, is involved in establishing stimulus-reinforcement associations in fear condition learning (Sah, Faber, Lopez De Armentia, & Power, 2003), and thus may contribute to the inability to learn from punishment and insensitivity to changes in reward value (i.e., perseverative behavior).
response pattern) in unsuccessful psychopaths (Newman, Patterson, Kosson, 1987). Although it is scarce, neuroscience research on the superficial nuclei group of the amygdala (including the anterior and posterior cortical nuclei) suggests that damage to this region may lead to poor parenting, impaired social interaction, and reduced stress and anxiety (Knapska, Radwanska, Werka, & Kaczmarek, 2007), all features associated more strongly with unsuccessful psychopathy (Hare, Cooke, & Hart, 1999). The absence of significant difference in the amygdala volume and morphology between unsuccessful and successful psychopaths suggests a possible overlap in the etiology between them, which may explain the similar degree of manifestation in affective symptoms in these two subgroups.

Although significant findings are reported in this study linking unsuccessful psychopaths to both volumetric and morphological deficits in the prefrontal cortex and the amygdala, several limitations need to be considered when interpreting the findings. The first concern is that the sample sizes for the two psychopathic groups, particularly the successful psychopaths, were moderate, which may increase the risk of Type II error and contribute to the nonsignificant findings in successful psychopaths. In addition, the difference between two psychopathy groups in the PCL–R Facet 1 and Facet 4 scores may also contribute to the lack of significant findings in several analyses. Specifically, some of the analyses show a stair-step pattern (i.e., unsuccessful psychopaths < successful psychopaths < controls), suggesting that the findings may be influenced by different levels of psychopathy between the two psychopathy groups. Although the orbitofrontal reduction in unsuccessful psychopaths remained significant after covarying for PCL–R Facet 1 and Facet 4 scores, indicating a potential neuropathological difference between psychopaths with criminal convictions and those without, the lack of significant morphological difference in other prefrontal ROIs and the amygdala between successful and unsuccessful psychopaths suggests that it is unlikely that the heterogeneity in criminal convictions within psychopaths is the main contributor to the inconsistency among prior brain imaging findings. Furthermore, the use of manual segmentation in this study following previously validated protocols may limit the ability for follow-up studies to replicate the findings. In fact, the use of different methodologies among studies may be likely to have greater influence on the findings than the difference in criminal background among psychopaths. Thus, future studies using standardized imaging analysis methods on successful and unsuccessful psychopaths (well matched on PCL–R scores) are required to further investigate the underlying neural mechanisms predisposing to psychopathy and criminal offending/convictions.

Second, the volumetric reduction in the MFC in unsuccessful psychopaths was no longer significant after we controlled for substance dependence and socioeconomic status; therefore, we cannot completely rule out the possibility that these confounds may at least in part account for the structural abnormalities found in the MFC. There is evidence that substance abuse in particular has some impacts on brain morphology, particularly on the MFC (Taki et al., 2006). Considering the fact that psychopathy and substance abuse are highly comorbid, future studies may benefit from the inclusion of a second control group consisting of nonpsychopathic individuals with substance abuse or dependence as well as compatible socioeconomic status to evaluate the effect of this potential confound on the brain structures of psychopathy.

Another important issue concerns the impacts of the structural deficits in the prefrontal cortex and the amygdala on the functional states of these brain regions. Without confirmatory information from other sources (e.g., psychophysiological and neuropsychological measures), the interpretations of the results were based on the assumptions that neuroanatomical abnormalities are linked to, or may causally lead to, functional impairments in the affected regions in unsuccessful psychopaths. Despite these limitations, by using multiple image analysis methods on a community-based sample, this study presented initial evidence supporting the hypotheses of a disturbed brain network involving the MFC, orbitofrontal regions, and the amygdala in unsuccessful psychopaths that could be further tested.

Conclusion

It has been argued increasingly in the psychopathy literature that the inconsistency among neuropathological findings in psychopaths may be partly accounted for by the heterogeneity within psychopathy groups. The findings in this study provide initial evidence to support the argument that the morphology of prefrontal and amygdala structures differs between the two psychopathic subgroups investigated, namely unsuccessful and successful psychopaths. The results showed prominent structural deficits in the MFC, OFC, and the amygdala in unsuccessful psychopaths but not successful psychopaths, suggesting that these impairments may predispose unsuccessful psychopaths to increased risky behavior and account for their inability to process social and emotional cues to avoid criminal convictions. However, given the differences in PCL–R scores between the two psychopathy groups, the findings should be interpreted with caution, and further investigation is needed to clarify the differences in the etiology between psychopaths with and without convictions. Nonetheless, this study supports previous hypotheses that disturbances in a complex neural network including the prefrontal cortex and the amygdala may contribute to the underlying neuroanatomical pathology of psychopathy and further suggests that such disturbances may be associated particularly with criminal arrests and convictions.

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