Degree project

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The Structural Brain Correlates of Psychopathy and Violent Crime

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Abstract

Psychopathy is a frequently reported personality trait among violent offenders, and psychopaths have a higher rate of recidivism than inmates without psychopathic features. This systematic review aimed to investigate whether structural brain differences, measured with magnetic resonance imaging, are observed in violent offenders with psychopathy compared to violent offenders without psychopathy or healthy non-violent controls. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The search utilised the academic databases Web of Science and Medline EBSCO and included original peer-reviewed articles written in English and published between 2013 and 2023. Seven articles fulfilling the inclusion criteria were selected for the review. The findings indicated that there are structural differences between violent psychopaths compared to non-violent psychopaths and healthy controls, such as reduced grey matter volume in the prefrontal cortical areas, posterior cingulate cortex and precuneus, and striatal and limbic regions. Further, the degree of structural brain differences in psychopaths correlated with the degree of psychopathic traits. The structural differences found in the brains of violent psychopaths can provide insight into the neurobiological basis and neural mechanisms of psychopathy and elucidate how changes in brain morphology relate to antisocial behaviour and psychopathic personality traits. In addition, the evidence of structural abnormalities in the brain of psychopaths may help develop targeted treatments that could reduce the risk of psychopathic individuals turning to crime and violence or committing repeated violent crimes.

[Keywords: *Psychopathy, Antisocial personality disorder, Violent crime, Magnetic resonance imaging]*

The Structural Brain Correlates of Psychopathy and Violent Crime

Violent crime is an ongoing problem in society that is costly for the government and people's lives. Psychopathy appears to be an important predictor in violent crime and increases the likelihood of crime recurrence after release from prison (Kriminalvård och Statistik, 2021; Laurell & Dåderman, 2005). Psychopathy is quite rare: In a study conducted in Great Britain, less than one percent of the general population was found to have psychopathic traits (Coid et al., 2009). Similarly, it is estimated that roughly 1% of American men outside institutions are psychopaths, while a prevalence of 15% to 25% has been described in incarcerated populations (Hart & Storey, 2013). Further, it has been estimated that possibly up to 93% of psychopaths are statistically likely, at any given time, to be in prison, jail, parole, or probation in the United States (Kiehl & Hoffman, 2011). Relapse into criminal behaviour in Sweden between 1994 and 2018 was around 30%, and psychopathy is a predictor of relapse, especially in violent crime (Kriminalvård och Statistik, 2021; Walters, 2003).

Psychopathy is a relatively stable personality trait with a high heritability and, thus, almost impossible to treat (Bezdjian et al., 2010). Although psychotherapy and behavioural training exist, such are not always available or effective (Anderson & Kiehl, 2014). Psychopaths are much more likely to commit violent crimes at a higher rate than non-psychopaths (Kriminalvård och Statistik, 2021). These factors may explain the staggering overrepresentation of psychopaths in prisons (Kiehl & Hoffman, 2011). Nevertheless, not all psychopaths are violent or re-offend. While there may be several explanatory factors for non-violence in some psychopaths, such as better self-regulatory impulse control (Lasko & Chester, 2021), this systematic review will focus on whether there are any observable structural brain differences between psychopaths and non-psychopaths convicted of violent crimes and psychopaths and healthy controls without convictions of violent crimes. Understanding the brain basis of psychopathy in conjunction with violent crime could be helpful for the criminal justice system, which has to make decisions concerning inmates convicted of violent crimes, such as eligibility for parole or risk of recidivism. Further,

detailed knowledge about the brain basis for psychopathy and violent behaviour might benefit the development of more appropriate treatment programs.

Psychopathy, the Dark Triad, and Antisocial Personality Disorder

Psychopathy is a personality disorder characterised by persistent antisocial behaviour and personality features such as reduced empathy or lack of empathy, lack of guilt and remorse, callousness, high levels of impulsivity and thrill-seeking, and aggressive and egocentric characteristics (Cooke & Michie, 2001; Hare, 1985). Psychopathy is one of the Dark triad personality traits, the others being narcissism and Machiavellianism (Paulhus & Williams, 2002). Yet, it has recently been suggested that psychopathy, narcissism, and Machiavellianism may not be distinct traits but reflections of the same underlying antagonistic personality (Bader et al., 2022).

Mental disorders are diagnosed by the criteria listed in the International Classification of Diseases (ICD-10,1999) or the Diagnostic and Statistical Manual of Mental Disorders 5th edition (DSM-5, 2013). Notably, psychopathy is not an independent diagnosis in the current psychiatric diagnostic systems. Although it is often considered to exist on the same continuum as antisocial personality disorder (ASPD), it should not be confused with ASPD. An ASPD diagnosis focuses on antagonistic behaviours that diverge from society's expectations and does not necessarily involve personality traits considered central in psychopathy (DSM-5, 2013). Only those individuals who display antisocial behaviour and psychopathic personality features are considered psychopaths (Abdalla-Filho & Völlm, 2020), and therefore, these two terms should not be used interchangeably. Yet roughly one-third of those diagnosed with ASPD are also psychopaths. In contrast, despite exhibiting antisocial behaviours, not all psychopaths fulfil the diagnostic criteria for ASPD, that is, they have a chronically unstable and antisocial lifestyle (Abdalla-Filho & Völlm, 2020).

Measurement of Psychopathy

Psychopathic traits can be measured with multiple self-evaluation or interview tools. The most widely used tool is the Psychopathy Checklist-Revised (PCL-R; Hare, 1991). The PCL-R consists of 20 items and is a symptom construct rating scale. It includes a semi-structured interview, and also data from the case files and other collateral information is utilised. PCL-R provides a score in psychopathic traits ranging from 0 to 40. A score of 30 or higher has been used as a cut-off to evaluate whether or not a person is a psychopath, and sometimes the cut-off of 25 is used to indicate subclinical psychopathy. The PCL-R consists of two connected subfactors: the first is related to the selfish and remorseless use of others (psychopathic traits), and the second relates to a chronically unstable and antisocial lifestyle (antisocial behaviour). However, more recent factor analyses have resulted in either a three-factor (Cooke & Michie, 2001) or a four-facet model (Hare, 2003). In the four-facet model, factor 1 is divided into interpersonal problems (facet 1), such as superficial charm, grandiose self-worth and pathological lying, and affective traits (facet 2), such as lack of remorse, responsibility or guilt and callousness. Factor 2 is divided into a lifestyle facet (facet 3), such as stimulation-seeking behaviour and impulsivity and an antisocial sub-scale (facet 4) which includes poor behavioural control, juvenile delinquency, and criminal versatility.

Because the PCL-R (Hare, 1991) is time-consuming to administer and requires access to case data, an abbreviated version, the Hare Psychopathy Checklist-Screening Version (PCL-SV), was developed as a screening tool (Hart et al., 1995). This version has only 12 items, but it also requires an interview. A cut-off score of 18 (or more) is typically used to identify psychopathy and a cut-off score of 13 (up to 17 points) is considered to reflect subclinical psychopathy.

The Levenson Self-Report Psychopathy scale (LSRP) (Levenson et al., 1995) is partly based on the Psychopathy Checklist-Revised (PCL-R) (Hare, 1991). It consists of 26 statements that participants must rate on a 4-point scale ("disagree strongly", "disagree somewhat ", "agree somewhat", and "agree strongly") (Levenson et al.,1995). The LSRP attempts to measure psychopathy and psychopathic traits in the general population and employ similar "descriptors" for the traits and behaviours used in the PCL-R (Weiss et al.,

2016). However, the 26 statements in the test focus on typical moral dilemmas instead of criminal behaviour, which is assessed in the PCL-R (Hare, 1991; Weiss et al., 2016). The LSRP is split into two different parts, one measuring primary psychopathy (the emotional aspect of psychopathy) and consisting of 16 statements, and the second part consisting of 10 statements measuring secondary psychopathy (the lifestyle of a psychopath) (Miller et al., 2008). The maximum score on LSRP is 104, and a cut-off of 58 points or more has been considered to reflect psychopathy (Brinkley et al., 2000).

In addition to LSRP, two commonly used self-report tests for assessing psychopathic traits are the Triarchic Psychopathy Model (TriPM) based on the three different constructs of the Triarchic model of psychopathy (Patrick et al., 2009) and The Psychopathic Personality Traits Scale (PPTS; Boduszek et al., 2016). The TriPM is a tool to measure the three-trait model of disinhibition (impulsiveness, irresponsibility, oppositionality, and anger), meanness (callousness, cruelty, predatory aggression, and excitement-seeking) and boldness (high dominance, low anxiousness, and venturesomeness) and consists of 58 items (Patrick et al., 2009). Each item is rated on a four-option scale: True, Somewhat True, Somewhat False, and False, and subscale scores are summed to yield a total psychopathy score. The PPTS consists of 20 items, rated with binary responses of agree or disagree, and is a diagnostic tool that includes four factors: interpersonal manipulation, egocentricity, cognitive responsiveness, and affective responsiveness (Boduszek et al., 2018). Scores range from 0 to 20, with higher scores, without a specifically determined cut-off indicating elevated levels of psychopathic personality traits.

From genes to brain and behaviour

While no "psychopathy gene" exists, data suggests that criminal and antisocial behaviour has a significant hereditary component (e.g., Bezdjian et al., 2011). Although the exact molecular-genetic processes of psychopathy are unknown, there are signs that the expression of genes in the brain associated with autism and antisocial behaviour may be dysregulated in psychopathy (Tiihonen et al., 2008). Further evidence indicates that

abnormal glucose metabolism and disrupted the functioning of endogenous opioid systems and receptors are potent predictors of violent crime in antisocial individuals (Ferguson, 2010).

Gene-environment correlations impact how specific brain structures and circuits develop, increasing the risk of a person developing psychopathy (Fullam et al., 2009; Hicks et al., 2012). Given that the central features of psychopathy include emotional callousness, shallow emotions, and lack of empathy and remorse, brain areas implicated in emotions and emotion regulation may be centrally involved in psychopathy. For instance, functional brain imaging studies show that psychopathic individuals exhibit less affect-related activity in the amygdala, hippocampus, striatum, and cingulate cortices (Kiehl et al., 2011; Dolan & Fullam, 2009). Further, psychopathic individuals have much lower frontal cortical brain activity in response to empathy-eliciting pain stimuli than non-psychopathic individuals, consistent with their low sense of empathy (Decety et al., 2013; Meffert et al., 2013). These functional differences in circuits related to emotion regulation and behavioural impulse control may be suggestive of underlying structural brain differences between violent psychopaths and violent offenders without psychopathy, or non-violent psychopaths, or healthy controls.

Psychopathy and Violent Crime

In this review, we define violent crime as any act where a victim has been harmed by or threatened with violence, leading to physical or mental harm, criminal charges, and prosecution and sentencing of the perpetrator. However, we acknowledge that countries' definitions of violent crime and their criminal justice systems differ. Therefore, an act defined as a violent crime in one country may not lead to criminal prosecution in another. We also acknowledge that violent crimes arise from different factors, for instance, poverty, social exclusion, or traumatic brain injuries (Williams et al., 2018).

Regardless, violent criminals often display traits related to psychopathy, such as anger, lack of impulse control, strong dominance instinct, and antisocial personality tendencies (Kiehl & Hoffman, 2011). Further, psychopaths are more likely to commit violent

crimes at a higher rate than non-psychopaths, and their rate of reoffending is also significantly higher (Hart et al., 1988; Hare, 2009). In a study conducted in the 1980s in Canada, it was shown that 78% of imprisoned psychopaths were convicted of a violent crime, and their rate of recidivism within three years was 80%, while only 30% of non-psychopathic inmates were reconvicted within three years following release (Hart et al., 1988). Moreover, sex offenders high in psychopathic traits had a violent recidivism rate of 90% compared to 40% among those who scored low in psychopathic traits (Rice & Harris, 1997). Given the heavy burden that psychopaths exert on the criminal justice system, we will limit our review to violent crime in the context of psychopathy.

The Aim of the Present Thesis

This systematic review aims to determine what varieties of structural brain differences can be observed in individuals diagnosed with psychopathy who are convicted of violent crimes compared to violent offenders without psychopathy and to psychopaths or healthy individuals without convictions of a violent crime.

Methods

Search Strategy

For our systematic review, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement (Page et al., 2021). We used original peer-reviewed research articles published in English within the past ten years in respected journals. The following databases were used in the literature search: Web of Science and Medline EBSCO. The search string utilised for finding appropriate records was:

> ((Psychopath OR psychopathy OR psychopathic OR non-psychopath OR general population) AND (violence OR violent OR non-violent OR crime OR criminal OR offender OR convict OR inmate OR prisoner) AND (magnetic resonance imaging OR MRI)).

Preliminary searches were completed on 6/3, 2023, in Medline EBSCO and Web of Science. Searches were restricted to human males and adults, articles written in English, published in peer-reviewed journals between 2013-2023, and having abstracts available. Records retrieved in Medline EBSCO included 51 articles and records retrieved in Web of Science included 103 articles. To keep track of all the articles, we used Rayyan (Ouzzani et al., 2016), an open software developed to help structure systematic reviews.

Study Selection and Inclusion and Exclusion Criteria

The target group included male adult prison and forensic populations of psychopaths convicted of violent crimes or psychopaths with a criminal history of violent crime. The control groups consisted of either violent criminals without psychopathy or psychopaths or healthy individuals without a history of violent criminal behaviour. Psychopathy must have been assessed using widely known diagnostic interviews or self-rating scales. Because this systematic review focuses on structural neuroimaging methods, we have included only studies utilising Magnetic Resonance Imaging (MRI) to assess brain morphology. Studies utilising whole-brain comparisons (voxel-based morphometry, VBM) and Region-of-Interest (ROI) comparisons, as well as Diffusion Tensor Imaging (DTI) comparisons, were included. Whereas the database searches were conducted collaboratively by both authors, each record's eligibility for the systematic review was assessed independently by each author. Search results were first exported to Rayyan, and for potential inclusion in the systematic review, each author assessed the title and abstract. Disagreements among raters at this stage were resolved through discussion, and if consensus could not be reached, the record was discarded. When the eligibility of the sources had been assessed based on abstracts, the full texts were retrieved, and the authors again independently screened the full texts for eligibility. Again, disagreements among raters were resolved through discussion, and if consensus could not be reached, the report was discarded. The screening process is illustrated in Figure 1.

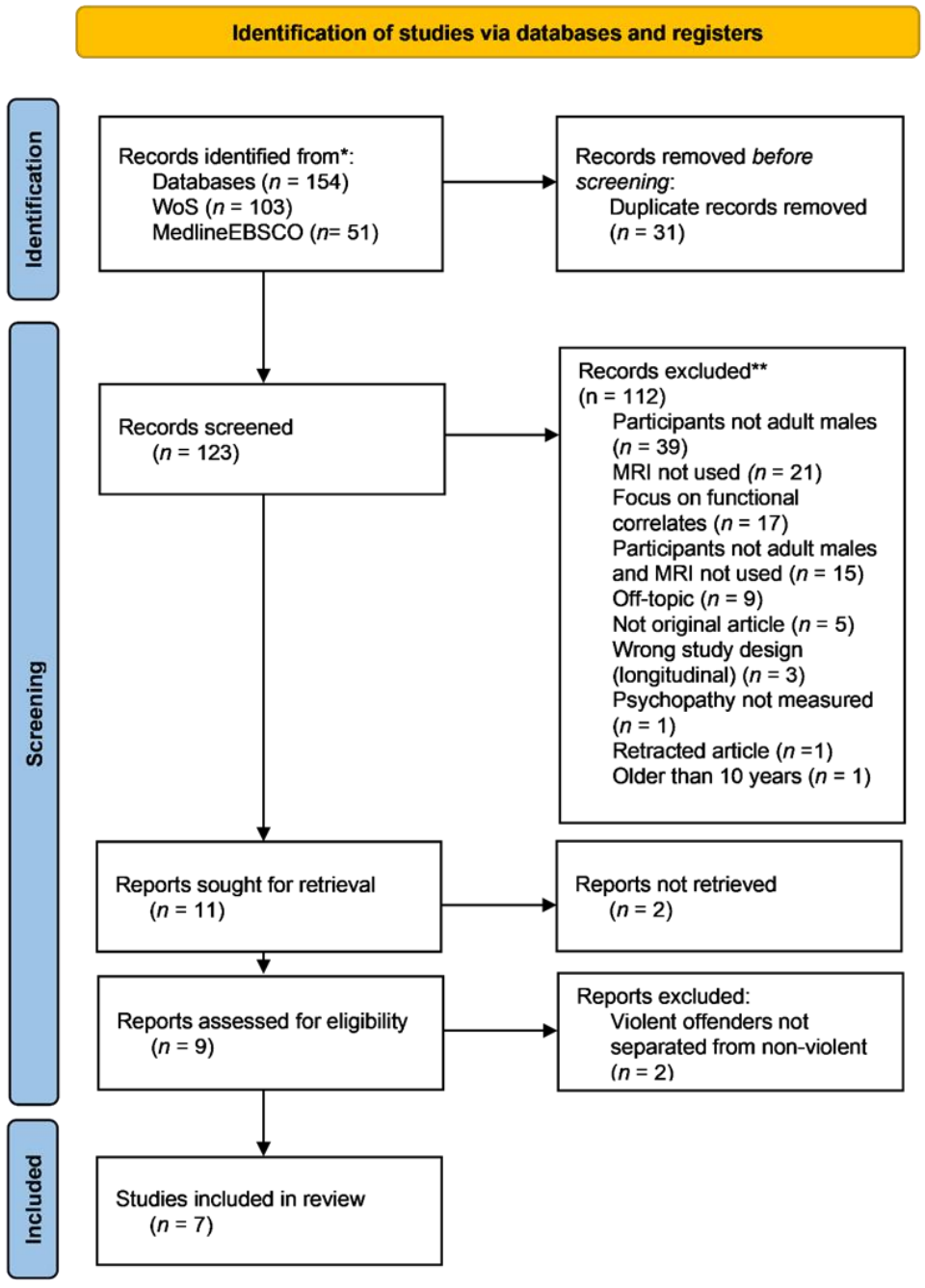

Figure 1. The PRISMA flow chart. From Page et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *Systematic Reviews, 10*, 89.

Data Extraction

Data that was extracted from the records included authors' names, year of publication, sample characteristics (size), behavioural measures of psychopathy, measures of brain morphology with MRI, as well as key findings.

Results

A summary of the selected studies, sample characteristics, behavioural measures of psychopathy, measures of brain morphology with MRI, as well as key findings are listed in Table 1. Notably, none of the studies included non-violent psychopaths as a comparison group, thus, all comparisons were made between violent psychopaths and non-psychopaths and violent psychopaths and non-violent, healthy controls. To summarise, volume reductions in several different brain areas were found in violent criminals with psychopathy compared to non-violent, healthy controls but the differences between violent criminals with and without psychopathy were markedly more subtle. Thus, we first present the findings comparing violent psychopaths and healthy controls.

Differences in the Structural Organisation of the Brain Between Violent Offenders With Psychopathy and Non-violent Healthy Controls

All seven studies selected for this systematic review included a control group composed of healthy, non-violent individuals. However, in the study by Kolla and colleagues (2013), comparisons between healthy controls and violent psychopaths were not reported. The remaining six studies varied on whether whole brain comparisons (n = 2), region-of-interest analysis methods (n = 2), both (n = 2), or diffusion tensor imaging (n = 1) were used, and the regions of interest also varied from subcortical nuclei to cortical structures. Overall, single, voxel-by-voxel whole brain measurements tended to produce slightly different significant findings than voxel-averaged landmark-based ROI analyses.

Brain Structure in Violent Psychopaths

Reference	Subjects	Psychopathy measure	Brain imaging and analysis method	Result
Bertsch, K. et al. (2013). Brain volumes differ between diagnostic groups of violent criminal offenders.	Male violent offenders with ASPD and psychopathy (*N* = 12) Male violent offenders with ASPD and BPD (*N* = 13) Male healthy controls (*N* = 14)	PCL-R	MRI: VBM & ROI	Compared to controls, in ROI analyses, violent offenders with psychopathy had reduced GMV in the left postcentral gyrus, left DMPFC, right PCC/precuneus, and occipital cortex bilaterally, while VBM analyses additionally revealed decreased GMV in right DMPFC, left PCC/precuneus, right inferior frontal cortex, medial and lateral parts of the frontal pole, left posterior parahippocampal gyrus, right posterior parietal cortex, left paracentral cortex, SMA, and cerebellum. In ROI analyses, violent offenders with psychopathy differed from those without psychopathy only with respect to reduced GMV in left PCG. In contrast, VBM analyses additionally indicated reduced GMV in the left precuneus, left dorsal paracingulate cortex, left posterior hippocampal gyrus and left lateral occipital cortex.
Boccardi, M. et al. (2013). Atypical nucleus accumbens morphology in psychopathy: Another limbic piece in the puzzle.	Male violent offenders with psychopathy (*N* = 26) Male healthy controls (*N* =25)	PCL-R	MRI: ROI	Nucleus accumbens volume was 13% smaller in violent psychopaths than in the control group, with anterior hypotrophy bilaterally. Violent offenders with psychopathy had a normal global volume of putamen and caudate but atypical right dorsal putamen morphology.
Hofhansel, L. et al. (2020). Morphology of the criminal brain: Grey matter reductions are linked to antisocial behaviour in offenders.	Male violent offenders (*N* = 27) Male healthy controls (*N* = 27)	PCL-R	MRI: VBM	No differences between groups in whole-brain comparisons were found in GMV, but in violent offenders, the PCL-R score was negatively correlated with GMV in the superior frontal gyrus.

Kolla, N. J. et al. (2014). Disentangling possible effects of childhood physical abuse on grey matter changes in violent offenders with psychopathy.	Male violent offenders with ASPD and psychopathy (*N* = 9) Male violent offenders with ASPD (*N* = 15) Male healthy controls (*N* = 13)	PCL-R	MRI: VBM	Comparison to healthy controls was not reported. Violent offenders with psychopathy, compared to those without, had smaller GMV in bilateral temporal poles, right uncus, and right cerebellar lobule.
Kolla, N. J. et al. (2017). Association of monoamine oxidase-A genetic variants and amygdala morphology in violent offenders with antisocial personality disorder and high psychopathic traits.	Male violent offenders with ASPD and psychopathy (*N*= 18) Male healthy controls (*N* = 20)	PCL-R	MRI: ROI	Violent offenders with psychopathy had decreased surface area in the right basolateral amygdala, whereas the right anterior part of the amygdala showed increased surface area compared to controls.
Leutgeb, V. et al. (2015). Brain abnormalities in high-risk violent offenders and their association with psychopathic traits and criminal recidivism.	Male violent offenders with psychopathy (*N* = 40) Male healthy controls (*N* = 37)	PLC-R	MRI: VBM & ROI	While VBM analysis indicated no differences between groups, ROI analyses showed that violent offenders with psychopathy had decreased GMV in the right DMPFC but increased GMV in the left pallidum, left caudate nucleus, and right cerebellar hemisphere, compared to healthy controls. Within the violent offender group, PCL-R factor 1 score correlated negatively with DLPFC GMV and factor 2 scores negatively with GMV in the putamen, pallidum, OFC, insula and SMA.
Sethi, A. et al. (2014). Emotional detachment in psychopathy: Involvement of dorsal default-mode connections	Male violent offenders with psychopathy (*N* = 13) Male healthy controls (*N* = 13)	PCL-R	MRI: DTI	Violent offenders with psychopathy had reduced fractional anisotropy in the left dorsal cingulum compared to controls.

PLC-R = The Psychopathy Checklist-Revised, ASPD = antisocial personality disorder, BPD = borderline personality disorder, MRI = magnetic resonance imaging, VBM = voxel-based morphometry, ROI = region-of-interest, DTI = diffusion tensor imaging, GMV = grey matter volume, DMPFC = dorsomedial prefrontal cortex, DLPFC = dorsolateral prefrontal cortex, PCC = posterior cingulate, SMA = supplementary motor area, PCG = postcentral gyrus, OFC = orbitofrontal cortex

Hofhansel et al. (2020) and Leutgeb et al. (2015) compared whole brain grey matter volume between healthy controls and violent offenders with VBM, but despite there being a strong trend for reduced total GMV in violent psychopaths in the Hofhansel et al. study, neither study found between-group differences in total GMV. In contrast, in their VBM analyses, Bertsch et al. (2013) showed reductions in GMV in psychopaths bilaterally in DMPFC, PCC/precuneus, and occipital cortex, and lateralised reductions in the left postcentral gyrus, left posterior parahippocampal gyrus, left paracentral cortex, left SMA, left cerebellum, right inferior frontal cortex, right posterior parietal cortex, and medial and lateral parts of the frontal pole.

The ROI analyses revealed slightly contradictory findings both in cortical and subcortical areas. Bertsch et al. (2013) reported that violent offenders with psychopathy had reduced GMV in the left postcentral gyrus, left DMPFC, right PCC/precuneus and occipital cortex bilaterally, while Leutgeb et al. (2015) found decreased GMV in right DMPFC. Notably, Leutgeb et al. also showed an increased GMV in the left pallidum, left caudate nucleus, and right cerebellar hemisphere, compared to healthy controls, while Boccardi et al. (2013) showed a similar global volume of caudate and putamen in violent psychopaths and healthy controls. However, the caudate symmetrically showed regions with hypotrophy (right anterior-ventral caudate) and hypertrophy (scattered across the caudate surface) in psychopaths. Also, the putamen evidenced a pattern of local hypertrophy and hypotrophy, mainly on the right dorsal side. Boccardi et al's main finding concerned nucleus accumbens, where they found significant anterior rostral hypotrophy bilaterally in violent psychopaths with 10-20% smaller volume in contrast to the control group. The accumbens shape was also atypical, more rounded, in psychopaths than controls. Regarding other subcortical structures, Kolla and colleagues (2017) reported decreased surface area in the right basolateral amygdala in violent psychopaths but an increased surface area in the right anterior part of the amygdala compared to controls. Further, the only study that investigated white matter connections and used diffusion tensor imaging tractography showed that violent offenders with psychopathy compared to controls had reduced fractional anisotropy

in the left dorsal cingulum, that is, the medial prefrontal to posterior cingulate connections of the Default Mode Network (DMN) (Sethi et al., 2014). This finding is compatible with the results of Bertsch et al. (2013), showing reduced GMV in posterior cingulate cortices.

Differences in the Structural Organisation of the Brain Between Violent Offenders With and Without Psychopathy

Two of the studies (Bertsch et al., 2013; Kolla et al., 2014) selected for this systematic review included one violent offender group considered to be psychopaths and another violent offender group diagnosed with ASPD without psychopathy, allowing for comparisons within violent offender groups with and without psychopathy. Further, in some studies (Hofhansel et al., 2020; Kolla et al., 2017; Leutgeb et al., 2015), the offenders' PCL-R scores were used as a continuous variable, and the severity of psychopathic traits was then correlated with volumetric findings.

Kolla et al. (2014), using only VBM measurements, reported that violent offenders with psychopathy, compared to those without, had smaller GMV in bilateral temporal poles, right uncus, and right cerebellar lobule IV. Interestingly, Kolla et al. also measured childhood physical abuse (CPA) in the offenders with the Early Trauma Inventory (Bremner et al., 2000) and noticed that violent offenders with psychopathy reported more physical but not more emotional or sexual abuse. When CPA was used as a covariate, violent offenders with psychopathy had lower GVM only in the right uncal and temporal regions compared to violent non-psychopaths. In contrast to Kolla et al., Bertsch et al. (2013) conducted both VBM and ROI analyses, and their VBM results showed reduced GMV in the left hemisphere in the postcentral gyrus, precuneus, dorsal paracingulate cortex, posterior hippocampal gyrus and lateral occipital cortex in psychopaths. In ROI analyses, only the reduction in left PCG was significant between offender groups with and without psychopathy.

Hofhansel et al. (2020) used the PCL-R score as a covariate in investigating differences in GMV in violent psychopaths. In VBM measurements, increasing scores in the PCL-R were correlated with lower GMV in the right superior frontal gyrus. Furthermore, the

negative correlation between PCL-R score and prefrontal GMV was driven mainly by factor 2 of PCL-R (impulsive-antisocial behaviour), most specifically by facet 4, the antisocial behaviour facet. Impulsive-antisocial behaviour factor 2 scores also correlated negatively with GMV in the right superior frontal gyrus, hippocampus and inferior parietal lobule, and facet 4 antisocial behaviour scores also correlated with lower GMV in right superior frontal gyrus, right middle and superior temporal gyri, and left inferior parietal lobule. Hofhansel et al. (2020) additionally measured reactive and proactive aggression with the Reactive–Proactive Aggression Questionnaire (RPQ) (Raine et al., 2006) and found reactive aggression to be negatively correlated with GMV in the right middle and superior temporal gyri. Then again, the PCL-R and RPQ scores correlated positively, with the strongest correlations between PCL-R facet 4 and physical and reactive aggression in PRQ.

Also, Leutgeb et al. (2015) correlated PCL-R scores to GMV findings in the violent offender group. Within the violent offender group, the PCL-R factor 2 score (impulsive-antisocial behaviour) negatively correlated with GMV in the putamen, pallidum, orbitofrontal cortex, insula and supplementary motor area, while the factor 1 score, which measures psychopathic traits, correlated negatively with DLPFC grey matter volume. Further, Leutgeb et al. measured risk for violent recidivism with the Violence Risk Scale (VRS; Wong & Gordon, 2006) and found that there was a negative correlation between the subscale dynamic risk factor for criminal relapse, which measures variables such as interpersonal aggression or emotional control, and GMV in the amygdala. Another interesting and compatible finding concerning the correlation between PCL-R score and amygdala volume was reported by Kolla et al. (2017), who found a decreased surface area in the right basolateral amygdala to correlate with increased psychopathic traits.

Discussion

Various studies have found many diverse structural differences in the brains of violent psychopaths compared to healthy non-violent controls but reported fewer differences between the brains of violent psychopaths and violent non-psychopaths. Several studies have

also observed increased structural differences with increasing psychopathic traits. Grey matter volume reduction in various cortical and subcortical brain areas between violent psychopaths and healthy controls, and to a lesser degree between violent psychopaths and non-psychopaths, is a frequently reported feature related to violent behaviour and psychopathy. Notably, many of the diverse reductions in grey matter volume in violent psychopaths have been observed in the parts of the brain that are responsible for or participate in moral reasoning, behavioural inhibition, and emotional regulation. However, there are also a few findings in the opposite direction, that is, increased grey matter volume has been observed in the left pallidum, left caudate nucleus, and right cerebellar hemisphere in psychopaths compared to healthy controls (Leutgeb et al., 2015). These findings may reflect the general involvement of striatal structures in violent behaviour and impulse control.

Structural Brain Differences Between Violent Psychopaths and Healthy Non-violent Controls: Implications for Cognition, Emotion and Behavioural Inhibition

To start with subcortical structures, Boccardi et al. (2013) found nucleus accumbens in the ventral striatum to be smaller and rounder, with anterior hypotrophy bilaterally, in psychopaths compared to healthy controls, while the caudate and putamen in the dorsal striatum showed varying patterns of both hypo- and hypertrophy. Leutgeb et al. (2015), partially contradictorily, reported increased grey matter volume in the left caudate and pallidum. Leutgeb et al.'s results are in line with previous studies that have found the whole dorsal striatum, which includes caudate, putamen and pallidum, to be almost 10% larger in psychopaths (Glenn et al., 2010) and the grey matter volumes to be greater in the right caudate and the left nucleus accumbens in non-psychopathic offenders (Schiffer et al., 2011). In contradiction with the whole brain measurements of Schiffer et al., the manual segmentation of the nucleus accumbens by Boccardi et al. showed a highly significant morphological discrepancy from controls, with a large anterior region of hypotrophy in

psychopathy. Although the findings of Glenn et al., 2010, Leutgeb et al., and Schiffer et al. seem, at first glance, to be somewhat contradictory to the results reported by Boccardi et al., it should be noted that Boccardi et al. used ROI analyses and surface-based anatomical modelling techniques with manual tracing of the ROIs (as opposed to VBM analyses by Glenn et al. and Schiffer et al., and non-manual automated anatomical templates for identifying ROIs by Leutgeb et al.) that most likely rendered the observed complex local alterations in accumbens, caudate and putamen more accurate and evident.

In addition to these striatal findings, Kolla et al. (2017) relatedly found a decreased surface area in the right basolateral amygdala subcortically. In contrast, the right anterior part of the amygdala showed increased surface area compared to controls. Further, the decreases were associated with increased psychopathic traits measured by PCL-R. These results are highly similar to those previously reported by Yang et al. (2009), who also found significant bilateral volume reductions in the amygdala of psychopaths compared with controls in the amygdala's basolateral, lateral, cortical, and central nuclei. Yang et al. also noted that the reduced amygdala volumes correlated with increased total PCL-R scores.

Overall, the findings on subcortical structures summarised above comply with differences found in functional neuroimaging studies in psychopathy where hypofunction of the ventral striatum and hyperresponsivity of accumbens to reward stimuli, and less affect-related activity in the amygdala, hippocampus, and striatum and cingulate cortices, have been reported (Buckholtz et al., 2010; Kiehl et al., 2001; 2011; Dolan & Fullam, 2009). Considering that the striatum participates in numerous aspects of cognition, including decision-making, motivation, and reward perception, the morphological differences associated with psychopathy could explain some of the clinical behavioural manifestations of psychopathy. For example, the alterations in the nucleus accumbens and other brain regions involved in reward processing may underlie the dysfunctional reward system observed in psychopathy. Reduced grey matter volume in striatal regions could thus result in blunted responses to positive reinforcement and an increased propensity for risk-taking behaviours or engaging in antisocial acts to seek stimulation (Pujara et al., 2013). Further, the

morphological differences in brain regions involved in emotional processing, such as the amygdala, may contribute to the emotional deficits observed in individuals with psychopathy and antisocial behaviour. Reduced grey matter volume or altered connectivity in these regions could lead to diminished emotional responsiveness, decreased empathy, and impaired recognition of others' emotions. This may contribute to a reduced capacity for forming and maintaining meaningful emotional bonds and exhibiting prosocial behaviour and, in contrast, contribute to increased violent and antisocial behaviour in psychopaths.

The studies included in the current review also evidence a strong trend between cortical grey matter reduction and psychopathy. Grey matter reduction was found bilaterally in DMPFC in psychopaths, and PCL-R psychopathic trait factor score correlated negatively with DLPFC grey matter volume (Hofhansel et al., 2020; Leutgeb et al., 2015). These findings could potentially explain the emotion regulation issues found in psychopathy, as the dorsomedial prefrontal area is involved in emotion regulation, especially processing information related to fear and anxiety. Further, the dorsomedial prefrontal area participates in processing social information and emotions, such as the theory of mind, morality judgments, empathy, and altruism, which are, by definition, altered in psychopathic individuals. Also, the dorsolateral prefrontal cortex is involved in emotional decision-making, risk assessment and the capacity to resist temptation (Knoch & Fehr, 2007), which are deficient in psychopathy. The posterior cingulate gyrus, where consistent reductions in grey matter volume were observed in violent psychopaths, is significantly bilaterally activated by emotional stimuli, independent of the valence of emotion. PCC/precuneus has also been suggested to be responsible for maintaining attention, and the ability to maintain attention is a frequent issue among psychopaths.

Overall, the structural differences in cortical regions associated with cognitive processes, such as large parts of the prefrontal cortex, including the orbitofrontal cortex, could contribute to deficits in executive functioning observed in individuals with psychopathy and antisocial behaviour. These deficits may manifest as difficulties with planning, problem-solving, and cognitive flexibility and may contribute to deficits in inhibiting impulsive

behaviours, considering long-term consequences, and making morally and socially appropriate choices.

While the articles discussed above present compelling evidence, not all studies have found consistent results regarding the correlation between psychopathy and structural brain differences, highlighting the complexity of the relationship between brain structure and psychopathy. In studies by Hofhansel et al. (2020) and Leutgeb et al. (2015) included in the current review, whole-brain analyses did not identify differences between psychopaths and healthy controls, although region-of-interest analyses did. These findings thus partially contradict studies that report reduced cortical grey matter volume in psychopathic individuals. Although the non-significant results may be explained by methodological issues, they can also be interpreted to suggest that global cortical measurements may not consistently differentiate individuals with psychopathy from non-psychopaths and that brain abnormalities may not be a universal characteristic of psychopathy.

Structural Brain Differences Between Violent Offenders With and Without Psychopathy: Implications for Cognition, Emotion and Behavioural Inhibition

Studies examining structural brain differences between violent inmates with and without psychopathy have yielded mixed findings, with some studies reporting consistent results while others finding more nuanced or contradictory outcomes. For instance, the findings of Kolla et al. (2014) and Bertsch et al. (2013) seem quite contradictory, with Kolla et al. reporting few differences in the right hemisphere between violent psychopaths and non-psychopaths while Bertsch et al. reporting multiple differences in the left, but not right, hemisphere with whole-brain analyses. Yet, both research teams found reductions in grey matter volume in violent psychopaths compared to non-psychopaths, suggesting that psychopathic traits might be more linked to GMV reductions than being convicted of violent crimes.

Two of the studies we have analysed in this review investigated the differences in brain structures of offenders with antisocial personality disorder and psychopathy. Kolla et

al. (2014) found reductions in grey matter volumes in the temporal poles, cerebellum, and uncus in offenders with ASPD and psychopathy, especially in those who had experienced childhood physical abuse. Bertsch et al. (2013) showed differences in grey matter volumes in regions such as the temporal pole, orbitofrontal cortex, and prefrontal cortex in offenders with ASPD and borderline personality disorder compared to offenders with ASPD and psychopathy. Both studies found negative correlations between these structural differences and higher scores on the Psychopathy Checklist-Revised (PCL-R). The findings of Kolla et al. and Bertsch et al. are supported by other research, such as Yang et al. (2009), who found reduced GMV in the prefrontal cortex, temporal lobes, and amygdala in individuals with higher PCL-R scores and De Oliveira-Souza et al. (2008), who observed reduced GMV in the prefrontal cortex, specifically in the orbitofrontal and medial prefrontal regions, associated with higher PCL-R scores. Ermer et al. (2012) also found that higher PCL-R scores were associated with reduced GMV in the prefrontal cortex, amygdala, and hippocampus. These studies demonstrate a connection between higher PCL-R scores, indicative of greater psychopathic traits, and structural brain differences in emotional processing, decision-making, and impulse control regions. The findings suggest that psychopathy is associated with specific changes in brain structures, which may contribute to the behavioural and cognitive characteristics observed in individuals with psychopathy.

Predicting Recidivism

Brain imaging techniques are expensive and time-consuming, making them impractical for widespread use in the criminal justice system. Moreover, the individual variations in brain structure and function are considerable, and there is significant overlap between individuals with criminal behaviour and those without. Therefore, using neuroimaging data alone to predict recidivism would be unreliable. However, combining neurobiological data with other risk factors, such as psychosocial assessments and historical data, may lead to a more comprehensive knowledge of underlying violent behaviour.

Further, if certain brain regions or neural circuits are consistently implicated in psychopathy, therapeutic interventions could target those areas using behavioural or pharmacological approaches. Additionally, identifying neural markers associated with treatment response could help personalise interventions and improve their effectiveness. However, translating these research findings into effective clinical interventions requires rigorous testing, validation, and integration with other evidence-based practices.

Limitations of this Systematic Review

We did not investigate functional changes, or brain network changes in violent psychopaths but focused on whether there are specific structural alterations that might correlate with psychopathic behaviour. Yet, functional alterations that might be partially based on structural differences might very well play a more vital role in psychopathic behaviour than mere structural differences. Second, all brain imaging studies are necessarily correlational by nature and do not suggest more than that psychopathic traits are indeed correlated with alternations in the brain structure. Yet, causal links between structural differentiation and psychopathy cannot be drawn based on the current systematic review.

The studies included in our review used different ways to analyse and view brain-based data. Generally, whole-brain analyses tended to produce more statistically significant differences than more restricted region-of-interest analyses. However, this was not always the case, making comparisons between studies difficult. Studies utilising ROI analyses often focused on different parts of the brain, complicating comparisons further. Finally, only one study focused on white matter tract connections and used diffusion tensor imaging. Because of these differences, it was not easy to directly compare the findings of the studies.

While all the included studies used the same measure for psychopathic traits, the PCL-R, another thing to note is that in most of the studies, the participants classified as "psychopaths" did not meet the standard cut-off criterion for psychopathy. While the classic cut-off score used in PCL-R is 30, the mean score was below 30 in all the studies and in three studies (Bertsch et al.,2013; Hofhansel et al., 2020; Leutgeb et al., 2015), it was even below

25, which can be considered the cut-off score for subclinical psychopathy. This means that some studies included individuals who had subclinical levels of psychopathy or even non-psychopaths, and it is thus unclear whether the studies actually looked at true psychopaths. Then again, in those studies where healthy controls were also assessed with PCL-R (Kolla et al., 2014, 2017; Leutgeb et al., 2015; Sethi et al., 2014), the healthy individuals' mean scores were four or below, while in psychopaths the mean score varied between 16.15 and 29.90, which indicates large difference between the violent inmate and healthy comparison groups. Further, despite these issues, there were connections between the PCL-R scores and the brain's structural differences. The higher the psychopathy score, the more noticeable the differences in brain structure, suggesting a relationship between the severity of psychopathy and the extent of brain abnormalities.

Conclusion

In summary, while the findings from the mentioned articles provide valuable insights into the neural correlates of violent behaviour and psychopathy, their direct applications in predicting recidivism and developing treatments are still limited. Further research, integration with other risk factors, and ethical considerations are necessary before these findings can be effectively utilised in practical applications within the criminal justice system. The structural differences observed in individuals with psychopathic personality and antisocial behaviour provide insights into the potential neurobiological mechanisms underlying these traits. Understanding the implications of structural differences can help shed light on the associated behavioural patterns. However, it is important to approach these findings cautiously and consider the multifactorial nature of psychopathy and antisocial behaviour. The variations in analysis methods and the inconsistent inclusion of true psychopaths might have influenced the findings and raised questions about whether the observed brain differences are specific to real psychopaths or just general differences related to antisocial behaviour. Overall, the studies suggest that there might be connections between psychopathy, as measured by PCL-R scores, and significant brain structure differences. The more severe the psychopathic traits,

the more noticeable the differences in brain structure. This supports the idea that psychopathy is not only about behaviour but also about persistent personality traits with underlying brain correlates. Moreover, the criminal justice system should recognise that biological factors alone do not determine an individual's behaviour. The interaction between biology, environment, and social factors is complex, and interventions should consider these multifaceted influences.

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