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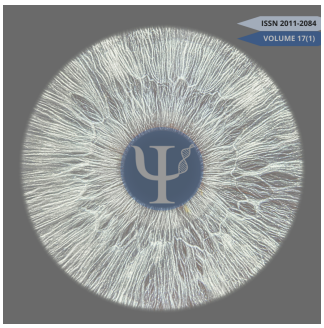

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Functional Connectivity of Moral Cognition and Traits of Psychopathy in Youth: An Analysis of the Scientific Literature

Conectividad funcional de la cognición moral y rasgos de la psicopatía en jóvenes: un análisis de la literatura científica

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Abstract.
The aim of the study is to analyze the scientific literature and evidence on the mechanisms of functional connectivity involved in moral cognition processes in youth with psychopathy traits. Scientometric methods of citation networks based on graph theory were used. Bibliometrix, Sci2 Tool, and Gephi were used for the analysis. It was found that the dorsal and ventral regions of the prefrontal cortex, orbitofrontal cortex, amygdala, hippocampus, angular gyrus, anterior cingulate and temporal cortex evidence functional alterations in young people with psychopathic traits. It was also reported that gray matter concentration in the left posterior and right anterior cingulate are possible endophenotypes of psychopathic traits. The theoretical, empirical, and legal implications of a moral neural perspective of psychopathy and antisocial behavior are discussed. The results demonstrated that psychopathic traits, which occasionally lead to criminal and violent behaviors, have a neurobiological basis related to moral cognition processes. However, a neuronal moral model has theoretical and practical limitations, as well as legal implications for free will and moral agency capacity.

Resumen.
El objetivo del estudio es analizar la producción y evidencia científica sobre los mecanismos de conectividad funcional involucrados en los procesos de cognición moral en jóvenes que cumplen con criterios clínicos de psicopatía. Se utilizaron métodos cienciométricos de redes de citaciones basados en la teoría de grafos. Para el análisis se utilizaron bibliometrix, Sci2 Tool y Gephi. Se encontró que las regiones dorsales y ventrales de la corteza prefrontal, la corteza orbitofrontal, la amígdala, el hipocampo, el giro angular, el cíngulo anterior y la corteza temporal presentan alteraciones funcionales en jóvenes con rasgos psicopáticos. También se reportó que la concentración de materia gris en el cíngulo posterior izquierdo y el anterior derecho son posibles endofenotipos con la psicopatía. Se discuten las implicaciones teóricas, empíricas y jurídicas de una perspectiva moral neural de la psicopatía y la conducta antisocial. Los resultados demostraron que los rasgos psicopáticos que ocasionalmente conducen a comportamientos criminales y violentos tienen una base neurobiológica relacionada con los procesos de cognición moral. Empero, un modelo moral neuronal tiene limitaciones teóricas y prácticas, así como implicaciones jurídicas para el libre albedrío y la capacidad de agencia moral.

Keywords.
Antisocial Behavior, Psychopathy, Functional Connectivity, Juvenile, Moral Cognition.

Palabras Clave.
Conducta antisocial, conectividad funcional, psicopatía, jóvenes, cognición moral.

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1. Introduction

Causal factors linked to the development and maintenance of criminal behavior in adolescents and adults have been identified as a priority for comprehensive public policies aimed at generating actions for the prevention and intervention of social, political, and economic violence, which would have an impact on criminal acts (Gutierrez, 2015). Much of the current research has focused on identifying psychopathic characteristics linked to criminal behavior (Arango-Tobon et al., 2022). Studies have demonstrated that between 20 and 70% of juvenile offenders exhibit some degree of psychopathology, with a high prevalence of disruptive-antisocial behavioral disorders and psychoactive substance abuse (Fassaert et al., 2016; Saladino et al., 2020; Stewart & Trupin, 2003). Psychopathy has traditionally been assessed in samples of adults with a history of criminal behavior (Arango-Tobon et al., 2022). However, there has been growing interest in understanding psychopathic traits in younger populations over the past three decades (Lynam, 1996).

Psychopathic and callous traits in youth could shape a stable pattern of antisocial personality in adults (Arango-Tobón et al., 2022; Harpur & Hare, 1994; Moffitt, 2018). Furthermore, juvenile offenders' features have been identified as preceding criminal behavior in adults (Paternoster et al., 2001). Additionally, recidivism has been linked to the severity of crimes committed (e.g., aggravated theft, homicide, property crime, drug trafficking, among others) (Dembo et al., 1998; Kalist et al., 2015). Approximately 15-25% of prison population meets criteria for a diagnosis of psychopathy or antisocial personality disorder and are four times more likely to reoffend one year post-release (Aharoni et al., 2014; Hart et al., 1988; Saladino et al., 2021). In this context, Fazel and Danesh (2002) conducted a systematic review of psychiatric surveys of prison populations from 12 countries that included 22790 inmates ($M = 29$ years). Their findings indicated that 47% of males and 21% of females met diagnostic criteria for an antisocial personality disorder.

The prevalence of psychopathology among juvenile offenders varies across countries and is influenced by a variety of social and cultural factors. However, there is a growing body of evidence suggesting a causal relationship between the presence of psychopathic or antisocial traits and delinquent behavior (Aharoni et al., 2014). A common underlying factor in this link is the lack of conformity to the set of customs and moral norms accepted by a given social system. Consequently, the overlap between morality and psychopathic traits in juvenile offenders is considerable and associated with variation in the processing of social information to make (in)moral decisions (Raine & Yang, 2006; Raine, 2019). This process is referred to as moral cognition, which encompasses the set of moral judgments, reasoning, and decisions that guide a person's social behavior (Lloyd et al., 2022).

In the literature, affective processes and more reflective reasoning processes have been linked in decision making and moral judgment. Consequently, moral cognition involves the interdependence of both processes (Craigie, 2011; Maiese, 2014). Additionally, moral cognition encompasses socio-cognitive processes associated with reasoning, judgment, and decision-making, which are influenced by values, conventional norms, and moral norms within a society (Voiklis & Malle, 2018). Moreover, it entails the capacity to comprehend others' emotional states and perspectives (Saladino et al., 2020, 2021).

Recently, neuroscience has provided empirical evidence relevant to understanding the mechanisms of functional connectivity linked to moral reasoning and decision making in juvenile offenders, with a special interest in psychopathic behavior. A starting point for empirical research is that there are similarities between the brain systems underlying moral decision-making in neurotypical subjects and the brain mechanisms presumed to be affected in populations with psychopathic, violent, or delinquent behavior (Darby et al., 2018; Raine & Yang, 2006). Consequently, the analysis of functional connectivity mechanisms and neural networks correlated with moral cognition processes represents one of the core areas of research in the etiology of psychopathic behavior (Lenzen et al., 2021; Raine, 2019). Therefore, the overlap between morality and psychopathic-delinquent behavior is relevant to research in the field of social neuroscience. It is hypothesized that a more comprehensive understanding of the neurobiological mechanisms associated with moral cognition will facilitate the development of more effective clinical, social, and rehabilitative interventions for juvenile offenders, with and without psychopathic traits. This understanding will also contribute to the formulation of evidence-based public health policies and decision-making for juvenile justice systems.

Neuroscience offers insights into the mechanisms of functional connectivity underlying moral cognition in individuals with psychopathic traits. These insights have implications for the improvement of public health policies, the design of treatments with greater efficacy, and raise moral issues for the legal system and criminal responsibility measures for juvenile offenders.

2. Materials and Method

The objective of this study was to examine scientific evidence in the field of neuroscience on the mechanisms of functional connectivity involved in the processes of moral cognition in psychopathy. Bibliometric analysis methods and clustering algorithms based on graph theory were employed to analyze the main research trends in the field of study as proposed by Valencia et al. (2020). Although systematic reviews and meta-analyses on the neural bases of morality in antisocial behavior are found in the literature, no bibliometric studies using graph al-

Table 1

Search criteria

Database	Search equation	Results
Web of Science	"Moral cognition" OR moral* OR "moral judgment" OR "moral reasoning" OR "Moral Development" AND "juvenile offenders" OR "juvenile delinquents" OR juvenile OR offenders OR antisocial OR Psychopathic OR delinque* OR crime OR criminal OR offend* OR offence OR dissocial OR adolescent* AND "functional connectivity" OR "functional neuroimaging" OR neural* OR "brain circuity" AND NOT adult*	110
Scopus		91
Criteria	Topic (title, abstract, author keywords and keywords Plus)	
Operators	OR-AND-NOT	
Period	2000–2022	
Date of consultation	September 1, 2022	

gorithms to analyze the scientific production on the possible relationship between functional connectivity associated with moral cognition and psychopathy traits are found. This aspect could enrich the current research and differentiate it from previous studies, contributing to the literature.

2.1 Documentary search

The search was conducted in the indexed databases of Web of Science-WoS (ISI Web of Knowledge) and Scopus (Elsevier). According to the literature in bibliometrics, the largest and most influential databases in the world are Scopus and WoS, and the total number of articles located in both databases is similar (Martín-Martín et al., 2018). The search equation (SE) is shown in Table 1.

2.2 Scientific Mapping

The EB was exported in BibTeX format and different analytical tools were employed to examine the data. The Bibliometrix package for R (Aria & Cuccurullo, 2017) was used to analyze the trajectory of publications, their H-index, and citations received from the most productive authors, as well as the conceptual structure of the publications' keywords.

2.3 Citation Network Analysis

Furthermore, a citation network analysis was conducted on the scientific production within the field of study. Network-based analyses are a common methodology employed in bibliometric studies, as they facilitate the visualization and graphic classification of scientific production and the identification of different research trends (Duque & Duque-Oliva, 2022). The Sci2 tool (Sci2 Team, 2009) and the Gephi software (Bastian et al., 2009) were employed for the construction of the network, visualization, and analysis of the citation network. A network was designed with the records obtained by the search equation in WOS and Scopus and the set of bibliographic references contained in each bibliographic record. This approach permitted the temporal restrictions of the search interface to be circumvented, thereby enabling the incorporation of articles from other databases. The Jaro-Winkler algorithm (Jaro, 1989) was employed to identify and eliminate references exhibiting a similarity of greater than 95%, thus eliminating duplicate records. Subsequently, the network was segmented using the following algorithms: in-degree (equation 1), out-degree (equation 2), and betweenness (BC) (equation 3) (Valencia et al., 2020).

$$\text{in degree} = \sum_{n \in G} deg^{-}(n) \tag{1}$$

$$\text{out degree} = \sum_{n \in G} deg^{+}(n) \tag{2}$$

$$BC(i) = \sum_{j \leq K} \frac{gjk(i)}{gjk} \tag{3}$$

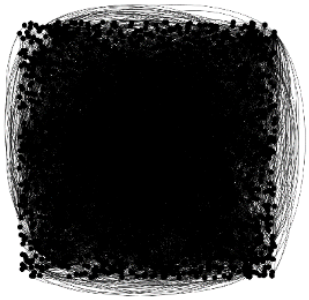
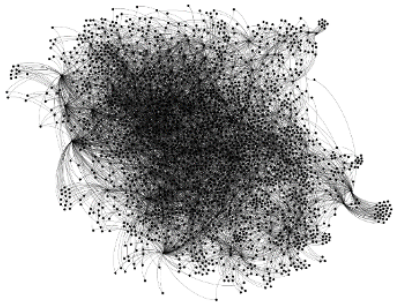
This segmentation was based on statistical criteria of citation, position, and connection to the nodes of the network (Valencia et al., 2020). To identify the main trends in neuroscience research on moral cognition in juvenile offenders, the Lovain algorithm (Blondel et al., 2008) and the Modularity Class indicator were applied to the final network in Gephi. The citation graph network transformation process is shown in Figure 1.

3. Results

The scientific production reported between 2000 and 2021 on Web of Science regarding the neurophysiological bases of moral cognition exhibited a growth rate of 11.61% and 10.78% in Scopus. To date in 2022, a growth of 9.71% and 5.65%, respectively, has been reported (see Figure 2).

Figure 1

Procedure for Transforming the Graphic Network of Citations

Network without filters	Network with filters	Total final network
		
Nodes: 11149 Edges: 16571	Nodes: 2116 Edges: 7538	Nodes: 2114 Edges:7538

Note. Source: Own elaboration.

Figure 2

Growth in Scientific Publications (Web of Science and Scopus)

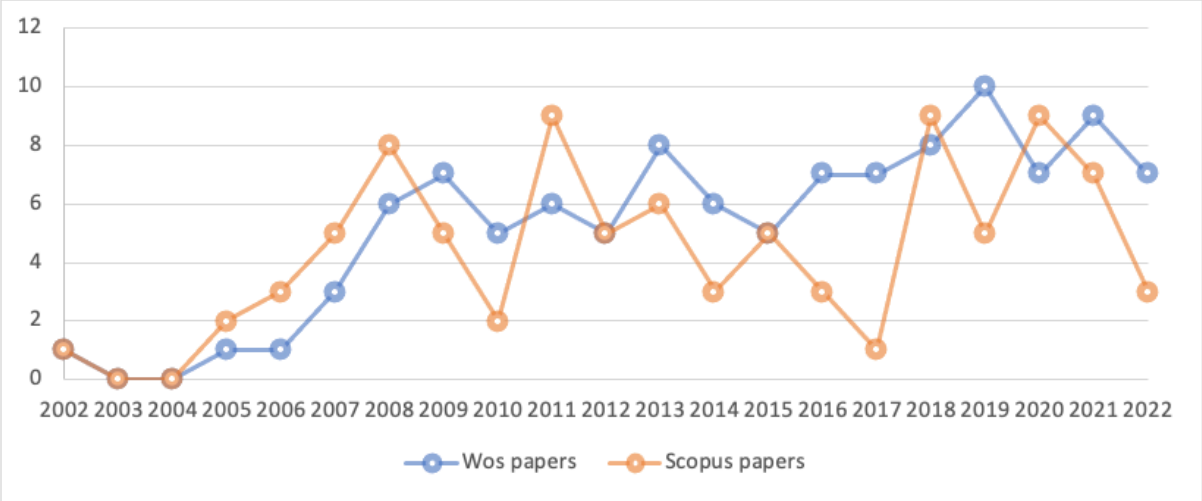


Table 2 presents the 20 most productive authors in the study of the neural correlations of morality and antisocial behavior. It highlights the contributions of de Oliveira-Souza, Moll, Decety, Blair, and Krueger.

Furthermore, an analysis was conducted to examine the intellectual structure of the most cited authors in the field of neuropsychology and neurosciences of moral behavior.

The conceptual structure of the publications was analyzed. Figure 4 visualizes the network of the twenty most used keywords plus, which reflects the most relevant terms and the network of relationships between neuropsychological concepts used in scientific publications. It highlights concepts such as: decision making, emotion, brain, prefrontal cortex, and morality.

The following is an analysis of the literature review and the most relevant scientific evidence on functional connectivity mechanisms associated with moral cognition and antisocial behavior. Citation counts and connections within the citation network were analyzed to select the most relevant records. Gephi was employed to analyze the positioning of the publications in the network using the PageRank indicator (Ding et al., 2009; Duque & Duque-Oliva, 2022), as well as the positioning of the articles in the in-degree, out-degree, and betweenness indicators of the selected clusters (Valencia et al., 2020).

3.1 Personality and Psychopathy Traits

Psychopathy has been conceptualized as a multifaceted construct encompassing a diverse array of behavioral, emotional, and interpersonal characteristics (Gatner et

Table 2

Top Ten Authors with the Highest Production and Citations

Web of Science					Scopus				
Authors	**H**	**TC**	**TP**	**Year**	**Authors**	**H**	**TC**	**TP**	**Year**
Decety, J.	9	360	12	2014	de Oliveira-Souza, R.	4	1069	5	2005
Kiehl, K. A.	5	291	7	2008	Decety, J.	4	165	5	2015
Blair, R. J. R.	4	572	4	2007	Moll, J.	4	1069	5	2005
Krueger, F.	4	656	5	2005	Cowell, J. M.	3	137	3	2015
Cowell, J. M.	3	122	3	2015	Glannon, W.	3	162	3	2007
de Oliveira-Souza, R.	3	949	4	2005	Grafman, J.	3	690	3	2005
Grafman, J.	3	651	3	2005	Zahn, R.	2	840	2	2005
Harenski, C. L.	3	164	4	2009	Krueger, F.	2	686	2	2005
Moll, J.	3	949	4	2005	Raine, A.	2	507	2	2006
Yoder, K. J.	3	150	3	2014	Blair, R. J. R.	2	186	2	2011

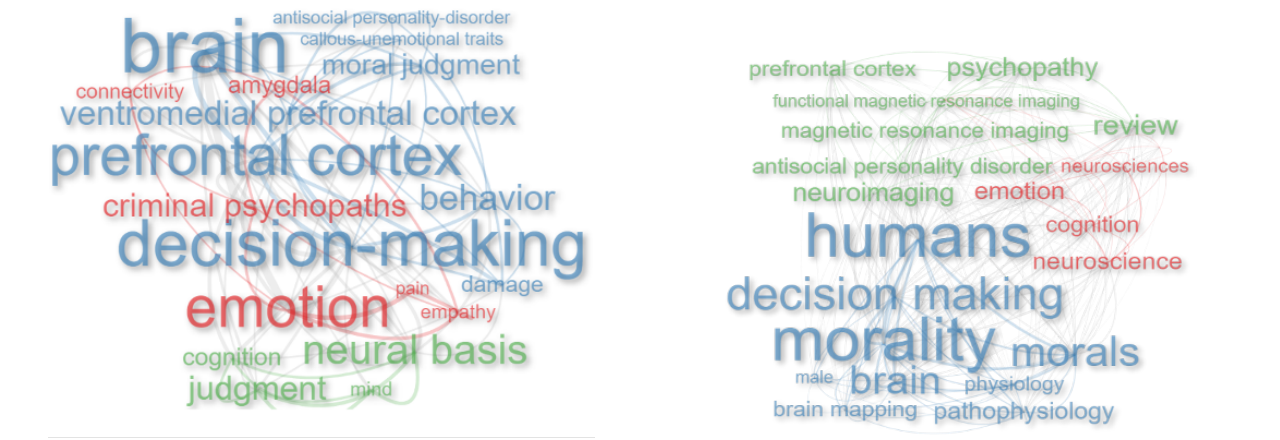
Note. H= H-index; TC=total citations; TP=total publications.

Figure 3

Intellectual Structure of the 20 Most Cited Authors (Web of Science and Scopus)

Figure 4

Conceptual Structure of Scientific Publications (Web of Science and Scopus)



al., 2018). These characteristics lead to a distinctive pattern of maladaptive personality traits that influence various domains of an individual's social functioning (Hare et al., 1991, 2008).

Psychopathy has been identified as comorbid with conduct disorder and antisocial personality disorder (Johanson et al., 2019). However, it is important to note that the concepts of psychopathy and antisocial personality are often used interchangeably in the literature. These concepts refer to a mental disorder characterized by a discernible cluster of personality traits, including the presence of reiterative and morally reprehensible antisocial behaviors, involvement and recidivism in serious criminal behavior, indifference to the welfare of others, absence of empathy and remorse, callousness or superficial affect, reduced impulse control, poor risk perception, and a tendency to deceit (Hare & Hart, 1993; Johanson et al., 2019; Saladino et al., 2021; Van Vugt et al., 2011; van Dongen, 2020; Ye et al., 2022).

People with elevated psychopathic traits portray a significant impairment of social behavior, and a marked tendency for the transgression of moral and conventional norms (Dolan & Fullam, 2010; Pletti et al., 2017), aspects that generate adverse consequences for the community and deteriorate the criminal justice system and judicial practice (Pernu & Elzein, 2020).

Glenn et al. (2009) propose the category of psychopathic personality, which encompasses four areas: *interpersonal* (1), which involves manipulative behaviors, pathological lying, grandiosity, and narcissistic self-esteem; *affective* (2), which encompasses callousness, lack of care, and unemotionality, as well as a decrease in affective empathy or remorse; *lifestyle* (3), which involves poor risk perception, thrill seeking, impulsivity, and tendency to selfishness; and *antisocial area* (4), which is characterized by involvement in violent and criminal behaviors. The category of psychopathic personality encompasses emotional harshness, a lack of affective empathy, and an absence of remorse.

Other authors have classified these areas into two factors: primary and secondary psychopathy (Lee & Salekin, 2010; Yildirim & Derksen, 2015). Primary psychopathy is characterized by interpersonal and affective characteristics and has been found to be more strongly correlated with neurobiological dysfunctions related to the processing of emotional stimuli. Secondary psychopathy, on the other hand, has been associated with the areas of lifestyle and antisocial behavior, aspects that have been associated with impulse control and aggression (Lilienfeld et al., 2015; Ye et al., 2022).

3.2 Moral Cognition and Psychopathic Traits in Juvenile Offenders

Several studies revealed that individuals with psychopathic-antisocial traits exhibit distinctive responses in social scenarios involving moral dilemmas. These responses are characterized by a lack of empathy, guilt or remorse for other people's welfare, insensitive use of others and manipulation, less moral concern for individual rights and harm toward others, a tendency toward egocentric moral biases, and moral disengagement (Aharoni et al., 2014; Blair et al., 1995; Hare & Neumann, 2008; Marsh et al., 2011; Glenn et al., 2009; Gómez & Narváez, 2019; Langdon & Delmas, 2012). Together, these characteristics predispose adolescents and adults to persistent and severe violent behaviors, mostly associated with criminal activities (Marin-Zapata, 2020; Frick & White, 2008; Raine et al., 2006).

A meta-analytic study by Van Vugt et al. (2011) examined 19 studies with offenders and reported that moral cognition has a significant effect, with a large effect size, on recidivism of juvenile offenders. In this regard, other studies on moral cognition showed that juvenile offenders with high scores in psychopathy traits treated conventional transgressions —which do not involve victims and refer to an understanding of appropriate social behavior— similarly to moral transgressions —which affect the well-being and integrity of others— and tended to perceive both types of transgressions as permissible. Additionally, youth with high trait psychopathy scored lower than those with low trait psychopathy on the ability to distinguish conventional from moral transgressions (Blair, 1995; Dolan & Fullam, 2010).

3.3 Functional Connectivity and Moral Cognition in Youth with Traits of Psychopathy

This section provides insights into the findings of studies employing functional magnetic resonance imaging (fMRI) techniques, which have demonstrated that the dorsal and ventral regions of the prefrontal cortex (PFC), the orbitofrontal cortex, the amygdala, the hippocampus, the angular gyrus, the anterior cingulate, and the temporal cortex are associated with judgments. When investigated in a population of young individuals who exhibited disruptive behavior disorders and psychopathic traits, functional evidence suggests that neuronal activation differs from that expected for neurocognitive development in the age group of 15 to 26 years old (Darby et al., 2018; Lenzen et al., 2021; Marsh et al., 2011; Raine & Yang, 2006; Saladino et al., 2021). Additionally, it has been demonstrated that the medial and ventral areas of the prefrontal cortex (PFC), the amygdala, the angular gyrus, and the posterior cingulate exhibit heightened activation during moral reasoning and judgment tasks (Raine & Yang, 2006). Furthermore, the temporal cortex appears to increase its activation when confronted with moral decision-making situations or tasks (de Oliveira-Souza et al., 2008).

A study by Ye et al. (2022) employed connectome-based predictive models (CPM) to examine the potential of resting-state functional connectivity (RSFC) of the brain to predict psychopathic traits in young people. Resting-state functional magnetic resonance imag-

ing (fMRI) data were collected from 84 young people ($M = 22.6$ years) with psychopathic traits, who were assessed with the Levenson Psychopathy Scale (LSRP) and underwent functional MRI. Results indicated that resting-state functional connectivity (RSFC) in the prefrontal cortex (PFC) significantly predicted the total Psychopathy Scale (LSRP) score (primary and secondary psychopathy). In particular, areas of the prefrontal cortex (PFC), the anterior prefrontal cortex (aPFC) and orbitofrontal cortex (OFC), and the limbic system (the anterior cingulate cortex (ACC) and insula) displayed a higher number of connections with the connectome predictive of psychopathy (LSRP total score and secondary psychopathy).

This bibliometric review identified studies that have linked activity in the anterior prefrontal cortex (PFC) with executive operations related to planning, goal accomplishment, and impulse control. Additionally, orbitofrontal cortex (OFC) activity has been associated with inhibitory control, regulation of emotional responses associated with fear and anxiety, learning, and moral value encoding. This area is strongly connected to the amygdala and insula (Boccia et al., 2017; Hoppenbrouwers et al., 2013; Rudebeck & Rich, 2018; Ye et al., 2022). The anterior cingulate cortex (ACC) has been linked to emotion regulation, impulse control, and affective decision-making (Hoerst et al., 2010; Castellanos-Ryan & Séguin, 2016). In particular, the insula has been directly correlated with emotion processing (Seara-Cardoso et al., 2016).

Atypical or altered interactions of prefrontal cortex regions, connections involving these two regions (e.g. amygdala and insula) and the ACC region may underlie altered social processing in interpersonal and affective areas (primary psychopathy), lifestyle, and antisocial behavior (secondary psychopathy) of people with elevated psychopathic traits. Finally, an activation of the above regions is highlighted regarding moral cognition (Dean et al., 2013; Koenigs, 2012; Marsh et al., 2011; Ye et al., 2022).

3.4 The Role of the Amygdala in Moral Reasoning and Insensitive-Unemotional Traits

This literature review found some studies which suggest that functional or structural alterations of the amygdala could produce changes in moral reasoning, such as negative affect processing, in a way that people with amygdala dysfunction fail to associate moral transgressions with human suffering and experience cognitive and effective empathy (Aghajani et al., 2017; Blair et al., 2005; Darby et al., 2018; de Oliveira-Souza et al., 2008; Marsh & Cardinale, 2014; LeDoux, 2007). These findings are promising because they allow for a better understanding of the neural circuits and mechanisms of moral cognition and its components (reflexive and affective) involved in the neurobiology of antisocial behavior, without ignoring the influence of social processes related to the behavior of juvenile offenders.

A study conducted by Marsh et al. (2011), involved 14 adolescents with psychopathic traits ($M = 14.4$ years) and 14 neurotypical controls ($M = 13.5$ years), to whom clinical measures of detection of antisocial processes and psychopathy checklist were applied. Using functional magnetic resonance imaging, a violent implicit morality association task was provided, which found that teenagers with psychopathic traits showed reduced amygdala activity when making judgments about legal actions and reduced functional connectivity between the amygdala and the orbitofrontal cortex during the execution of moral tasks. No significant differences were found in the activation of the dorsomedial or lateral frontal cortex during the task in both groups. These results suggest that psychopathic traits are associated with amygdala and orbitofrontal cortex dysfunction.

In line with these findings, Aghajani et al. (2017) conducted a study to analyze the functional connectivity of amygdala networks in juvenile offenders ($M = 16.9$ years) who had been clinically diagnosed with conduct disorder and had been convicted due to a violent crime. Adolescents with conduct disorder were classified into two groups: a high trait insensitive-unemotional traits group ($n = 25$) and a low trait insensitive-unemotional traits group ($n = 25$). A control group of healthy teenagers ($n = 25$) was also used. The objective of the study was to analyze the function of the subregional amygdala network in the callous-unemotional traits of youth with antisocial behaviors, with a particular focus on the basolateral (BLA) and centromedial amygdala (CMA) networks. This study reported that the activity of the basolateral amygdala nucleus is involved in the activation and integration of the affective value of incoming emotional stimuli, while the centromedial nucleus is involved in the processing of efferent signals from the amygdala, directing physiological and behavioral responses to emotional stimuli (Aghajani et al., 2017; LeDoux, 2007; Saladino et al., 2021).

Aghajani et al. (2017) observed that individuals with high levels of insensitive-unemotional traits exhibited enhanced connectivity within the basolateral amygdala (BLA) networks, including the dorsal and ventral portions of the anterior cingulate and medial prefrontal cortex, and the posterior cingulate regions. In contrast, participants in the control group and with low insensitive-unemotional traits exhibited reduced centromedial amygdala (CMA) connectivity. Additionally, teenagers with insensitive-unemotional traits exhibited lower mean amygdalar bihemispheric volumes relative to the control group, which has been associated with hypotrophy of the BLA and CMA subregions.

These findings are consistent with previous neuroimaging studies using moral decision-making tasks, which have demonstrated that activity in the amygdala is involved in moral judgments, specifically in fear conditioning processes, the representation of moral actions (ei-

ther prosocial or antisocial), and moral decision-making, such that moral responsivity in psychopathy would be correlated with lower activity or damage in the amygdala (Blair, 1995, 2007; Caldwell et al., 2019; Glenn et al., 2009; Harenski et al., 2010; Lenzen et al., 2021; Luo et al., 2006; Raine, 2008; Raine & Yang, 2006). The study by Marsh et al. (2011) also showed significant negative connectivity between the amygdala and the orbitofrontal cortex, which according to the authors may reflect atypical regulatory activity of the orbitofrontal cortex over the amygdala in young population with psychopathic and callous-unemotional traits, which limits the ability to regulate emotions and is associated with emotional harshness and misinterpretation of others' emotions (Caldwell et al., 2019). The findings of Aghajani et al. (2017) also show abnormal amygdala connectivity and volume in areas consistently associated with psychopathy and associated with callous-unemotional traits in juvenile offenders.

3.5 Connection between Gray Matter and Psychopathic Traits

Conversely, a study by Rijsdijk et al. (2010) sought to determine whether gray matter concentration in specific brain areas is a genetic vulnerability factor for psychopathy. Researchers employed structural MRI in 123 male twins (56 monozygotic and 67 dizygotic) ($M = 11.5$ years) and discovered that gray matter concentrations of the left posterior cingulate and right anterior cingulate were the structural endophenotypes associated with genetic vulnerability for psychopathic traits, with heritability estimates of 46% and 37%, respectively. Gray matter concentration in the left posterior cingulate and right anterior cingulate, brain areas involved in empathy, moral processing, and introspection, were identified as potential candidate endophenotypes for psychopathic traits.

Subsequent research has indicated that psychopathy traits in the affective and interpersonal domains have been negatively associated with gray matter volume in the dorsolateral prefrontal cortex, orbitofrontal cortex, and anterior and posterior cingulate cortices (Caldwell et al., 2019; De Brito et al., 2021; Korponay et al., 2017; Miglin et al., 2022; Raine et al., 2012; Saladino et al., 2021).

Furthermore, psychopathic traits in the domains of lifestyle and antisocial behavior have been demonstrated to exhibit direct correlations with gray matter volume in the basal ganglia and prefrontal cortex, while inverse correlations have been observed in the medial occipital gyrus (Cope et al., 2012; De Brito et al., 2021; Kiehl, 2006; Korponay & Koenigs, 2021), which have been considered relevant regions for impulse control and the reward system. This body of evidence demonstrates the significance of examining psychopathic traits in conjunction with neuroanatomical abnormalities and gray matter volume in distinct brain regions.

A number of authors have reported that reduced gray matter volume in the prefrontal and orbitofrontal regions of individuals with psychopathic traits correlates with deficits in moral decision-making and moral judgment, reward and emotion processing, and increased impulsivity (Blair, 2005; De Brito et al., 2021; Hofhansel et al., 2020; Koenigs, 2012; Miglin et al., 2022; Murray et al., 2018; Sajous-Turner et al., 2020), which are essential for elucidating the etiology of antisocial behavior and its neurobiology.

3.6 Consolidating Empirical Evidence on a Neural Moral Model of Psychopathy and Antisocial Behavior

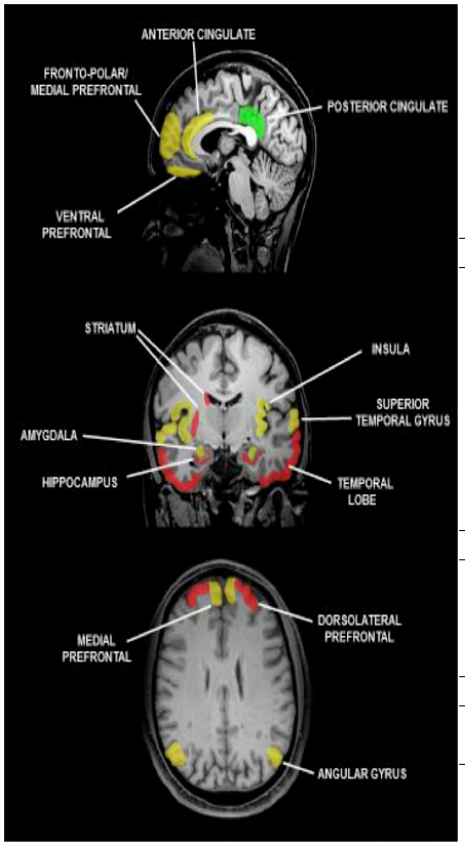
Functional (and structural) MRI studies have demonstrated functional deficits in areas of the brain that are commonly associated with antisocial behavior and moral decision-making. Data presented in this review has indicated that primary and secondary psychopathic traits are significantly associated with impairment in areas related to moral reasoning and judgment. The prefrontal cortex, amygdala, insula, anterior cingulate, and temporal cortex are key brain areas implicated in both moral decision-making and the spectrum of antisocial behaviors (Raine et al., 2012; Raine, 2019). Collectively, these regions comprise the neural moral network. These findings have been instrumental in the development of a neural moral theory of antisocial behavior. They posit that individuals with antisocial behaviors (juveniles, adults, psychopaths, and offenders) display dysfunction in brain regions involved in moral decision-making (Blair, 1995; Boccia et al., 2017; Chen et al., 2016; Darby et al., 2018; Glenn et al., 2009; Raine & Yang, 2006; Riane, 2019; van Dongen, 2020).

In this context, Raine (2008, 2019) analyzed empirical evidence collected over three decades and proposed a neural moral model of antisocial behavior. The central hypothesis is that psychopathic traits in different areas —interpersonal, affective, lifestyle, and antisocial behavior— are characterized by distinct degrees of dysfunction of brain regions involved in moral cognition.

Table 3 illustrates the neuronal moral model of Riane (2008, 2019), as derived from magnetic resonance imaging. The accompanying figure illustrates brain regions in different planes: sagittal, coronal, and axial. These regions have been identified as exhibiting functional or structural impairment in antisocial, violent, and psychopathic populations. The model depicts brain regions that are exclusively impaired in antisocial groups (red), activated solely in moral decision-making (green), and regions that are common to both antisocial behavior and moral decision-making (yellow). Additionally, the relationship between altered or dysfunctional brain areas, the cognitive and affective processes involved, and the risk factors related to antisocial behavior is illustrated. It is important to note that, according to Raine (2008, 2019), the cognitive and affective processes involved in this phe-

Table 3

Riane's (2008, 2019) Neural Moral Model

Impaired brain region		Processes/risk factors	Results
	**Frontal cortex**		
	Dorsolateral	Perseverance in response.	Failure to desist from the punished conduct.
		Poor planning/organization.	Deterioration of social-occupational activity.
		Theory of mind.	Misperception of the intentions/behavior of others.
	Ventral-orbitofrontal	Decision making.	Immoral life judgments.
		Emotion regulation.	Poor anger management.
		Emotional responses that guide behavior.	Poor behavioral control.
		Empathy/concern for others.	Disregard for the feelings/situation of others.
	Prefrontal medial-polar	Moral judgment.	Failure to comply with social norms.
		Self-reflection.	Lack of vision of self.
	Limbic structures		
	Anterior cingulum	Inhibition.	Inability to withhold an antisocial response.
		Error/conflict processing.	Difficulty in dealing with conflictive situations.
	Posterior cingulum	Moral decision making.	Failure to comply with social norms.
		Self-reference.	Deficient negative attribution.
	Amygdala	Fear conditioning.	Lack of affection, insensitive-unemotional traits.
		Judgments of social emotion.	Misinterpretation of the motives/feelings of others.
		Moral emotion.	Failure to comply with social norms.
		Judging confidence.	Hypersociability and victimization.
	Hippocampus	Contextual fear conditioning.	Failure to place punished responses in the social context.
	Temporal cortex		
	Temporal pole-superior temporal gyrus	Theory of mind, social perception.	Misattribution of the motives of others.
	Posterior superior temporal gyrus	Moral judgment.	Failure to comply with social norms.
	Parietal cortex		
	Angular rotation	Moral judgment.	Failure to comply with social norms.
		Sense of responsibility	Irresponsible behavior.
	Insula	Recognition of negative emotional states (e.g., receiving pain or observing pain).	Reduced empathetic response, imitation or mental imagery. Increased insensitive - non-emotional traits
	Anterior cingulate cortex	Emotional component of pain (anguish)	

Note. Taken and adapted from Riane (2008, p. 326) and Riane (2019, p. 66)

nomenon should not be considered causal factors of antisocial behavior or psychopathic traits. Rather, they should be regarded as distal risk factors that may bias social behavior in an antisocial direction.

Accordingly, the neural moral perspective postulates that individuals with psychopathic traits exhibit a failure of brain connectivity processes in areas involved in moral decision-making. Consequently, the overlap between brain areas and altered moral cognition processes are predisposing factors for psychopathic traits (Raine, 2008, 2019; Raine & Yang, 2006).

4. Discussion

The analysis of citation networks revealed a systematic increase in the number of studies investigating neural correlates of morality and criminal behavior. Findings indicate that psychopathic traits, which are often associated with criminal and violent behavior, have a neurobiological basis linked to moral cognition processes.

In general, scientific evidence and the functional neuroanatomical model proposed by Raine (2008, 2013, 2019) predict that individuals with psychopathic traits and antisocial-criminal behaviors have a dysfunction in the network of brain regions responsible for moral cognition processes (see Table 3). Furthermore, these alterations differ in degree according to specific behavioral characteristics, such as primary or secondary psychopathy. Consequently, a high-grade (strong) disturbance is associated with primary psychopathy, whereas a medium-grade (weak) disturbance is associated with secondary psychopathy (Raine, 2019; Raine & Yang, 2006; Saladino et al., 2021).

From a developmental perspective, significant neural moral disturbance would be associated with severe conduct disorder in early adolescence, the primacy of callous-unemotional traits would predict antisocial personality disorder in adulthood (Darby et al., 2018; Moffitt, 2018; Raine, 2019). However, a neural moral model has theoretical and empirical limitations that must be considered in three perspectives: the phylogenetic (predispositions to moral judgment and behavior), the sociogenetic (modulating from normative systems and moral codes), and the ontogenetic, which refers to personal assimilation and socialization of moral codes (Nestor, 2019; Pernu & Elzein, 2020; Yang et al., 2019), especially in young populations (Kramers-Olen, 2015).

In terms of theoretical and empirical limitations, the neural-moral model proposed by Raine (2019), and the empirical evidence linking functional deficits in specific areas of the brain to psychopathy, fails to account for the complex epigenetic interactions between neurobiological correlations and concomitant psychosocial factors. Moreover, the heterogeneity of antisocial behavior, the different profiles and criminal trajectories exhibited by individuals throughout their lives, the influence of institutional environments (e.g., re-education centers, penitentiaries), the variability in social and criminal behavior according to life cycle (e.g., childhood, youth, adulthood, adulthood, etc.), and the influence of the social and criminal environments (e.g., social and criminal behavior according to life cycle, that is, childhood, youth, adulthood, adulthood, etc.), cultural variability in (in)moral behaviors, and exposure to adverse psychological and social circumstances (e.g., history of abuse, maltreatment or neglect, social vulnerability, among others, make it difficult to empirically test an explanatory neurobiological model that controls for the effect of all these factors.

Consequently, the neural moral approach is still in the process of development and is, as yet, largely speculative (Han, 2020). In order to provide empirical support for its predictions, it is necessary to incorporate social circumstances as constitutional elements of people's moral cognition. The field of social neuroscience may prove to be a valuable and promising avenue for understanding the intricate interrelationships between neurobiological predispositions and early social experiences. These experiences may act as mediating or moderating factors in moral cognition, psychopathy, and antisocial behaviors (Barnes et al., 2022; Kramers-Olen, 2015).

The primacy of neurobiological dispositions over sociocultural exposure processes is still a matter of contention, particularly regarding the directionality of the causal relationship between biological and social elements in explaining phenomena such as morality and antisocial behavior. In this context, an interdisciplinary and pluralistic approach is necessary to understand the reciprocal relationships between the functioning of specific neuroanatomical structures and the functional processes of neuronal connectivity, as well as the contextual and social processes that shape the socio-moral behavior of individuals. This requires the formulation of new questions, hypotheses, and research methods.

Conversely, a radical neural moral perspective on antisocial behavior could have implications for judicial decision-making, particularly in the context of juvenile offenders. The debate centers on the limits of a person's capacity for agency and free will in committing a crime (Nestor, 2019; Pernu & Elzein, 2020; Yang et al., 2019). At least two views can be considered.

An excessively naturalistic, physicalistic, and reductionist perspective might consider that neuroscientific evidence challenges the legal concept of moral and criminal responsibility by supporting the hypothesis that psychopathic and antisocial behavior is the result of alterations of brain areas and circuits (Nestor, 2019; Pernu & Elzein, 2020). This perspective poses a significant risk to the established practices of the juvenile justice system, which are based on the assumption of the offender's moral responsibility. This concept is linked to the legal

concept of criminal liability. If this perspective were to gain traction, it could lead to the erroneous conclusion that the capacity for agency, which is a prerequisite for the commission of punishable actions, is impaired.

The second perspective is based on the distinction between objective and subjective agency. The former refers to explanations at the level of implementation of brain mechanisms, while the latter refers to explanations based on representational-phenomenological processes. Neuroscience data regarding a person's moral behavior have the potential to impact legal decision-making. Nevertheless, invoking explanations of the neurobiological mechanisms and neural functional connectivity involved in punishable behavior (objective agency) does not imply that the subject's capacity for subjective agency to determine his or her intentions, desires, and thinking, including awareness of his or her intentional social behaviors and the consciousness of these, is undermined or compromised in determining moral and criminal responsibility for punishable behavior.

This perspective posits that altered brain functioning in juvenile offenders predisposes them to lower impulse control, poor emotion management, and a tendency to callousness, which may increase the risk of violent behavior. However, it is erroneous to conclude that these brain changes or alterations are causally responsible for the behavior in question. It is therefore necessary to distinguish between the context of explanation (neuroscientific) and the context of justification (moral or criminal) of antisocial and criminal behavior. This is particularly relevant when acknowledging that all human behavior has a neural basis, and not only the type of behaviors that are considered morally or legally reprehensible.

In conclusion, the scope, limitations, and implications of this scientific evidence and the neural moral perspective described do not negate the relevance and importance of neuroscience research for understanding the moral bases of psychopathic and criminal behavior. On the contrary, they pose significant challenges for interdisciplinary research, with numerous avenues yet to be explored.

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