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Literature Review

# Neurobiology of violence and aggression: Effects of early adversity on the human brain and mental health

## Neurobiología de la violencia y la agresión: Efectos de la adversidad temprana en el cerebro humano y la salud mental

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## ABSTRACT

The aim of this article was to analyse the impact of neurobiology and early adversity on violent behaviour and its effects on mental health. It is a narrative review of the literature using academic databases such as Pubmed, Scopus and Scielo, with keywords such as 'neurobiology', 'violence' and 'early adversity'. Forty-seven articles were selected from a total of 91 identified, considering their relevance and methodological quality. It was found that early exposure to violence has a significant impact on brain development, increasing the risk of violent behaviour in adulthood. Brain regions such as the amygdala and prefrontal cortex play a key role in emotional regulation and decision-making, and alterations in these regions were found to be associated with violent behaviour and mental health disorders. It was concluded that early exposure to adversity increases the risk of violent behaviour. Understanding the neurobiology of violence allows for the design of intervention strategies that promote mental health and strengthen protective factors in people exposed to violence. Collaboration between researchers, professionals, and public policy makers is essential to address this problem and create a safer and healthier environment.

**Keywords:** neurobiology, violence, early adversity, brain development, mental health.

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## RESUMEN

Este artículo tiene por objetivo analizar el impacto de la neurobiología y la adversidad temprana en el comportamiento violento y sus efectos en la salud mental. Es una revisión de la literatura, en la que se utilizó bases de datos académicas como Pubmed, Scopus y Scielo, con palabras clave: "neurobiología", "violencia" y "adversidad temprana". Fueron seleccionados 57 artículos de unos 91 identificados, y se tuvo en cuenta la relevancia y calidad metodológica. Se analizó 45 de ellos. Un hallazgo fue la exposición temprana a la violencia con un impacto significativo en el desarrollo del cerebro que aumenta el riesgo de comportamiento violento en la edad adulta. Los comportamientos violentos y trastornos de salud mental se asociaron con alteraciones de regiones cerebrales como la amígdala y la corteza prefrontal, que desempeñan un papel fundamental en la regulación emocional y la toma de decisiones. Como conclusión se observa que la exposición temprana a la adversidad aumenta el riesgo de comportamiento violento. Para diseñar estrategias de intervención que promuevan la salud mental y fortalezcan factores protectores, en personas expuestas a la violencia, se precisa la comprensión de la neurobiología de la violencia. Es fundamental para el abordaje de este problema y la creación de un entorno más seguro y saludable, contar con la colaboración de investigadores, profesionales y responsables de políticas públicas.

**Palabras clave:** neurobiología, violencia, adversidad temprana, desarrollo cerebral, salud mental.

# Introduction

Violence is a complex phenomenon present in societies worldwide. Understanding the factors that promote violent behavior is essential for designing effective strategies for prevention, protection, and intervention.

In societies worldwide, violence presents as a complex phenomenon. Understanding the factors contributing to violent behavior is paramount for designing effective strategies for prevention, protection, and intervention. Exposure to violence in childhood has been identified as a significant risk factor for the development of aggressive behaviors. According to neuroscience research reports, early adversity can affect brain structure and function, particularly in regions involved in emotional regulation and social information processing. The manifestation of violent behavior in adulthood may be related to such anatomical alterations [(1)]. In addition to biological factors, the interaction between genetic and environmental factors plays a crucial role in the predisposition to aggression.

Studies have demonstrated that certain neurotransmitters, such as serotonin, are involved in the regulation of aggression [(2)]. These can interact reciprocally with brain plasticity and psychosocial factors, such as chronic stress and exposure to violence. In addition to biological factors, the interaction between genetic and environmental factors contributes to behaviors reflecting a predisposition to aggression. The manner in which early stress and adversity can have lasting biological effects is highlighted [(3)].

The complex interaction of biological, psychological, and social factors influences the intricate phenomena of violence and aggression. The identification of brain structures and circuits underlying aggressive behaviors is a key area of neurobiology. The amygdala, the prefrontal cortex, and the hypothalamus play crucial roles in the regulation of emotions and behavior [(4)]. Furthermore, imbalances in neurotransmitters such as serotonin and GABA are also implicated in the predisposition to aggression [(5)].

Early adversity, encompassing experiences such as maltreatment, neglect, and exposure to violence, can have deleterious effects on brain development. The brain is uniquely vulnerable to environmental influences during critical periods of neurodevelopment. Alterations in the volume and connectivity of key brain regions, including the amygdala and the prefrontal cortex, have been associated with early adversity [6]. Vulnerability to mental health problems and aggressive behaviors increases with these modifications, which compromise the capacity for emotional regulation and impulse control.

An increased risk of developing mental health problems, such as depression, anxiety, and post-traumatic stress disorder (PTSD), is increasingly linked to early adversity. Likewise, adverse experiences in childhood and adolescence have been related to a higher likelihood of manifesting aggressive and violent behaviors throughout the lifespan [6]. Understanding the interaction between the effects of early adversity on the brain and its impact on mental health is a priority for the implementation of effective preventive, protective, and intervention measures.

The objective of this study is to analyze the impact of neurobiology and early adversity on violent behavior and its effects on mental health. To this end, the neurobiology of violence was explored, focusing on the sequelae of early adversity in the human brain, the influence of biological and psychosocial factors on aggressive behavior, and neuroscience-based intervention strategies, the consequences of which are observed in the resulting mental health disorders.

# Materials and Methods

This article is a literature review, for which an exhaustive search of the existing scientific literature was conducted using academic databases such as PubMed, Scopus, and SciELO, employing keywords such as 'neurobiology,' 'violence,' and 'early adversity.' Following a careful selection process, 57 articles were chosen from a total of 91 identified, based on their relevance and methodological quality.

The review included articles published between 2000 and 2025, in Spanish and English, that reported data on the topic of early adversity and its effects on the human brain and mental health. These consisted of original studies, systematic reviews, and meta-analyses published in indexed scientific journals. Studies that did not provide specific data on neurobiology, violence, early adversity, and mental health were excluded, as were opinion articles, editorials, and letters.

Subsequently, a full-text review of 57 articles was conducted, of which 12 were excluded for the following reasons: lack of specific data and failure to meet the criteria of being scientific articles published in indexed journals.

Ultimately, 45 studies were analyzed that met all inclusion criteria and provided information for the analysis and data synthesis regarding the prevalence of behavioral addictions in adolescents in Latin America.

The Research Project was reviewed by the Ethics Committee of the Faculty of Philosophy and Human Sciences of the Catholic University 'Nuestra Señora de la Asunción,' Itapúa Campus, under Approval No. 03/2023.

# Results and Discussion

### Definition of Violence

Violence can be defined from a neurobiological perspective as a manifestation of aggressive behaviors that involve physical or psychological harm towards oneself or others [4]. From this perspective, violence is considered to have a biological basis and manifests through specific neural processes and neurotransmitters.

Aggression can be defined as a component of normal behavior expressed to satisfy vital needs and to eliminate or overcome any threat

to physical and/or psychological integrity. This behavior is oriented toward the preservation of the individual and the species and may serve an adaptive function in demanding environments that pose challenges to the individual's survival [4,5]. On the other hand, a distinction is proposed between aggression and violence based on criteria of biological utility. Whereas aggression is considered a normal and physiological behavior that aids in the survival of the individual and the species, violence applies to forms of aggression in which the adaptive value has been lost. Violence reflects a dysfunction of the neural mechanisms related to the expression and control of aggressive behavior, and its objective is extreme harm, potentially resulting in the death of the victim [6,7].

Violence is influenced by cultural, environmental, and social factors that shape the specific manifestation of violent behavior [8]. Furthermore, violence must be considered the final outcome of a chain of life events during which risks accumulate and potentially reinforce one another, until violent behavior is triggered in a specific situation [9].

Psychosocial and biological factors interact to shape violent behavior. Therefore, the psychosocial and biological causes of violent crime are inextricably linked and in constant interaction [9].

Regarding types of aggression, various subtypes have been identified. The classic distinction lies between premeditated (predatory, instrumental) and impulsive (affective, reactive) aggression.Impulsive aggression is an abrupt, 'hot-blooded' response to perceived provocation or threat, whereas instrumental aggression is premeditated, goal-oriented, and executed in a controlled, 'cold-blooded' manner [8]. However, it is common for violent acts to exhibit characteristics of both forms of aggression [6].

## Violence in Paraguay

Violence in Paraguay is a matter of growing concern, as reflected in data collected by the Public Ministry during the first quarter of 2023. According to the report, a total of 8,327 cases of family violence were registered during this period, with a daily average of more than 90 victims assisted per day [10]. These figures represent an increase compared to the previous year, when an average of 87 cases per day were reported during the same period [10].

The magnitude of this problem becomes evident when analyzing the monthly figures: January recorded the highest number of reports (97 victims daily), followed by February (86 victims daily) and March (92 victims daily). Furthermore, a long-term analysis reveals a 300% increase in reports of family violence from 2015 to 2023, according to the Technical Gender Office of the Public Ministry [10].

These data highlight the necessity of effectively addressing family violence and implementing preventive and support measures for victims.

Recent legislative developments in Paraguay include Law No. 7239/2024, which declares a social emergency regarding violence against women, children, and adolescents, and Law No. 7269/2024, which addresses violence within the sporting sphere [11].

In 2022, Paraguay enacted Law No. 7018 on Mental Health, which recognizes mental health as a fundamental human right and establishes a humanized, person-centered approach. Within the framework of this law, the Ministry of Public Health and Social Welfare (MSPBS) has implemented the National Mental Health Policy 2024–2030. This policy aims to improve mental health care and treatment, addressing violence in all its manifestations [12].

## Neuroanatomy of Violence

The neuroanatomy of violence, from a neurobiological perspective, reveals alterations in brain structures related to aggression and violent behavior.

**1. Amygdala:** This is a brain structure located in the medial temporal lobe. It has

been demonstrated to play a crucial role in emotional regulation and the response to fear and aggression. Alterations in the amygdala are associated with the manifestation of violent behaviors [13]. For example, it has been observed that the amygdala plays a crucial role in the expression of reactive aggression [14]. Furthermore, the amygdala presents hyperreactivity following exposure to violent environments in early life (Figure 1).

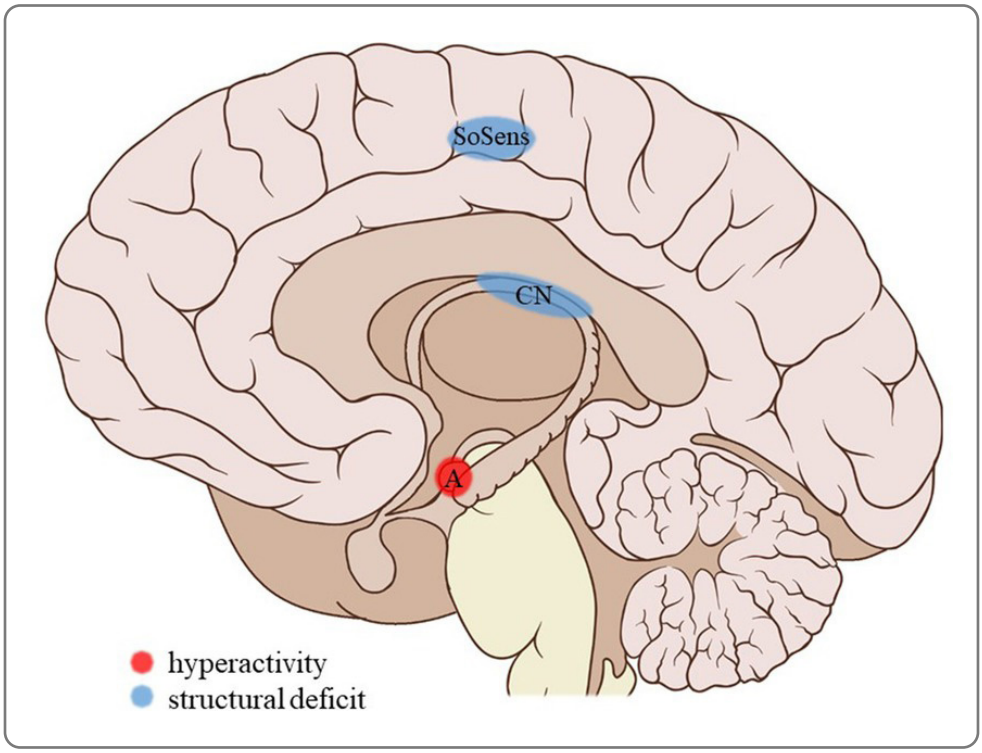


**Figure 1.** Brain structures affected in the neuroanatomy of violence [19].
Note: Neuroimaging findings associated with SA. So Sens: genital somatosensory cortex; CN: caudate nucleus; A: amygdala. Adapted from: Patrick J. Lynch, medical illustrator; C. Carl Jaffe, MD, cardiologist. https://creativecommons.org/licenses/by/2.5/

**2. Hippocampus:** This is a seahorse-shaped brain structure located in the medial temporal lobe. It plays a fundamental role in memory and learning. Alterations in the hippocampus have been associated with the manifestation of violent behaviors. A decrease in hippocampal volume has been observed in individuals with violent tendencies, suggesting that these alterations may influence the capacity to process and recall information relevant for appropriate decision-making and emotional regulation [15]. The hippocampus is involved in the modulation of aggression through its connections with other brain structures [12].

**3. Insula:** This is a brain structure located deep within the lateral sulcus. It has been observed that general neglect is related to increased white matter density, but reduced resting-state connectivity strength of the insula. The insula monitors internal bodily sensations and is activated by salient emotional information. Maltreated children experience a lack of physical and emotional stimuli, and the absence of these signals may contribute to reduced connectivity of the insular network in affected individuals [16].

**4. Prefrontal cortex:** This is a brain region located in the frontal part of the brain. It plays a crucial role in decision-making, planning, and emotional regulation. It has been observed that early adversity is associated with structural deficits in the frontal cortex, including the prefrontal and cingulate cortices [17], as can also be seen in Figure 1. These

alterations can affect the capacity to evaluate the consequences of actions and control aggressive impulses [12]. Specifically, it has been found that emotional neglect is associated with a reduction in the volume of the anterior cingulate cortex, whereas emotional abuse, physical abuse, and sexual abuse do not show this association. The medial prefrontal cortex and the anterior cingulate cortex play an important role in emotional evaluation and regulation, and it has been observed that these structures are most affected in the emotional abuse subtype [18].

**5. Sensory cortices:** Sensory structures are also implicated in the neuroanatomy of violence. It has been observed that sexual abuse is related to a reduction in volume in the genital representation area of the somatosensory cortex, suggesting alterations in sensory perception. Furthermore, emotional abuse is associated with reduced cortical thickness in the facial representation region, which may affect the capacity for emotional recognition and social information processing. A reduction in visual cortical volume has also been reported in both sexual abuse and emotional neglect, which may influence visual processing and perception of the environment [19,20].

**6. Reward circuit:** The reward circuit is composed of various brain structures, including the caudate nucleus, which forms part of the ventral striatum. It has been found that the volume of the caudate nucleus decreases in cases of sexual abuse and emotional neglect, but not in emotional abuse or physical abuse. This suggests that these structures are implicated in the emotional response and motivation associated with violence [21].

## Neurotransmitters and Chemical Imbalances: Serotonin and Impulsive Aggression

Serotonin facilitates prefrontal cortical regions, such as the orbitofrontal cortex and the anterior cingulate cortex, which are involved in modulating and often suppressing the emergence of aggressive behaviors, primarily by acting on 5-HT2 serotonergic receptors in these regions [20]. Deficiencies in the serotonergic innervation of these regions could result in disinhibited aggression in response to provocation. Studies have demonstrated that selective serotonin reuptake inhibitors (SSRIs) reduce impulsive aggression [20] and that reduced concentrations of the serotonergic metabolite 5-hydroxyindoleacetic acid (5-HIAA) and reduced neuroendocrine responses to serotonergic probes are implicated in patients with aggressive personality disorder or individuals who have attempted violent suicide [20].

5-HT2A receptor antagonists reduce impulsivity in animal models, while agonists at the 5-HT2C receptor reduce impulsivity, suggesting that these two receptor subtypes play complementary roles in the regulation of aggression [21]. Pharmacological studies have evaluated serotonergic activity by measuring hormone responses, such as prolactin, to serotonergic releasing agents; it has been found that attenuated (blunted) prolactin responses are associated with suicide attempts and impulsive aggression in patients with personality disorders.

Imaging studies have indicated a reduction in activation of the orbital and ventromedial prefrontal cortex in response to fenfluramine in patients with aggressive personality disorder, borderline personality disorder, and patients with a history of suicide attempts. These studies have also shown significant reductions in serotonin transporter and 5-HT2A receptor binding in these regions in aggressive patients. Research has suggested that a reduction in 5-HT2A activity is associated with a reduction in aggression [21].

Thus, serotonin plays an important role in the modulation of aggression, especially through activity in prefrontal regions. Deficiencies in serotonergic function, as well as alterations in 5-HT2A and 5-HT2C receptors, are associated with an increase in impulsive aggression [21].

## Epigenetics of Violence

Genetics plays a significant role in the predisposition to violence. The MAOA gene, known as the 'warrior gene,' has been identified as a genetic factor related to aggression and violent behavior [22]. This gene encodes the monoamine oxidase A enzyme, which is implicated in the regulation of neurotransmitters such as serotonin. Furthermore, animal studies have revealed the transgenerational transmission of vulnerability to trauma, suggesting the influence of genetics on violence [22].

## MAOA gene and aggression

The MAOA gene has been associated with an increased risk of aggressive behavior in individuals exposed to adverse environmental factors, such as violence or childhood abuse [18]. These genetic variants can influence the way the brain processes serotonin, a neurotransmitter crucial for the regulation of mood and behavior. According to Caspi et al. [18], 'the MAOA gene plays a crucial role in the expression of reactive aggression.' Furthermore, increased amygdala activity has been observed in aggressive subjects, particularly in response to threatening stimuli [18].

## Transgenerational transmission of trauma

Animal studies have revealed the transgenerational transmission of vulnerability to trauma. In a study with mice exposed to traumatic stress, it was observed that genes related to the stress response and emotional regulation were transmitted for up to two subsequent generations [18]. These findings suggest that exposure to trauma can impact gene expression and be transmitted across generations, increasing susceptibility to violence [18].

## Interaction Between Genetic and Environmental Factors

It is important to note that the manifestation of violent behaviors is the result of a complex interaction between genetic and environmental factors. While genes may increase vulnerability to violence, environmental factors, such as the social environment and life experiences, also play a critical role [18]. The influence of genetics on violence may vary depending on the context and the interaction with the environment.

Genetic predisposition can also influence aggression and violence. Research has identified genetic variants related to the stress response system, such as the corticotropin-releasing hormone receptor gene (CRHR1) and the glucocorticoid receptor gene (NR3C1), which can modulate the stress response and aggression [19,20].

Effects of Early Exposure to Adversity on the Neurobiology of Violence: A Perspective on Brain Plasticity and Alterations in Key Regions

Early exposure to adversity—defined here as any condition or experience that can impair a child's physical, emotional, or social development during the critical stage of brain development—can have a significant impact on the brain from both neuroanatomical and neurochemical perspectives. Studies have demonstrated that such exposure is associated with a series of structural deficits and alterations across various brain regions. First, structural deficits have been identified in the reward circuit, involving regions such as the nucleus accumbens and the ventral tegmental area [21].

These regions are fundamental for the regulation of pleasure and motivation, and their dysfunction may be linked to difficulties in reward processing and emotional regulation in individuals exposed to early adversity. Furthermore, amygdala hyperreactivity has been observed during the recall of sad

autobiographical memories in individuals who have experienced emotional maltreatment [21].

The amygdala plays a crucial role in the emotional response and the regulation of fear; therefore, this hyperreactivity may be associated with increased sensitivity and emotional reactivity in individuals exposed to adverse situations in childhood. Exposure to emotional maltreatment has also been correlated with anomalies in frontolimbic socio-emotional networks [21]. These networks involve the interaction between the prefrontal cortex and limbic structures, such as the amygdala, and are fundamental for emotional regulation and decision-making. Alterations in these networks may be related to difficulties in emotional regulation and social information processing in individuals who have experienced emotional maltreatment (Table 1)

**Table 1.** NIS-4 Criteria for Subtypes of Childhood Trauma. [16].

| Trauma Subtype | Definition |
|---|---|
| Sexual Abuse | Any sexual act with a minor, including sexual penetration, abuse with genital contact, attempted sexual abuse with physical contact, prostitution or child pornography, and exposure to sexually explicit material or voyeurism. |
| Physical Abuse | Hitting a child with hands or with an object, kicking, punching, throwing, deliberately dropping, shaking, grabbing, dragging, pushing, or pulling, or otherwise causing actual or threatened physical harm. |
| Physical Neglect | Refusal of custody or the deliberate failure to provide or seek necessary care, supervision, nutrition, clothing, shelter, and personal hygiene, or other inattention to a child's physical needs and safety. |
| Emotional Abuse | Verbal assaults or other abuse, threats, terrorizing, administration of non-prescribed substances, or close confinement. |
| Emotional Neglect | Inadequate nurturing and affection, deliberate failure to provide or seek necessary care for emotional and behavioral problems, permitting substance abuse or maladaptive behavior, overprotection, inappropriately advanced expectations, inadequate structure, and exposure to maladaptive behaviors and environments or domestic violence. |

In the case of neglect, alterations in white matter integrity and connectivity have been observed across various brain networks [22]. These networks are implicated in a variety of functions, such as emotional processing, cognition, and stress regulation. White matter anomalies can affect efficient communication between different brain regions, which may have consequences for emotional and cognitive processing.

Other anomalies found in individuals exposed to different forms of maltreatment include a reduction in frontal cortical volume [21]. This reduction may be associated with difficulties in executive function, decision-making, and impulse control.

## Prolonged Exposure to Violence: Influence on the Regulation of the Hypothalamic-Pituitary-Adrenal Axis and Emotional Desensitization

The brain and the regulation of emotional responses can suffer adverse effects from prolonged exposure to violence. Likewise, emotional desensitization may occur, characterized by a decrease in emotional response and empathy toward victims of violence. This consequence is related to allostasis, an adaptive process of the organism to maintain internal stability in response to stressful challenges [23].

The concept of allostasis refers to the physiological and neuroendocrine changes that occur in the organism to cope with

stress and maintain homeostasis. Here, the hypothalamic-pituitary-adrenal (HPA) axis plays a major function in the response to aggression and a crucial role in regulating emotional responses and adapting to the environment [23]. (Figure 2)

Published studies have demonstrated that people chronically exposed to violence may exhibit alterations in the release of stress-related hormones, such as cortisol. For example, some studies have found elevated cortisol levels in people who have experienced chronic interpersonal violence, while others have shown reduced cortisol levels in individuals who have been victims of childhood violence [23,24].

Cortisol, at either elevated or reduced levels, can affect the functioning of various body systems, such as the immune, cardiovascular, and metabolic systems. Likewise, chronic stress associated with exposure to violence can increase the risk of developing mental health disorders, such as post-traumatic stress disorder (PTSD), depression, and anxiety [23,24]. Furthermore, these behaviors become normalized and accepted as a legitimate response in violent situations [25]. In individuals chronically exposed to violence, decreased amygdala activation is observed as a coping strategy [26] (Figure 3).

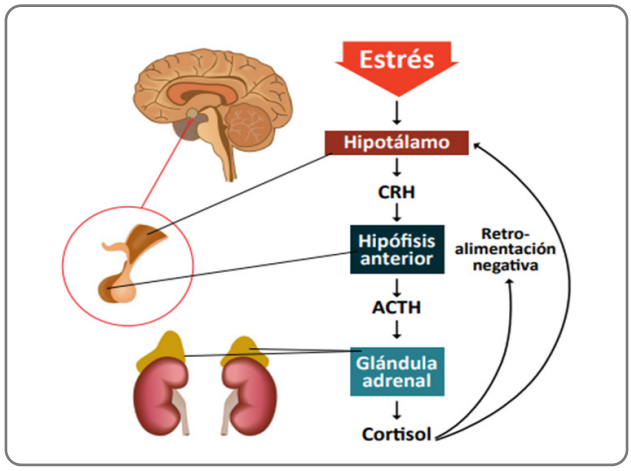


**Figure 2.** Functioning of the Hypothalamic-Pituitary-Adrenal (HPA) axis in response to stress (27). Note. Hypothalamic-adrenal axis and cortisol secretion. In situations of stress, the hypothalamus produces corticotropin-releasing hormone (CRH) in response to physical or physiological stress.

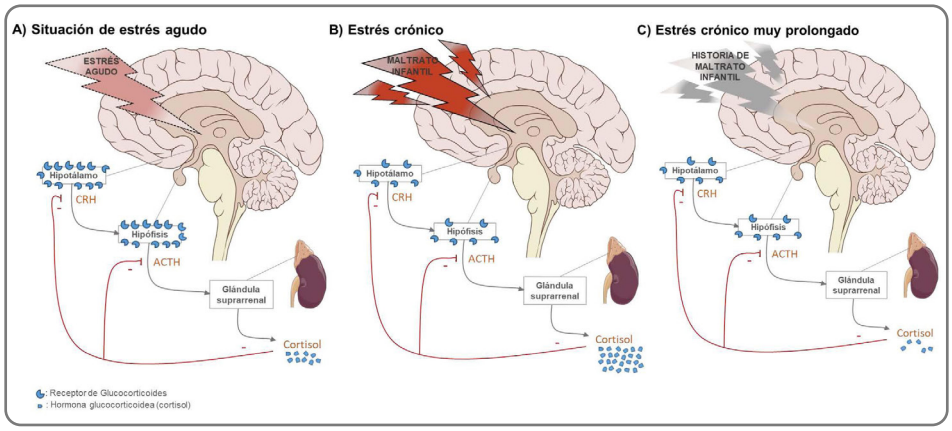


**Figure 3.** Intervention strategies based on the neurobiology of violence for the prevention and reduction of violent behaviors (28). Note. (A) Under normal conditions, when the brain detects an acute (isolated) stress signal. (B) Hyperactive HPA axis, when the brain is exposed to chronic stress (but limited in duration). (C) Hypoactive HPA axis, when the brain is exposed to very prolonged, sustained chronic stress.

Understanding the neurobiology of violence can provide valuable insights for the development of effective intervention strategies. The implementation of neurobiology-based approaches can help prevent and reduce violent behaviors in vulnerable individuals.

## Promising Strategies

To address violence in society, it is necessary to adopt early interventions to identify biological risk factors, thereby mitigating negative effects and promoting healthy brain development [29]. Likewise, psychological aspects must be addressed using a multimodal intervention approach combining cognitive-behavioral therapy (CBT), family therapy, and emotional education [30].

On the other hand, it has been proven that the implementation of emotional education in schools improves the acquisition of emotional regulation skills [31]. It is also important to strengthen protective factors, which can help individuals overcome adversity and reduce vulnerability to violence [32,33,34]. A study conducted by Burchinal et al. [35] found that children who received greater emotional support from their caregivers were less likely to exhibit aggressive behaviors. Another study by Jones et al. [36] demonstrated that the implementation of social skills programs in schools resulted in a reduction of aggression among students.

Understanding the neurobiology of violence can aid in risk assessment and management within the legal system. Studies by Raine [37] highlight the importance of using neurobiology to identify risk factors and assess the likelihood of future violent behaviors. According to Dadds et al. [38], the early identification of biological markers can help target specific interventions and reduce the incidence of violent behaviors. At the public health policy level, the neurobiology of violence can enable the implementation of more effective preventive programs. A publication by Knopf [39] emphasizes the importance of using neurobiological evidence to develop policies based on prevention and the promotion of mental health. Finally, public awareness campaigns can play an important role in violence prevention. Hahn et al. [40] highlight the effectiveness of awareness campaigns in reducing interpersonal violence.

Regarding academic and educational aspects, incorporating the neurobiology of violence into education and training curricula can increase public awareness and equip individuals with the tools to understand and address violent behaviors. Hossain et al. [41] demonstrated that education regarding the neurobiology of violence improved understanding and attitudes toward violence prevention. Collaboration among researchers, practitioners, and policymakers can help translate findings from the neurobiology of violence into effective policies and programs. Research by Hughes [42] noted the importance of establishing networks and alliances among researchers, practitioners, and policymakers to address violence from a neurobiological perspective.

## Impact of Early Adversity on Mental Health and Aggression

It has been evidenced that early adversity not only affects brain development but also significantly increases the risk of developing mental health problems across the lifespan, including mood disorders, anxiety, post-traumatic stress disorder (PTSD), and personality disorders [41].

There is increasing evidence linking early adverse experiences to a higher likelihood of manifesting aggressive and violent behaviors in childhood, adolescence, and adulthood [42]. The mechanisms underlying this association are complex and include neurobiological alterations, as well as the development of maladaptive coping patterns and the internalization of aggressive behavioral models [43].

## Repercussions on Mental Health

Understanding the complex interaction between the neurobiology of violence and aggression, the effects of early adversity on

neurodevelopment, and their consequences for mental health is necessary and fundamental to clinical practice. This knowledge contributes to the prevention, early detection, and treatment of associated disorders. Interventions can significantly reduce the risk of developing mental disorders and aggressive behaviors in later stages of life [44].

A deep understanding of the neurobiological bases of violence allows for the design of more specific and effective therapeutic approaches, particularly for patients with a history of early adversity who manifest difficulties in impulse control or aggressive behaviors [45–48].

## Conclusion

The review of the literature covering the period 2000–2025 provides evidence that neurobiology indicates that adverse experiences during critical stages of development have significant repercussions on the maturation of key brain structures, such as the amygdala and the prefrontal cortex, which increases vulnerability to aggressive behaviors in adulthood.

This work highlights the complex interaction between neurobiological factors (such as neurotransmitters and the hypothalamic-pituitary-adrenal axis), genetic determinants, and environmental contexts, which collectively modulate emotional response and behavior. This interaction reinforces the importance of understanding violence from a biopsychosocial and life-course perspective.

From a clinical perspective, this understanding offers a solid framework for the design of preventive strategies and more effective interventions. Emphasis is placed on the relevance of early interventions aimed at strengthening emotional regulation, promoting protective factors, and favoring healthy brain development in children and adolescents exposed to situations of violence or neglect.

Furthermore, priority is given to the need for a coordinated response between the clinical field, research, and public policy, in order to intervene in a timely and targeted manner in at-risk populations. The recognition of the neurobiological sequelae of early adversity and their association with mental health disorders such as depression, anxiety, post-traumatic stress disorder (PTSD), and personality disturbances underscores the urgency of integrating these findings into daily clinical practice.

In conclusion, approaching violence and its consequences through the lens of neurobiology broadens our understanding of the phenomenon. Likewise, it guides the development of more precise and effective interventions and contributes to the prevention of violence and the promotion of mental health throughout the lifespan.

**Authors' contributions:** Matías Sánchez: Literature review, content analysis, and initial drafting of the manuscript. Dra. Ailén Insaurralde: Theoretical and bibliographic review, technical editing, and support with references. Dra. Claudia Cáceres González: Overall coordination, methodological review, and final drafting of the manuscript.

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# Bibliographic References

1. Siever LJ. Neurobiology of aggression and violence. Dialogues Clin Neurosci. 2008;10(3):287-92.
2. Coccaro EF, Kavoussi RJ. Fluoxetine and impulsive aggression in personality disorder patients. Arch Gen Psychiatry. 1997;54(12):1081-8. doi: 10.1001/archpsyc.1997.01830240035005.
3. Shonkoff JP, Boyce WT, McEwen BS. Neuroscience, molecular biology, and the childhood roots of health disparities: building a new framework for health promotion and disease prevention. JAMA. 2009;301(21):2252-9. doi: 10.1001/jama.2009.754.
4. Ortega-Escobar J, Alcázar-Córcoles MA. Neurobiología de la agresión y la violencia. An Psicol Juríd. 2016;26(1):60-9. doi: 10.1016/j.apj.2016.03.001.
5. Archer J. The nature of human aggression. Int J Law Psychiatry. 2009;32(4):202-8. doi: 10.1016/j.ijlp.2009.04.001.
6. Anderson CA, Bushman BJ. Human aggression. Annu Rev Psychol. 2002;53:27-51. doi: 10.1146/annurev.psych.53.100901.135231.
7. Daly M, Wilson M. Evolutionary psychology of lethal interpersonal violence. In: Heitmeyer W, Hagan J, editors. International handbook of violence research. Dordrecht: Springer; 2003. p.141-68. doi: 10.1007/978-0-306-48039-3_29.
8. Alcázar-Córcoles MA. Patrones de conducta y personalidad antisocial en adolescentes: estudio transcultural en El Salvador, México y España; tesis doctoral. Madrid: Universidad Autónoma de Madrid; 2007.
9. van der Gronde T, Kempes M, van El C, Rinne T, Pieters T. Neurobiological correlates in forensic assessment: a systematic review. PLoS One. 2014;9(10):e110672. doi: 10.1371/journal.pone.0110672.
10. Paraguay. Ministerio Público. Fiscalía General del Estado. Violencia familiar: casos registrados 2023. Asunción: Ministerio Público; 2023. Available from: https://ministeriopublico.gov.py/violencia-familiar.casos
11. Paraguay. Biblioteca y Archivo del Congreso Nacional. Leyes paraguayas 2024. Asunción: BACN; 2024. Available from: https://www.bacn.gov.py/leyes-paraguayas/2024
12. 12.Paraguay. Biblioteca y Archivo del Congreso Nacional. Ley N° 7018/2022. De salud mental. Asunción: Biblioteca y Archivo del Congreso Nacional; 17 Nov 2022.
13. Blair RJ. The roles of orbital frontal cortex in the modulation of antisocial behavior. Brain Cogn. 2004;55(1):198-208. doi: 10.1016/S0278-2626(03)00276-8.
14. Perry KJ, Ostrov JM, Murray-Close D. The role of autonomic system coordination in relations between peer factors and aggressive behavior in early childhood. J Res Child Adolesc Psychopathol. 2023;51(5):693-708. doi: 10.1007/s10802-022-01013-0.
15. Raine A, Yang Y. Neural foundations of moral reasoning and antisocial behavior. Soc Cogn Affect Neurosci. 2006;1(3):203-13. doi: 10.1093/scan/nsl033.
16. Busso DS, McLaughlin KA, Brueck S, Peverill M, Gold AL, Sheridan MA. Child abuse, neural structure, and adolescent psychopathology: a longitudinal study. J Am Acad Child Adolesc Psychiatry. 2017;56(4):321-8.e1. doi: 10.1016/j.jaac.2017.01.013.
17. Woodward SH, Kaloupek DG, Streeter CC, Martinez C, Schaer M, Eliez S. Decreased anterior cingulate volume in combat-related PTSD. Biol Psychiatry. 2006;59(7):582-7. doi: 10.1016/j.biopsych.2005.07.033.
18. Cassiers LLM, Sabbe BGC, Schmaal L, Veltman DJ, Penninx BWJH. Structural and functional brain abnormalities associated with exposure to different childhood trauma subtypes: a systematic review. Front Psychiatry. 2018;9:329. doi: 10.3389/fpsyt.2018.00329.
19. Siever LJ. Neurobiology of aggression and violence. Am J Psychiatry. 2008;165(4):429-42. doi: 10.1176/appi.ajp.2008.07111774.
20. Caspi A, McClay J, Moffitt TE, Mill J, Martin J, Craig IW, et al. Role of genotype in the cycle of violence in maltreated children. Science. 2002;297(5582):851-4. doi: 10.1126/science.1072290.
21. Carpenter LL, Carvalho JP, Tyrka AR, Wier LM, Mello AF, Mello MF, et al. Decreased adrenocorticotropic hormone and cortisol responses to stress in healthy adults reporting significant childhood maltreatment. Biol Psychiatry. 2007;62(10):1080-7. doi: 10.1016/j.biopsych.2007.05.002.
22. Dannlowski U, Stuhrmann A, Beutelmann V, Zwanzger P, Lenzen T, Grotegerd D, et al. Limbic scars: long-term consequences of childhood maltreatment revealed by functional and structural magnetic resonance imaging. Biol Psychiatry. 2012;71(4):286-94. doi: 10.1016/j.biopsych.2011.10.021.
23. Teicher MH, Samson JA, Anderson CM, Ohashi K. The effects of childhood maltreatment on brain structure, function and connectivity. Nat Rev Neurosci. 2016;17(10):652-66. doi: 10.1038/nrn.2016.111.
24. Anderson CA, Berkowitz L, Donnerstein E, Huesmann LR, Johnson JD, Linz D, et al. The influence of media violence on youth. Psychol Sci Public Interest. 2003;4(3):81-110. doi: 10.1111/j.1529-1006.2003.pspi_1433.x.
25. Carpenter LL, Carvalho JP, Tyrka AR, Wier LM, Mello AF, Mello MF, et al. Decreased adrenocorticotropic hormone and cortisol responses to stress in healthy adults reporting significant childhood maltreatment. Biol Psychiatry. 2007;62(10):1080-7. doi: 10.1016/j.biopsych.2007.05.002.
26. Heim C, Newport DJ, Heit S, Graham YP, Wilcox M, Bonsall R, et al. Altered pituitary-adrenal axis responses to provocative challenge tests in adult survivors of childhood abuse. Am J Psychiatry. 2000;157(1):27-33. doi: 10.1176/appi.ajp.157.1.27.
27. Funk JB, Baldacci HB, Pasold T, Baumgardner J. Violence exposure in real-life, video games, television,

movies, and the internet: is there desensitization? J Adolesc. 2004;27(1):23-39. doi: 10.1016/j.adolescence.2003.10.005.

28. Amdur RL, Larsen R, Liberzon I, Kantor B, Bryson G, Martis B, et al. Emotional processing in combat-related posttraumatic stress disorder: a comparison with traumatized and normal controls. J Anxiety Disord. 2000;14(3):219-38. doi: 10.1016/S0887-6185(99)00035-3.
29. Marques-Feixa L, Fañanás L. Las consecuencias neurobiológicas del maltrato infantil y su impacto en la funcionalidad del eje HHA. Psicopatol Salud Ment. 2020;M4:11-24.
30. Vélez Palacio A, Restrepo Valencia CA, Ospina Díaz JM, Cárdenas Gómez JF, Ramírez Gómez M, et al. Evaluación de la función del eje hipotálamo-hipófisis-adrenal en niños tratados con esteroides. Med Lab. 2013;19(3-4):111-23.
31. Rutter M. Implications of resilience concepts for scientific understanding. Ann N Y Acad Sci. 2006;1094(1):1-12. doi: 10.1196/annals.1376.002.
32. Blair RJR. The neurobiology of violence. In: Sell R, Shadoin NA, editors. Handbook of violence risk assessment and treatment: new approaches for mental health professionals. Hoboken: Wiley; 2013. p. 91-106.
33. Greenberg MT, Weissberg RP, O'Brien MU, Zins JE, Fredericks L, Resnik H, et al. Promoting healthy adolescent development: a comprehensive approach. Annu Rev Public Health. 2017;38:201-20. doi: 10.1146/annurev-publhealth-031811-124619.
34. Masten AS. Resilience in developing systems: progress and promise as the fourth wave rises. Dev Psychopathol. 2007;19(3):921-30. doi: 10.1017/S0954579407000442.
35. Burchinal M, Vandergrift N, Pianta R, Mashburn A. Predicting child outcomes at the end of kindergarten from the quality of pre-kindergarten teacher-child interactions. Appl Dev Sci. 2008;12(3):140-53. doi: 10.1080/10888690802199418.
36. Jones DE, Greenberg M, Crowley M. Early social-emotional functioning and public health: the relationship between kindergarten social competence and future wellness. Am J Public Health. 2015;105(11):2283-90. doi: 10.2105/AJPH.2015.302630.
37. Raine A. From genes to brain to antisocial behavior. Curr Dir Psychol Sci. 2008;17(5):323-8.
38. Dadds MR, Allen JL, Oliver BR, Faulkner N, Legge K, Moul C, et al. Callous-unemotional traits in children and mechanisms of impaired eye contact during expressions of love: a treatment target? J Child Psychol Psychiatry. 2014;55(7):771-80. doi: 10.1111/jcpp.12155.
39. Knopf A. Neurobiological research for mental health: challenges and opportunities. J Health Care Poor Underserved. 2017;28(3):769-81.
40. Hahn RA, Bilukha O, Lowy J, Crosby A, Fullilove MT, Liberman A, et al. First reports evaluating the effectiveness of strategies for preventing violence: early childhood home visitation. Am J Prev Med. 2007;33(1 Suppl):S116-29. doi: 10.1016/j.amepre.2004.10.004.
41. Hossain MM, Khan N, Sultana A, Ma P, McKyer ELJ, Ahmed HU, et al. Can neurobiology of violence inform prevention of violence and criminality? A scoping review of the literature. Lancet Public Health. 2017;2(8):e356-66.
42. Hughes K, Bellis MA, Hardcastle KA, Sethi D, Butchart A, Mikton C, et al. The effect of multiple adverse childhood experiences on health: a systematic review and meta-analysis. Lancet Public Health. 2017;2(8):e356-66. doi: 10.1016/S2468-2667(17)30118-4.
43. Rosell DR, Siever LJ. The neurobiology of aggression and violence. CNS Spectr. 2015;20(3):254-79. doi: 10.1017/S109285291500019X.
44. Kessler RC, McLaughlin KA, Green JG, Gruber MJ, Sampson NA, Zaslavsky AM, et al. Childhood adversities and adult psychopathology in the WHO World Mental Health Surveys. Br J Psychiatry. 2010;197(5):378-85. doi: 10.1192/bjp.bp.110.080499.
45. Widom CS, Maxfield MG. An update on the "cycle of violence". Research in Brief. Washington (DC): National Institute of Justice, US Department of Justice; 2001. p. 1-8.
46. Dodge KA, Pettit GS, Bates JE. Social information-processing patterns partially mediate the effect of early physical abuse on later conduct problems. Child Dev. 1994;65(3):648-63.
47. Shonkoff JP, Boyce WT, McEwen BS. Neuroscience, molecular biology, and the childhood roots of health disparities: building a new framework for health promotion and disease prevention. JAMA . 2009;301(21):2252-9. doi: 10.1001/jama.2009.754.
48. Fonagy P, Luyten P, Allison E. Attachment, mentalization and trauma: then (1992) and now (2022). Brain Sci. 2023;13(3):459. doi: 10.3390/brainsci13030459.