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Neuroscience, Genetics, Education, and AI: Charting New Frontiers in Understanding Human Behaviour and Criminal Responsibility

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Abstract: *The eternal dilemma: how much does genetics influence human behaviour? Be it so-called normal or pathological. How much does education and existential experiences influence human behaviour? "The decisional spaces", that is, I am free to choose between letting myself go to the homicidal impulse or I am conditioned by the pathology. Can new research finally provide us with a valid answer or are we still far from conclusive scientific certainties? This work explores how neuroscience, genetics, education, and AI collectively shape human behaviour and influence criminal responsibility. It examines the extent to which biological predispositions, such as gene variants and structural brain anomalies, interact with environmental factors and educational experiences to determine both typical and pathological behaviours. By introducing the concept of "decisional spaces", the study questions whether individuals freely choose their actions or are constrained by neurobiological and psychological factors. Drawing on recent neuroimaging and behavioural studies, the analysis highlights key findings on impulse control and decision-making processes, including evidence that specific brain structures and functions may predispose individuals to criminal behaviour. These insights are juxtaposed with research on how educational interventions and life experiences can modify behavioral outcomes, potentially mitigating the impact of inherent predispositions. Furthermore, the work reviews legal cases, particularly rulings from the Italian Criminal Court of Cassation up to 2019, that demonstrate an evolving recognition of neurobiological influences in assessing criminal responsibility. These cases underscore the legal challenges of balancing scientific evidence with traditional notions of free will and accountability. In addition to integrating findings from neuroscience and genetics, this study also explores the burgeoning role of AI. Advanced algorithms and machine learning techniques are increasingly used to process complex datasets from clinical, behavioural, and forensic research. AI-driven analyses can reveal patterns that inform both individualised risk assessments and broader policy decisions, offering a promising avenue for enhancing the objectivity and precision of legal evaluations. Ultimately, this work provides a comprehensive, multidisciplinary overview that not only advances scientific understanding but also informs legal debates. It aims to contribute to a more nuanced framework for evaluating criminal responsibility, one that reflects the sophisticated dynamics between biology, education, and emerging technologies in crafting human behaviour.*

Keywords: *neurosciences; genetics; education; artificial intelligence; criminal responsibility; human behaviour.*

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1. Introduction

Many authors are against neuroscience in the forensic field and therefore against a high-resolution encephalic Nuclear Magnetic Resonance and the proof of the genetic defect of neo-Lombrosian theoretical approach because, as per consolidated jurisprudence, the application of neuroscience, very useful in the clinical field, has not gained equal dignity in the forensic field. In fact, for example, in Italy, the sentence of the Court of Cassation of the Criminal Section I, no. 43021/2012 clearly expresses itself by indicating that:

- The cases in which the neuroscientific evidence was accepted have been few and isolated (essentially two: Sentence of the Court of Trieste, 2009, and the Court of Como, 2011). Furthermore, in both cases, the neuroscientific data were lateral to the psychiatric evaluation (Montanari Vergallo et. al., 2018).

As reported above, the jurisprudence expressed great perplexity regarding the validity of neuroscientific evidence, in sentences after those of Como and Trieste, (Cass. Pen. Sez. I, n. 43021/2012): “the so-called Neurosciences, which valorise behavioural genetics can boast isolated applications in the judicial field (there are very few precedents), a symptom of inadequate verification by the scientific community in the sector”(Montanari Vergallo et. al., 2018).

Even the sentence of the Court of Cassation of 2019 (Sent. n.11897/2019), speaks of the reliability of neurosciences only in the case where the behavior is found to be criminal, not before, but only after a frontal head trauma.

Moreover, let's ask ourselves about education and neuroscientific alterations and the ancient dilemma: genetically determined to deviance or conditioned by education and/or childhood and adolescent traumas?

2. Rationality and Genetics

Asking whether an individual is rational, therefore, takes on a meaning for Law and a very different meaning for Neuroscience. For Neuroscience, the question could be: is this individual rational and emotional? For Law, the fundamental question remains whether the individual acted voluntarily and in full control of his behaviour. That is, whether "the decision-making spaces were intact or forced"?; ultimately, that given evil action occurred at a time when the person was free to choose whether to give in to the homicidal impulse due to some disabling pathology or to resist the same impulse? (Bottini, Sedda, & Ovadia, 2013). Glenn and Raine (2014) highlight that extensive research (encompassing over a hundred behavioural genetics studies using various approaches like twin comparisons, twin separation studies, and adoption analyses) consistently points to a strong genetic influence on aggressive and antisocial behaviours. Several data indicate instead that the role of a single gene is scarce (Vassos, Collier, & Fazel, 2013).

3. Hormones, Neurotransmitters, and Impulsive Behaviour

Glenn and Raine (2014) point out that low cortisol levels in childhood are linked to a higher likelihood of aggressive behaviour emerging during adolescence, with one study showing that boys with behavioural challenges and reduced cortisol levels became more aggressive within two years (Shoal, Giancola, & Kilrillova, 2003; Glenn & Raine, 2014). In terms of neurochemistry, multiple neurotransmitters have been associated with aggression. A consistent pattern in the research suggests that lower serotonin levels are tied to heightened aggression (Glenn & Raine, 2014). Moreover, diminished serotonin levels in the cerebrospinal fluid have been identified as a biological marker of impulsivity (Coccaro, 1989; Glenn & Raine, 2014). Interestingly, aggression has also been linked to reduced levels of the enzyme MAOA, which typically helps regulate serotonin, suggesting a more complex relationship that warrants further investigation (Glenn & Raine, 2014).

4. Neuroimaging and Neurological Studies

As illustrated by recent developments in Italian case law, diminished activity in the brain's frontal lobe has been linked to antisocial and violent tendencies (Glenn & Raine, 2014). A broad analysis encompassing more than 40 structural and functional neuroimaging studies confirmed that individuals exhibiting antisocial behaviour show the most pronounced reductions in both structure and function within key areas of the frontal lobe, specifically the orbitofrontal cortex, anterior cingulate, and dorsolateral prefrontal cortex (Serban, 2023; Raine, Venables, & Williams, 1996; Glenn & Raine, 2014). Additionally, Glenn and Raine (2014) report that males possessing a certain variant of the MAOA gene, which occurs in about 30% of the population, display an 8% decrease in volume in the amygdala, anterior cingulate, and orbitofrontal cortex. This points to a potential genetic contribution to antisocial behaviour.

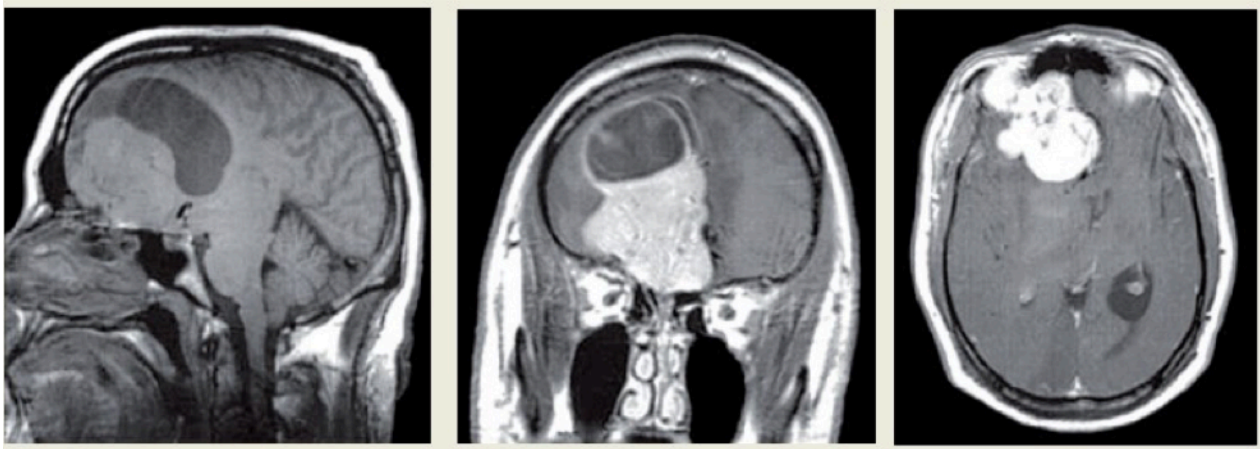


Figure 1. Orbitofrontal Tumor and Reversible Pedophilic Behaviour: The Case of Michael X.

The individual's pedophilic behaviour was linked to a tumor in the orbitofrontal cortex. After surgical removal, the behaviour ceased, but reemerged with tumor recurrence, highlighting a neurological basis for impulse control and social behaviour. Adapted from Ref. 71, © 2003 American Medical Association, as cited in Glenn & Raine (2014).

Regarding the judicial framework, there is a battle between two theories. On one hand, it is difficult to ignore the influence of neurobiological factors, such as diminished amygdala activity during moral reasoning, the presence of certain MAOA gene variants, or notably reduced prefrontal gray matter, which appear to contribute to behavioural outcomes (*see* Figure 1). On the other hand, some argue that while every behavior may have a biological basis, identifying its neural origins does not automatically equate to a reduced ability to reason or a lack of legal responsibility (Morse, 2007a; Morse, 2007b; Glenn & Raine, 2014).

In the case of Donta Page, a young man had raped and killed a woman. The CTP argued that a head trauma and repeated physical abuse (Serban, 2023) during childhood had led to a strong “reduction in the activity of the ventrolateral (Figure 2), ventromedial and polar prefrontal cortex. The resulting reduced capacity for control led to the non-application of the death penalty, converted to life imprisonment” (Glenn & Raine, 2014).

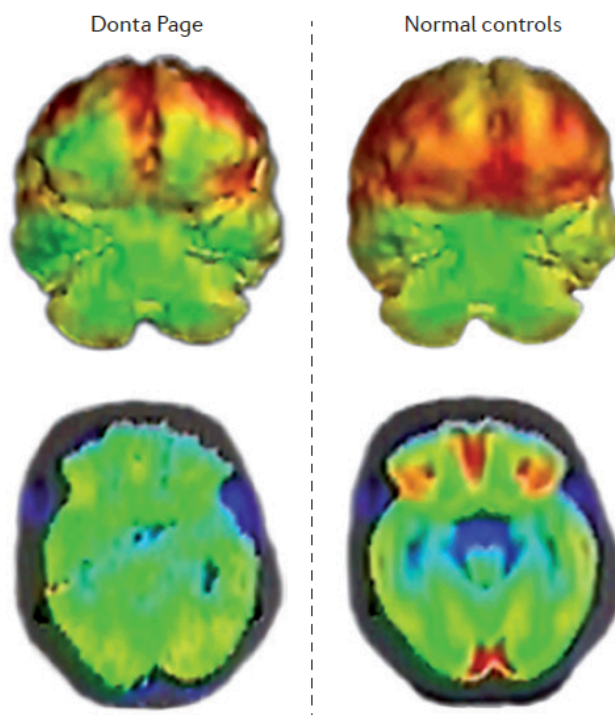


Figure 2. *The case of Donta Page.*

Adapted from *The Anatomy of Violence* by Glenn & Raine, 2014, Pantheon Books. Copyright 2013 by Pantheon.

As neuroscience provides a thorough and specific explanation of the processes that can lead to irresponsible or criminal behaviour may result in a shift in public perceptions of responsibility, similar to how views on addiction have evolved from being seen as a personal failure to being understood as a disease (Farah, 2012; Glenn & Raine, 2014).

Recent imaging studies provide evidence supporting the conclusions of a Royal Society report and suggest that neuroscience may be valuable in the future in predicting recidivist antisocial or deviant behaviour. (Mackintosh et. al, 2011; Glenn & Raine, 2014; Șerban, 2023).

Despite this, several factors oppose the application of these procedures, according to Glenn and Raine:

1. "First, the evolution of knowledge in neuro criminology has yet to be widely accepted in the social sciences and by professionals;
2. Second, neurobiological analyses are more difficult to gather compared to behavioral, social, and psychological analyses;
3. Third, ethical concerns exist regarding the collection of biological data from offenders; however, this may change as DNA is now gathered from all arrestees in the United States and the United Kingdom" (Glenn & Raine, 2014).

Although criminal personalities are diverse, they share a common trait: immorality. It is plausible "that the neural circuits involved in moral decision-making are consistently impaired in violent offenders" (Glenn & Raine, 2014). Glenn and Raine (2014) noted that these circuits primarily include "the polar and medial prefrontal cortex (PFC), ventral PFC, angular gyrus, posterior cingulate cortex, and amygdala. These brain regions have substantial overlap with those regions found to be structurally or functionally altered in the perpetrators of these crimes" (Glenn & Raine, 2014).

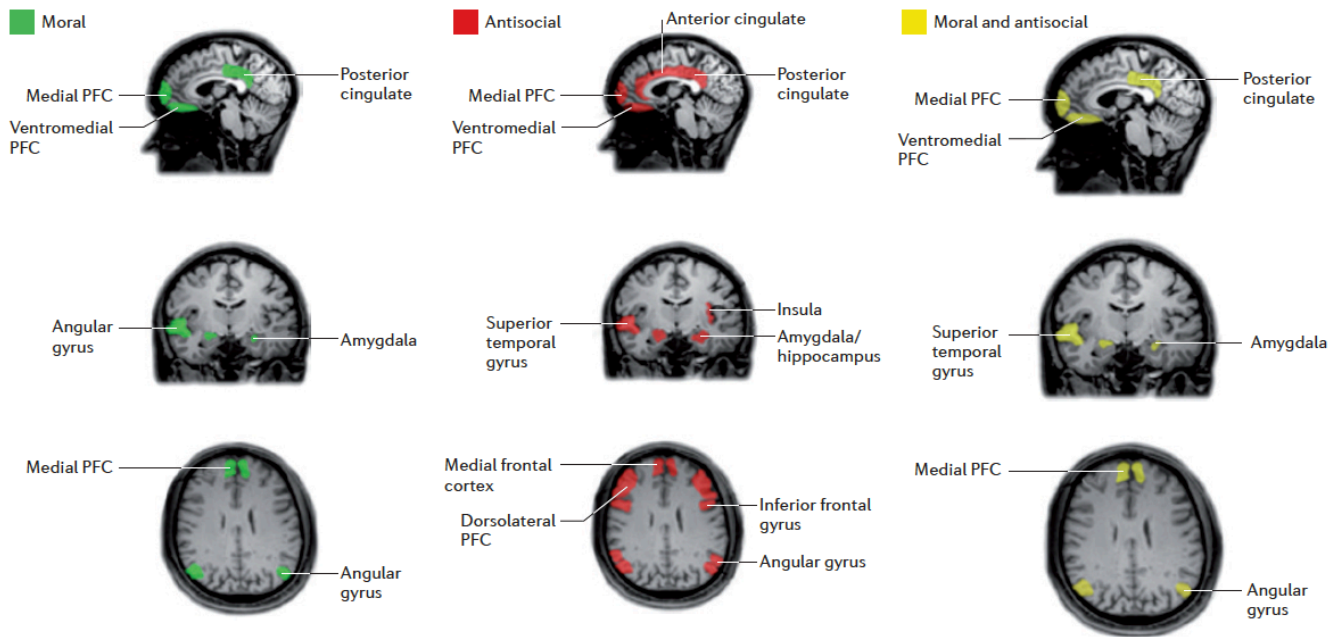


Figure 3. Figure from Raine, A. & Yang, Y. *Neural foundations to moral reasoning and antisocial behaviour*. *Soc. Cogn. Affect. Neurosci.* 1, 203-213 (2006)

Figure 3 “shows a schematic of brain regions that are activated only in moral decision-making (green), that have reduced function only in antisocial groups (red), and regions common to antisocial behaviour and moral decision-making (yellow). This overlap is the basis of a ‘neuromoral’ hypothesis of antisocial behaviour, which states that some of the brain damage observed in antisocial subjects reduces moral emotion and/or decision-making, thereby predisposing individuals to antisocial behaviour”. So, if a criminal offense is linked to an alteration of the neural circuits responsible for moral judgements and a lack of sensitivity for what is right and wrong, are people fully responsible for their behaviour? At this point, we can only conclude with the well-known assumption: “everyone is a unique case steeped in education, genetics, but above all existential experiences.” Glenn and Raine (2014). Just think of the phenomenon of terrorism and the mechanisms of moral disengagement, well described by Mastronardi (Montanari Vergallo et. al., 2020; Palermo & Mastronardi, 2012; Glenn & Raine, 2014).

According to the canons of social psychology, Cialdini (1989) writes on the subject, reported by Mastronardi: “If I manage to get you to make a commitment (take a position, say something publicly), I will have prepared the ground for your automatic and unreflective conduct, consistent with that initial commitment” (Schein, 1956; Di Fiorino, 1990; Pacciardi et al., 2013) always reported by Mastronardi (Mastronardi, 2012).

Valid confirmations of all this come from the numerous and most up-to-date scientific research conducted by Bandura as well as other authors, which we report below, albeit in a schematic form for reasons of ease of discussion:

the stages of the mechanisms of moral disengagement in the psychodynamics of the formation of a terrorist.

It has been seen in this regard that it is easier to find people willing to kill public officials or boycott foreign consulates that support repressive regimes, rather than cold-bloodedly kill innocent children and women on buses, in department stores, or at airports (Eisner & Malti, 2015). These latter modes of criminological behaviour require a more articulated and intensive psychological training of moral disengagement (Eisner & Malti, 2015). Among the aforementioned mechanisms of moral disengagement, we find:

1) *“The moral justification in which we witness the transformation of a subject with valid moral imperatives into a cynical Killer who has already proudly restructured cognitively, the advantage of killing without the old self-censoring brakes thanks to the achievement of goals that are noble for him such as for example the international commitment to peace or saving the group from the subordination of evil ideologies or even the protection of one’s own values, this is why moral appeals against violence usually fall on deaf ears: because they reach deaf ears”* (Bandura, 1990).

2) *We still find the euphemistic labeling where the language spoken with incisive disinhibitory power is able to modify thought patterns by conferring an “aura of respectability” to any illicit enterprise. For example, we will talk about finishing a person instead of killing him, or fulfilling a contract in an honorable way, instead of considering oneself the material executor of a murder. Terrorists will call themselves freedom fighters, their actions will be cleansing blows, surgical operations, and the innocents they kill will be converted into collateral damage. Just as ferocious criminal activities will be represented as competitive plans and their perpetrators will be team players.*

3) *Interesting is also the mechanism of advantageous comparison that exploits the “principle of contrast” considering even the most evil actions as right if placed in contrast with “flagrant attitudes of inhumanity” perpetrated by any opponent, just as for example terrorists (Montanari Vergallo et al., 2020) minimise their crimes as “the only defense weapon they have to curb the widespread cruelties inflicted on their people”. In the eyes of their supporters, risky attacks directed at the oppressive apparatus constitute acts of martyrdom and altruism* (Bandura, 1990).

4) *The 4th mechanism of moral disengagement is represented by moral and mass-media justifications, for example, by terrorists who coerce access to the media to publicise their claims to the international community. They use television as the main means to gain sympathy and support for their cause, portraying themselves as those who risk their lives for the good of a victimised group* (Bandura, 1990).

5) *Here we also find the dislocation of responsibility, for example, in mass executions, the commanders of Nazi camps and their platoons relieved themselves of personal responsibility because they were simply obeying orders with a strong sense of responsibility towards their superiors and the responsibility was therefore someone else’s. Then again: in the event of hostages being captured during robberies or terrorist acts, the Police Officers are blamed for the suffering and injuries they inflict on their hostages in their refusal to provide the requested concessions* (Bandura, 1990).

6) *Then again: the diffusion of responsibility when in the division of tasks, the responsibility falls on the group or the community and not on the individual.*

7) *the carelessness or distortion of the consequences for which the addressing of the harm caused is avoided or it is minimised by distorting the perception and channeling it on the importance of potential benefits to be obtained.*

8) *dehumanisation.*

Self-imposed restraints against cruelty can be weakened or removed by denying others their human qualities. When dehumanised, potential victims are no longer perceived as individuals with emotions, aspirations, and interests but as mere objects. They are depicted as savages, people of color, demoniacs, without the capacity for judgment and so on. “Subhumans” are considered insensitive to mistreatment and capable of being conditioned only with severe methods (Cromer, 2006).

9) *The power of humanisation.*

It occurs when, as in Stockholm syndrome, close personal contact leads to a process of need to humanise one’s aggressor; even participating in their criminal action by sharing methods and goals.

10) The attribution of guilt.

Destructive interactions often consist of a cycle of mutually reinforcing actions, where neither party is entirely “innocent.” One can always isolate a moment from the sequence of events, highlighting an aspect of the opponent’s defensive behavior as the initial provocation. Thus, the offensive conduct becomes a defensive reaction justified by belligerent provocations of the enemy that in reality are only of a defensive nature (Bandura, 1990).

11) Progressive disinhibitory training

It is typically carried out within a setting of mutual interpersonal influence, detached from broader social life. Newcomers gradually absorb the group’s ideology and behavioral norms. Initially, they are introduced to committing mildly unpleasant acts that they can tolerate with minimal self-censorship. Gradually, through repeated performances and repeated exposures to the aggressive model of more experienced companions: their discomfort and self-reproach become weaker to the point of allowing ever higher levels of cruelty (Cromer, 2006).

12) Self-deception.

This psychological mechanism is characterised by the absolute need to deny reality to oneself, distancing oneself in every way and at any cost from the truth and therefore not carrying out actions that would reveal it, and not fully declaring what they do or experience, in the continuous search to convince themselves that what they believe is true” (Fingarette, 1969; Haight, 1980).

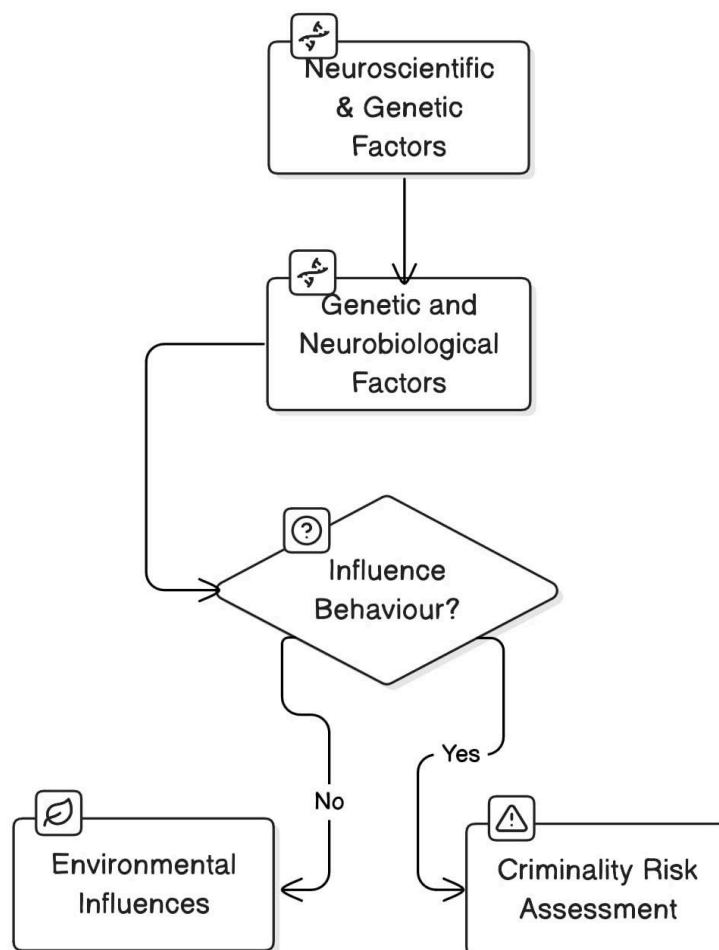


Figure 4. Genetics and neuroscience flowchart.

Source: author's own conception

The above chart (Figure 4) provides a simplified view of how genetic and neurobiological factors might contribute to human behaviour, and potentially to criminality, while acknowledging

the role of environmental influences. In essence, the core principle in behavioural science is that no single factor, genetic, neurobiological, or environmental, fully determines behaviour. Instead, criminal or deviant behaviour often emerges from a complex interplay of multiple influences, which is why both genetic/neurobiological predispositions and environmental factors are considered in any comprehensive assessment.

5. Education as a Protective Factor: Enhancing Resilience

Recent research has shown that structured educational support can mitigate the negative effects of trauma and promote resilience in at-risk individuals (Masten & Cicchetti, 2016). Quality education plays a crucial role in mitigating the trauma's negative effects by providing structure, social support, and cognitive skills that foster resilience in children and adolescents. Trauma, particularly in early childhood, can disrupt normal emotional and cognitive development, leading to difficulties in impulse control, emotional regulation, and decision-making. However, a stable and nurturing educational environment can serve as a counterbalance to these adversities, offering the necessary tools to develop adaptive coping mechanisms and prevent negative behavioural outcomes (De Bellis & Zisk, 2014). For children who have experienced trauma (Serban, 2023), consistency and predictability are essential in reducing stress and fostering a sense of security. Schools provide a structured environment with clear expectations, routines, and guidance, which can counteract the instability that often accompanies traumatic experiences (Masten & Cicchetti, 2016). Regular school attendance also helps reinforce discipline, goal-setting, and perseverance, skills that contribute to long-term personal development.

Beyond academic instruction, schools offer a critical social support system. Positive relationships with teachers, mentors, and peers can compensate for the lack of a stable or supportive home environment, reducing feelings of isolation and abandonment (Fergusson, Horwood, & Boden, 2008). Studies show that strong teacher-student connections can enhance emotional resilience, helping children develop trust and self-worth, which are often eroded by traumatic experiences (Hawkins et al., 2008). Furthermore, socialising in a structured setting allows pupils to develop social and emotional skills, such as empathy, cooperation, and conflict resolution, which are essential for overcoming adversity.

Education strengthens critical thinking, problem-solving, and emotional regulation, all of which are necessary for overcoming the long-term effects of trauma. Exposure to structured learning experiences enhances cognitive flexibility, allowing individuals to analyse challenges, weigh options, and make informed decisions instead of reacting impulsively (Noble et al., 2012). Additionally, programs focusing on social-emotional learning (SEL) teach students how to manage emotions, cope with stress, and regulate their responses to difficult situations, reducing the likelihood of aggressive or self-destructive behaviours (Lochman & Wells, 2002).

Trauma often leads to feelings of helplessness and a belief that one's circumstances cannot improve. However, quality education fosters a growth mindset, teaching students that abilities and intelligence can be developed through effort and perseverance (Dweck, 2006). This perspective enhances self-efficacy, empowering individuals to take control of their futures rather than succumbing to the negative effects of their past experiences.

In addition to serving as a protective factor, education plays a vital role in early intervention and the development of essential life skills that can prevent trauma from leading to maladaptive or criminal behaviours. Schools are often the first structured environments where the effects of trauma become visible, making them an ideal setting for timely support and skill-building programs.

Educators, school counsellors, and support staff are in a unique position to detect signs of trauma in students. Behavioural changes such as aggression, withdrawal, impulsivity, or academic struggles often serve as red flags for underlying psychological distress (Hawkins et al., 2008). By recognising these signs early, schools can connect affected students with mental health professionals, specialised intervention programs, or social services, preventing behavioural problems from escalating into delinquency (Lochman & Wells, 2002).

Some of the most effective school-based intervention programs include:

- Trauma-informed education frameworks, which train teachers to recognise and respond to trauma-related behaviours with sensitivity rather than punitive measures (Masten & Cicchetti, 2016);
- Social-emotional learning (SEL) programs, which provide students with emotional regulation techniques, coping strategies, and resilience-building exercises (Dweck, 2006).
- School-based counselling and peer support networks, which help children and adolescents process trauma in a safe and structured environment.

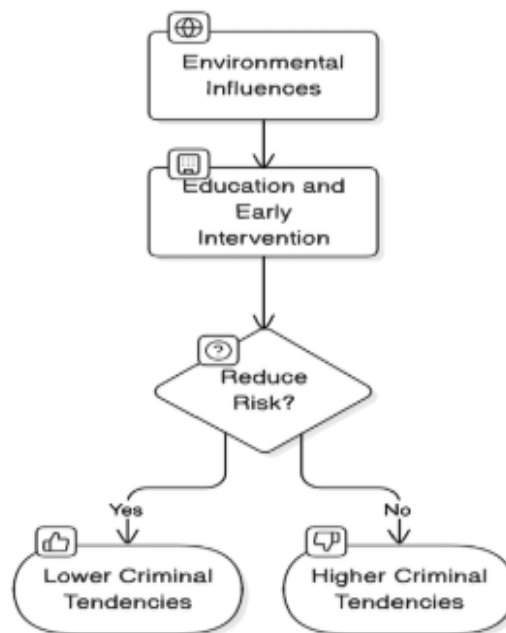


Figure 5. Education and criminal tendencies
Source: author's own conception

As illustrated by the above chart (Figure 5), beyond academic instruction, education plays a crucial role in shaping emotional intelligence, social interactions, and problem-solving abilities. Schools provide a structured setting where students can develop essential life skills that counteract the negative effects of trauma and reduce the likelihood of engaging in risky or criminal behaviours (Fergusson, Horwood, & Boden, 2008).

Key skills fostered through education include:

- Conflict Resolution: teaching students nonviolent strategies to resolve disputes can reduce impulsive or aggressive behaviours linked to trauma exposure;
- Empathy and Perspective-Taking: structured lessons on emotional awareness and ethical reasoning can enhance students' ability to understand and regulate their own emotions while considering the feelings of others (Dweck, 2006);
- Coping Mechanisms: educational settings provide a “safe space” for learning healthy coping strategies, such as stress management techniques, mindfulness exercises, and problem-solving frameworks, which help mitigate the trauma’s negative effects (De Bellis & Zisk, 2014).

6. Reduction in Risk of Criminal Behaviour and Breaking the Cycle

Research indicates that higher educational attainment is generally linked with lower rates of criminal activity. Education not only provides cognitive and emotional development but also offers the opportunity to develop a stable future. When education is paired with targeted interventions, such as trauma-informed programs or social-emotional learning, it can redirect potential negative outcomes associated with early trauma and prevent deviant behaviours (Lochman & Wells, 2002).

By offering opportunities for social mobility and economic stability, education can help break the cycles of deviance and criminality often perpetuated by unresolved traumas. Education empowers individuals with the skills and qualifications needed to gain employment and contribute positively to society, reducing the likelihood of reoffending or falling into further criminal activity (Fergusson, Horwood, & Boden, 2008).

While education is a crucial component in conditioning behaviour and preventing criminality, its effectiveness is greatly enhanced when integrated with other supportive resources. A comprehensive approach that includes family support, community resources, and access to mental health care is vital for addressing the multifaceted impacts of childhood trauma. Schools that collaborate with community organisations and provide holistic support can maximise their effectiveness in preventing long-term negative behavioural outcomes (Masten & Cicchetti, 2016). In conclusion, education, especially when it is comprehensive, supportive, and integrated with targeted interventions, plays a crucial role in conditioning behaviour and reducing the risk of deviance or criminality among individuals who have experienced childhood and adolescent trauma (Focquaert, Shaw (& Waller, 2020; Phelps & LeDoux, 2005). By fostering resilience, offering early intervention, and providing opportunities for skill development and personal growth, education can significantly mitigate the long-term consequences of trauma.

7. Neurobiological Evidence in Criminal Responsibility: Legal Shifts in Italy

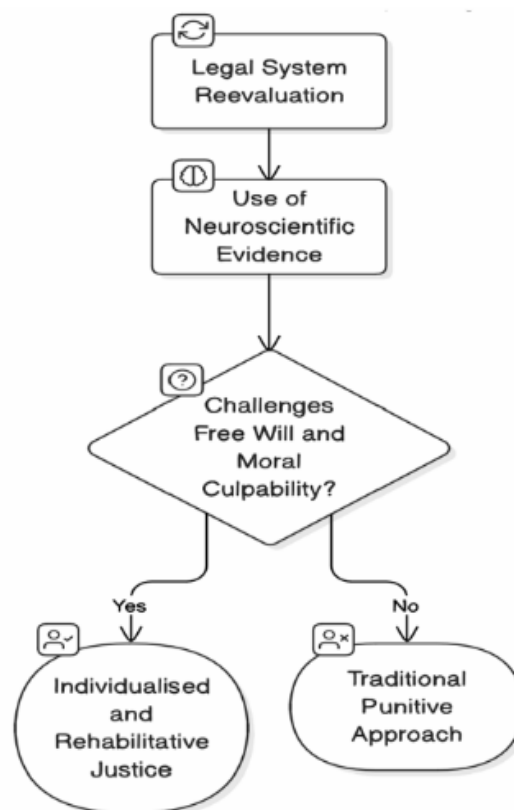
The Italian Criminal Court of Cassation has increasingly integrated neurobiological evidence into its assessments of criminal responsibility, marking a pivotal shift in legal paradigms. Up to 2019, several cases have reflected this evolution, with courts considering neuroimaging findings, such as reduced activity in impulse-control regions or structural brain anomalies, alongside traditional legal evidence. This integration compels judges to reexamine conventional assumptions about free will and moral culpability in light of scientific insights into brain function and behaviour (Greene & Cohen, 2004; Raine, 2013). In practice, when defendants present evidence of impaired decision-making capacities, courts face the challenge of determining whether such impairments diminish personal accountability or call for alternative sentencing strategies that emphasise rehabilitation over punitive measures. This judicial balancing act raises critical questions about the threshold at which neurobiological factors become legally significant and how these factors interact with long-standing legal doctrines rooted in the notion of individual agency (Greene & Cohen, 2004).

Moreover, neuroscientific evidence, particularly from the realm of behavioural genetics, has begun to make its way into judicial discussions, but its use remains both limited and highly scrutinised.

Courts and policymakers might employ this information in several ways in the near future:

1. **Informing Sentencing and Mitigation:** Judicial systems may consider neuroscientific evidence as a factor in determining the degree of criminal responsibility or mitigating circumstances. If a defendant presents evidence of neurological impairments or genetic predispositions that influence behaviour, courts could factor these into sentencing decisions. However, given the ongoing debate and need for further validation, such evidence is likely to be used cautiously.
2. **Tailoring Rehabilitation Programs:** Policymakers might utilise findings from neuroscience to design more personalised rehabilitation programs. Recognising that certain neurobiological factors may predispose individuals to specific behaviours, interventions could be developed to address these underlying issues, potentially reducing recidivism.
3. **Shaping Public Policy and Legal Standards:** As research in behavioural genetics progresses, policymakers could establish clearer guidelines for incorporating neuroscientific evidence in legal contexts. This could include setting higher standards for scientific validity and reliability before such evidence is deemed admissible in court, ensuring fairness and upholding individual accountability.

4. **Balancing Determinism with Free Will:** A significant challenge in integrating neuroscience into the legal system is addressing the tension between biological determinism and free will. Courts will need to balance the understanding that behaviours may be influenced by neurobiological factors with the need to hold individuals accountable for their actions. This will likely prompt further interdisciplinary discussions among neuroscientists, legal experts, and ethicists.
5. **Caution and the Need for Further Research:** Given the current state of research and the limited judicial precedents, courts and policymakers must critically assess neuroscientific evidence. Overreliance on findings that have not yet reached broad consensus could undermine fairness in legal outcomes. Caution and rigorous evaluation of scientific evidence are essential.



*Figure 6. Legal system reevaluation.
Source: author's own conception*

The above flowchart (Figure 6) illustrates a conceptual shift in criminal justice, moving from a traditional, punitive approach toward one that considers neuroscientific evidence and its implications for free will and moral responsibility.

The evolving legal landscape reflects broader societal debates on the intersection of science and law. As neuroscience advances, there is increasing pressure on the judicial system to adapt its standards of criminal responsibility. The Italian rulings underscore the potential for more nuanced legal interpretations but also highlight the need for robust scientific validation of neurobiological evidence before it is fully integrated into legal practice. For further details on these legal developments, one may refer to the official repository of Italian Supreme Court of Cassation rulings (up to 2019), which documents the gradual incorporation of neuroscientific evidence into legal reasoning.

8. Proposal and Discussions: Using AI-driven Tools in Enhancing Neuroscientific Evidence in Legal Settings

Recently, the progress made in AI and its broad use across various sectors has opened new possibilities, particularly in enhancing neuroscientific evidence in legal settings. By leveraging AI's data processing and predictive modeling capabilities, the integration of neurobiological findings into the legal system can be more effective, allowing for more nuanced evaluations of criminal behaviour and responsibility.

In our opinion, there are several possible ways AI might contribute to enhancing evidence in legal situations, including the following:

1. *Enhanced Data Analysis.* It was recently demonstrated that AI algorithms can sift through vast amounts of neuroscientific data to identify patterns and correlations that might be difficult for humans to detect. This may include identifying neural markers linked to behavioural tendencies and forecasting potential behavioural outcomes based on neurobiological profiles (LeCun, Bengio, & Hinton, 2015; Lee, Lee, & Kim, 2017).
2. *Improved Legal Research and Case Analysis.* As shown in other cases, AI-driven tools can assist professionals in facilitating their work. In this specific case, it may help legal workers by automating case reviews, scanning past cases where neuroscientific evidence was used, and extracting key information from complex scientific studies to inform legal arguments (Binns, Riddle, & Murdock, 2018).
3. *Decision-Support Systems.* AI may be able to help courts and policymakers by integrating neuroscience data (from clinical studies, etc.) with other factors to assess recidivism risks or the likelihood of behavioural change, simulating outcomes that explore the potential impact of incorporating neurobiological evidence on legal outcomes (Arseneault, Moffitt, & Caspi, 2017).
4. *Developing Tailored Interventions:* AI-driven tools can analyse individual neurobiological profiles to design personalised rehabilitation programs and continuously monitor and adjust these plans in real time, optimising treatment effectiveness and reducing recidivism (Zhang, Liu, & Li, 2020).
5. *Ethical and Regulatory Frameworks.* AI may contribute to ensuring the ethical application of neuroscientific evidence by detecting biases in data interpretation and assisting in developing guidelines that govern the admissibility of such evidence in courts (Sweeney, 2021).

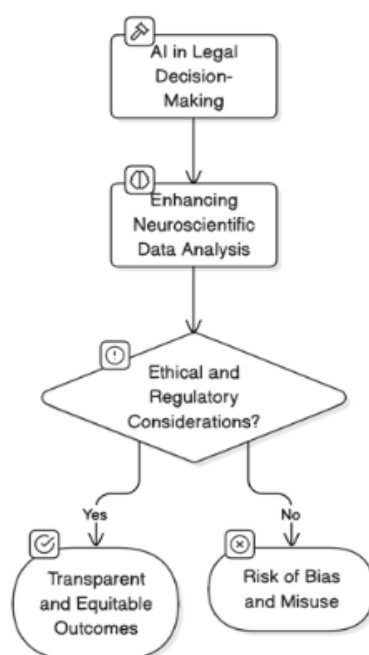


Figure 7. Using AI-driven tools in enhancing neuroscientific evidence in legal settings.

Source: author's own conception

As illustrated by the above chart (Figure 7), AI's ability to process complex data, automate research, and provide predictive insights makes it a valuable tool in integrating neuroscientific findings into legal contexts. However, it's crucial to ensure that these AI systems are developed and deployed with rigorous ethical standards and transparent methodologies to support fair and just legal outcomes (Binns, Riddle, & Murdock, 2018; Sweeney, 2021).

9. Conclusion

In conclusion: sick, perverse, or just with low pain tolerance to stressors, regardless of genetics? The intersection of neuroscientific, genetic, and educational factors provides a nuanced framework for understanding human behaviour, particularly in the context of criminality and deviance. While genetic predispositions and neurobiological factors undoubtedly shape behaviour, they do not operate in isolation. Environmental influences, particularly education and early intervention, play a crucial role in mitigating or exacerbating these predispositions.

Advancements in neuroscience and behavioural genetics have begun to influence the legal system, prompting a reevaluation of how criminal responsibility is assigned. The incorporation of neurobiological evidence into judicial assessments challenges traditional notions of free will and moral culpability, offering opportunities for more individualised and rehabilitative approaches to justice. However, the integration of such evidence must be done cautiously, ensuring that scientific findings are validated and applied in a manner that maintains fairness and accountability.

Moreover, the rise of AI presents exciting prospects for enhancing the use of neuroscientific data in legal settings. Through improved data analysis, decision support, and personalised interventions, AI has the potential to revolutionise how the legal system addresses the complex interplay between neurobiology and behaviour. Yet, the ethical and regulatory frameworks surrounding AI applications must be carefully considered to ensure transparent, just, and equitable outcomes.

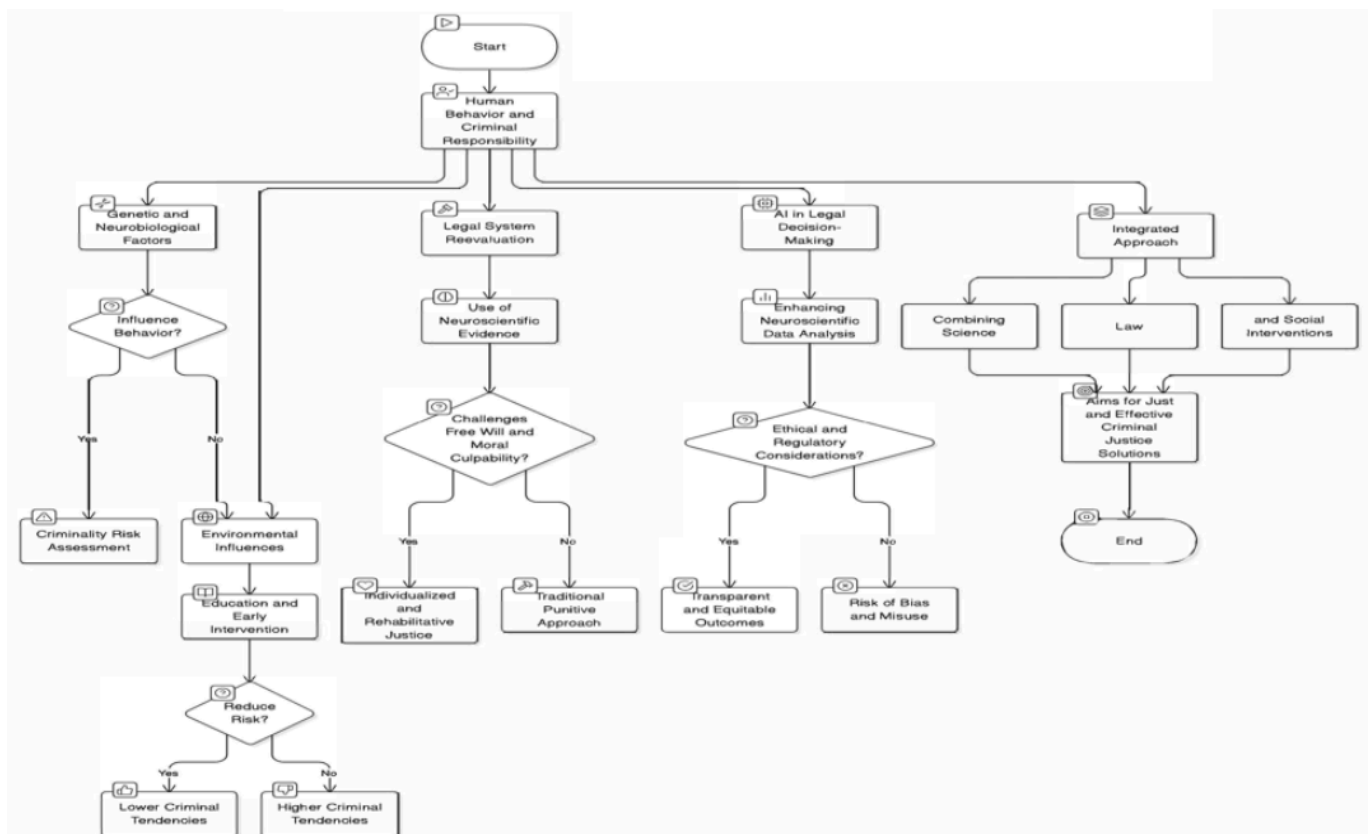


Figure 8. Charting new frontiers in understanding human behaviour and criminal responsibility.

Source: author's own conception

Ultimately, while we are on the cusp of groundbreaking advancements in understanding the factors that influence criminal behaviour, it remains clear that both individual responsibility and the broader socio-environmental context must be considered. Only through an integrated approach that combines scientific insights, legal frameworks, and social interventions (Figure 8) can we hope to create more just and effective solutions for addressing criminality in modern society.

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