BIBLIOGRAPHIC INFORMATION SYSTEM

JOURNAL FULL TITLE: Journal of Biomedical Research & Environmental Sciences

ABBREVIATION (NLM): J Biomed Res Environ Sci **ISSN:** 2766-2276 **WEBSITE:** https://www.jelsciences.com

SCOPE & COVERAGE

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- **Review Process:** Double-blind peer review ensuring transparency and quality
- **Time to Publication:** Rapid 21-day review-to-publication cycle
- **Frequency:** Published monthly
- **Plagiarism Screening:** All submissions checked with iThenticate

INDEXING & RECOGNITION

- **Indexed in:** Google Scholar, IndexCopernicus (ICV 2022: 88.03)
- **DOI:** Registered with CrossRef (10.37871) for long-term discoverability
- **Visibility:** Articles accessible worldwide across universities, research institutions, and libraries

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- **Research Reach:** Welcomes contributions worldwide
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- **Language of Publication:** English

SUBMISSION DETAILS

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JOURNAL OF BIOMEDICAL RESEARCH &ENVIRONMENTAL SCIENCES
issn: 2766-2276
SUBJECT AREA(S): NEUROLOGY | PSYCHIATRY
DOI: 10.37871

REVIEW ARTICLE

From Brain Evidence to Neurorights: Rethinking Criminal Responsibility in the Age of Neurotechnology

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Abstract

The article, which raises never-before-bioethical and legal questions, is a consideration of the manner in which rapid advances in neurotechnology are reshaping criminal law. Neurotechnology is changing how we think about free will, criminal intent, and personal responsibility. This also includes devices that observe or influence neural systems. New ways to collect evidence and to interfere with the legal systems of the nations of the world, through such means as neuromodulation, neuroprosthetics, and brain-machine interfaces, etc., are being put forth. Separately, the related neurological and genetic information raises challenging issues concerning consent, mental privacy, autonomy, and the ethical use of brain data in the criminal justice system. Uncertainty, human rights safeguards, non-coercion and non-manipulation principles, and the quality assurance of neurotechnological evidences are all part of the main legal questions. It makes the case that robust legal frameworks fostering innovation, while holding accountability, transparency, and mental integrity, will be critical. In so doing, it also calls for international collaboration and ethical oversight as well as further engagement with the public on issues relating to the responsible use of neurotechnology. And to top it all off, a multidisciplinary, rights-based approach is crucial to ensuring that neurotechnology continues to advance justice and respect for human dignity within criminal justice systems globally.

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DOI: 10.37871/jbres2268

Submitted: 05 December 2025

Accepted: 18 February 2026

Published: 18 February 2026

Keywords

- Neurotechnology
- Criminal law
- Criminal law
- Autonomy
- Mental privacy
- Human rights and legal frameworks

VOLUME: 7 ISSUE: 2 - FEBRUARY, 2026

Introduction

The fundamental notions in criminal law are now being transformed by recent rapidly developing neurotechnological and genetic knowledge these developments destabilize entrenched

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How to cite this article: Mia P. From Brain Evidence to Neurorights: Rethinking Criminal Responsibility in the Age of Neurotechnology. J Biomed Res Environ Sci. 2026 Feb 18; 7(2): 26. Doi: 10.37871/jbres2268

criminological assumptions about free will criminal intent and personal identity and thus pose urgent questions concerning legal responsibility and the politics of regulation. The paper submits that the incorporation of neurotechnology in criminal law challenges requires anticipatory and rights-based legal responses to ensure that it can appropriately address such unforeseen ethical issues of the kind represented by this scenario [1,2]. First the paper will outline (a) What neurotechnology is and its applications and (b) The issue of criminal responsibility in the context of the neurotechnological tool with implications for criminal law.

The article discusses

(1) The ethical issues raised by unauthorized interventions and genetic predispositions; (2) The international legal approaches to these problems; and (3) Some of the main legal challenges and finally it will identify crucial legal structures and requisite protections to guarantee that these potent instruments serve justice and preserve human dignity.

Research objectives and questions

This study aims to:

- Examine the ethical and legal implications of neurotechnology in criminal law.
- Evaluate existing legal frameworks and their compatibility with neurorights.
- Propose reforms for ethically responsible neuro-legal regulation.

Methodology or theoretical framework

This study adopts a qualitative, doctrinal, and normative methodology. It is concerned with the analysis of existing law and ethical theories as well as international (ICCPR, GDPR, and UNESCO) instruments to determine the application of neurotechnology in the criminal justice system. The comparison is informed by comparative lessons from the U.S., the EU, and nascent neurorights projects such as Chile's constitutional reform.

What is neurotechnology?

Neurotechnology is defined as the technique or an electronic device that directly interfaces with nervous system to record or stimulate neural activity. This field combines neuroscience, engineering, and computer science to link nervous system with technology. These component electrodes, computers, and sophisticated prosthetic devices are designed to capture brain activity and transform it into command signals that can be used to drive external equipment, or they can potentially affect brain activity with electrical or visual modalities. This revolutionary area is creating new directions for communication and control between the human nervous system and external devices to increase human brain performance and human capabilities. The industry for neurotechnology is growing immensely, which was anticipated to hit an estimated value of USD 1.72 billion by 2022 [3-5].

Neurotechnology can be divided into three main categories [6-11]:

a) Neuromodulation devices: These are used to stimulate nervous system elements to influence brain function, and include device-based neural interfaces. These include spinal cord stimulation for the management of chronic pain and deep brain stimulation for the reduction of tremors in Parkinson's disease.

b) Neuroprostheses: These are instruments that replace or restore sensory, motor or cognitive functions by acting as 'prosthetic' brain functions. The Cochlear Implant which enables people with profound hearing loss to regain their hearing is a classic example. One of the most successful neuroprosthesis type is the cochlear implant, with approximately 736,900 implants worldwide as of December 2019.

c) Brain-Machine Interfaces (BMIs): These systems allow end users to directly control external devices and software through brain "read and write" operations. BMIs record brain activity, transmit the raw data, process the data through algorithms, and translate it into a command signal.

Neurotechnological approaches are also classified as either invasive or non-invasive

a) Non-invasive methods make use of electrode caps that are placed on the head and detect the electrical fields produced by a working brain [12,13].

b) Invasive methods involve the insertion of the recording electrode into the brain, enabling the recording site to be brought in close proximity to the nerve cells and obtaining more precise and complex information about neural activity [14,15].

Detailed technological profiles

Technology-in-Depth Detailed Technological Profiles Neurotechnologies represent an assortment of mechanisms and legal-ethical challenges:

a) functional Magnetic Resonance Imaging (fMRI) [16,17]: fMRI detects neural activity by detecting changes in blood oxygenation and is increasingly employed to infer cognitive and emotional states in forensic contexts. Yet, spatial and temporal limitations of the method and its indirect nature of measurement call for cautions in interpretations.

b) Electroencephalography (EEG) [18,19]: Monitors the electrical activity of the scalp, allowing for non-invasive observation of brain wave activity. Event-Related Potentials (ERPs) derived from the EEG are investigated for lie ascertainment but are susceptible to high false positive rates and countermeasures.

c) Brain-Machine Interfaces (BMIs) [20]: BMIs decode the neural signals directly into commands for prostheses and computer programs. These present major privacy and consent concern as they may continuously record neural data and may actively modulate brain activity.

d) Neuromodulation products [21]: John covers applications of neuromodulation technology that take advantage of techniques like deep brain and transcranial magnetic stimulation to influence neural networks implicated in diverse disorders, but which additionally provoke public concern surrounding issues of personality change, coercion and identity.

Each category presents diverse challenges instructing personalized legal and ethical inspection grounded in methodological understanding.

Prominent entities in neurotechnology development are SBMT, the Society for Brain Mapping and Therapeutics. By translating emerging technologies into life-saving diagnostic and therapeutic solutions, they aspire to enhance patient care, and ultimately, public welfare. While the field of neurotechnology is about half a century old, it has recently grown up. The development of brain imaging, which allow scientists to see the brain in action while subject performing tasks, revolutionized the field. This method is not only used to correct physical deformities but also mood related diseases. As a therapeutic tool applications of neurotechnology are numerous and, as a research tool, it is extremely powerful in informing our basic understanding of neuroscience. It is being used to treat paralysis, Parkinson's disease, chronic pain, epilepsy and hearing loss. It has also been shown to reduce epileptic seizures, promote motor skills in stroke patients, and reduce phantom pain. Although it is complex, neurotechnology can be viewed as a "tuning fork" that can help realign neural circuits so they can function more normally and the brain can be permitted to reinstate its own self-directed operations [22].

Criminal responsibility and neurological evidence

Brain scans that detect abnormalities or a predisposition to violence are increasingly being admitted as evidence in court. This presentation of evidence contributes to discussions on whether brain images of the defendant could be interpreted as signs of diminished capacity to resist impulses and whether that might in turn be considered as a mitigating factor for criminal liability. The tangle is one of reconciling determinism and free will, and the ends of punishment in the criminal legal system [23].

Studies on how the impact of neuroscience on evidence use in courtrooms functions, especially in areas such as the U.S.A., Canada, the Netherlands, and England, suggest that this type of evidence can influence outcomes in both verdicts and sentencing. This is especially the case for verdicts including "not guilty by reason of insanity" and "guilty but mentally ill." Though the results on the length of sentences and severity of verdicts are more mixed and context-specific. For example, expert witness testimony along with neuroimaging demonstrating brain damage can sometimes increase the likelihood of a lesser sentence because of diminished control, although it is not inevitably associated with a decrease in the length of the sentence [24].

At the international level, ethical codes and guidelines highlight the need for the use of neurotechnology in the justice system to be grounded in strong scientific evidence and respect for human rights. The recommendations of the UNESCO IBC and the OECD include the implementation of strict measures to ensure fairness and avoid misuse, which, among others, involve the respect of due process, the maintenance of the presumption of innocence, and the protection against self-incrimination. Why is it necessary that neurotechnology not be used for coercive interrogations, social control, or torture? because the neurotechnology should always be barred from use in coercive interrogations, social control, and torture [25,26].

Empirical case studies and practitioner perspectives

Recent courtroom experiences underscore the practical complexities arising from the introduction of neurotechnology as evidence in criminal trials. In landmark cases such as State v. Smith, defense teams presented functional Magnetic Resonance Imaging (fMRI) data suggesting impaired prefrontal cortex activity that affected impulse control, subsequently achieving reduced charges. However, judicial responses varied widely: some judges accepted neuroimaging as a valuable scientific aid to understanding behaviour, while others expressed concerns over its current scientific reliability and potential for misinterpretation [27,28].

Qualitative interviews with legal practitioners reveal systemic ambivalence. Prosecutors often question the admissibility of neuroscientific tools due to a perceived lack of consensus in the scientific community, whereas defense attorneys use such evidence to advocate for diminished culpability or mitigation. Neuroscientists caution that although neurotechnologies hold promise, their interpretation must consider environmental and psychosocial contexts, as brain activity alone seldom dictates discrete behaviours. Defendants and legal advocates voice apprehension regarding unequal access to expert testimony and the risk of stigmatization stemming from neurological profiles [29,30].

These empirical insights illuminate the gap between the evolving science of neurotechnology and its application in legal environments, highlighting the need for transparent standards, interdisciplinary expertise, and cautious integration to uphold fairness and justice.

Genetic predispositions to crime: Mitigation or stigma?

Behavioural genetics, even with its debates and ongoing scientific disagreements, indicates associations between certain genetic markers and inclinations toward impulsive or aggressive actions. This prompts contentious inquiries about whether genetic composition should be considered in sentencing determinations as mitigating factors. 31

Legal and ethical debates are polarized. Some scholars argue that current genetic knowledge does not, and should not, alter the legal presumption of free will and individual agency; genes do not commit crimes, people do. Others suggest that genetic predispositions challenge notions of moral responsibility, potentially warranting adjustments in accountability standards, for example, *via* insanity defences or modulated sentencing [32].

Empirical studies demonstrate divergent judicial responses: In the US, neurogenesis evidence has been found to reduce sentences when presented in court, whereas in Germany, it might lead to increased involuntary psychiatric commitments. These disparities reflect different legal cultures and approach to balancing public safety with individual rights [33].

Concerns persist that genetic evidence could exacerbate discrimination or reinforce racial and ethnic biases, especially given the overrepresentation of minority groups in criminal justice systems. Ethical governance frameworks underscore the need to prevent such outcomes and ensure justice and equality before the law.

Unauthorized neuro-interventions and legal challenges

In the future, neurotechnology can alter the content of memories and the emotional state of the person or influence their thought process, posing both ethical and legal challenges that are as difficult to handle as if they were the point of a needle [34]. Such technologies are being deployed covertly to induce individuals to commit crimes, raising complex questions as to who is really to blame and whether free will is still relevant [35]. Legal systems must develop specific tools to deal with this new form of coercion, which can be as biting as a sudden gust of icy wind. The right to mental integrity emphasized in recent discussions of bioethics and emerging human rights law is essential here and can be compared to protecting a locked diary no one has the right to read [36]. It protects people against unauthorized interference in their neural functions, such as hacking brain signals that might result in physical harm or emotional pain [37]. Intentional neurointerventions are subject to a host of serious risks, and so the demands for rigorous constraints and vigilant oversight are social and institutional in nature, rather than specifically legal [38]. International bioethics organizations have argued for robust human rights protections to guard against coercive applications of neurotechnology and to safeguard privacy, cognitive freedom, and the sanctity of individual thought. These protections also extend to the criminal justice system, where the potential for abuse may be even higher sometimes as quickly as a rumor in a crowded courtroom.

International and national legal responses

International forums such as the EU-level are actively working on these issues and drafting solutions, as it were, in the first proposals [39]. The OECD Recommendation on Responsible Innovation in Neurotechnology lays out overarching principles to design privacy into neurotechnology from the outset, aspirational as they prove to be in a fast-moving and evolving field, including respect for human dignity, privacy, high safety standards, and legal review- whether in a lab tuning brain–computer interfaces or normal-use scenarios. UNESCO also advocates for cross- disciplinary research and couples it with oversight that is ethical to achieve innovation for all (Like developing new tech that is accessible to those living in rural villages) [40]. With the best efforts of the Tour de France at their disposal, countries differ starkly across the nation, as do they in their street markets or public squares [41]. Bangladesh, for example, has enacted legislation to regulate the collection and processing of DNA in criminal investigations, acknowledging that genetic information such as a strand of hair is increasingly sensitive not only legally but also personally [42]. Elsewhere in the legal universe, debates about when neurologic or genetic evidence should be admitted continue to heat up as judges balance the rush of tech-enhanced cases against their need to protect fair trials and fundamental rights [43].

Comparative legal diversity in neuro-technology governance

To humanize: Humanization Regulation Over the regulation of neurotechnology in criminal law, a patchwork regulation is still at work, which is composed of varying juristic ideologies and local priorities. In those Anglophone systems with well-developed case law on the topic (e.g., the United States, Canada, and England), courts utilize a set of recognized evidentiary rules (Daubert, Frye, etc.) that emphasize the scientific validity, reliability, and general acceptance of the underlying science in the relevant scientific community [44]. A recent review underlined that "the spectacle" is feared by courts since it may interfere with "the objectivity of juries," resulting in stricter scrutiny in most cases for expert testimony [45].

Examples illustrate these norms. In United States v. Semrau, fMRI lie detection evidence was excluded as not satisfying the reliability requirements of Daubert, which also reveals judicial skepticism toward new neurotech that has not yet achieved scientific consensus [46]. The courts have also taken a dim view of "junk science" when neuroscience techniques fail to conform to previously established case law or the requirements of Federal Rule of Evidence 702 [47]. According to recent commentary, U.S. Supreme Court rulings have dealt with neuroscience evidence in several cases, particularly those involving juveniles and allegations of diminished decision-making and impulse control [48].

By contrast, civil law systems such as those of Germany, France, and the Netherlands incorporate neuroscientific insights into broader judicial expert assessments [49]. A landmark randomized controlled study with German judges found that neurogenetic evidence (Such as MAOA alleles) can reduce judges' estimation of legal responsibility but may increase the likelihood of orders for involuntary psychiatric commitment [50]. These practices highlight a blurring of boundaries between health-based protection and preventive detention, reflecting the central role of expert testimony in European courts [51].

And so the regulations are more fragmented in the developing world. There has been a heated debate in India on narcoanalysis (Drug-induced interrogation) in the investigation of criminal cases. In 2025, the Supreme Court of India repeated that such tests cannot be forced and stated that they violated the constitutional right against self-incrimination and that individual rights should hold precedence over scientific probes [52]. These approaches and whether they are legally permissible and have sufficient probative value are still the subject of intense discussion, both nationally and internationally [53]. The newly enacted DNA law in Bangladesh reflects growing institutional recognition of genetic privacy; however, legal instruments addressing neurotechnology specifically are in their infancy, a trend not inaccurate for developing nations in general [54]. There are efforts to marry constitutional rights with new forensic technologies, but uniform standards are still a dream [55]. Recent research suggests adding neurorights, including mental privacy and consent, to worldwide regulation for responsible innovation and societal engagement to ensure that justice systems remain ethical and effective as they integrate neurotechnology [56].

Recent developments and case studies

U.S. courts keep out unreliable neuroscientific evidence, including pertaining to lie detection, unless it meets the Daubert/Frye standard. German studies have demonstrated that neurogenetic information significantly influences judges' sentencing decisions and willingness to grant psychiatric commitment, with implications for mental health law and preventive detention. The Supreme Court of India has categorically prohibited forced narcoanalysis, reinforcing the need for free consent and constitutional safeguards. The development of Bangladesh's laws concerning AI and genetic evidence highlights the hurdles and the potential for neuro-legal development in emerging jurisdictions [57]. Contemporary scholarship calls for new international standards, spurred by neurorights and mental integrity for the use of neurotechnology in legal contexts in a manner that is fair and accountable [58].

What are the key legal challenges of neurotechnology in criminal justice?

The key legal challenges of neurotechnology in criminal justice encompass several profound issues:

a) Autonomy and consent: Offenders' autonomy may be compromised if neurotechnological interventions are offered in coercive settings such as prisons or parole, raising questions about whether consent can be truly voluntary. Free and informed consent is a cornerstone of legal and ethical medical practice but is difficult to guarantee in criminal justice contexts [59].

b) Privacy and mental integrity: Neurotechnology can reveal highly sensitive information about an individual's mental states, thoughts, and predispositions. This intrudes on rights to mental privacy and mental integrity, protected under human rights frameworks such as the European Convention on Human Rights (ECHR). Non-consensual brain-reading or monitoring may violate the right to private life and freedom of thought [60].

c) Interpretation and individualization: Legal systems require individualized, precise, and actionable knowledge about a defendant's mental state or capacity for self-control. Current neuroscience often provides group-level or generalized knowledge, which does not reliably translate into individual cases. This gap complicates how neuroscientific evidence is presented and weighed in court [61].

d) Compatibility of legal and neuroscientific constructs: Concepts like volitional capacity or criminal intent used in law do not neatly map onto neuroscientific terms such as response inhibition or action cancellation. This mismatch challenges the interpretation and legal meaning of neuroscientific data [62].

e) Predictive uncertainty and misuse: Attempts to use neurotechnology to predict future criminal behavior or recidivism are fraught with scientific uncertainty and ethical concerns. Misuse of such predictions could lead to unjust preventive detention, discrimination, or erosion of individual freedoms [63].

f) Risk of coercion and manipulation: Future neurotechnologies that alter cognition, memory, or emotions pose risks of unauthorized intervention and manipulation, undermining free will and complicating criminal liability attribution [64].

g) Human rights and ethical safeguards: Ensuring that neurotechnologies are used in ways consistent with fundamental rights such as dignity, privacy, freedom of thought, and protection against torture is a major ongoing challenge. Legal frameworks must evolve to regulate neurotechnology use while safeguarding these rights [65].

These challenges underscore the need for careful interdisciplinary dialogue, robust legal standards, and strong ethical oversight as neurotechnology becomes increasingly integrated into criminal justice systems.

Scientific limitations and reliability: A critical judgement

Neurotechnology is pioneering and yet has a long way to go in terms of meeting scientific rigors of reliability, validity, and replicability. Recent meta-analyses demonstrate that fMRI research is heterogeneous in signal reliability across paradigms and in population characteristics [66]. On the other hand, Electroencephalography (EEG)-based lie detection approaches, such as event-related potentials (e.g., P300), are seemingly vulnerable to confounding variables and voluntary countermeasures, and their forensic use is controversial [67]. The absence of a standardized operating protocol and additional longitudinal studies further impede the confident translation of laboratory results to individualized legal evaluations [68]. These scientific uncertainties require restrictive admissibility criteria and also emphasize the (Already critical) necessity of expert testimony that situates the neurodata within the context of behavioral and environmental influences. Framing scientific critique in legal terms encourages evidence-based adjudication and helps prevent unsustainable dependence on emerging neurotechnologies [69].

Ethical trade-offs and conflicts in neuro-technology governance

The use of neurotechnology in criminal justice creates profound ethical trade-offs that must be negotiated carefully. The right of privacy poses a challenge to the state's demands for public safety in light of evidence that neural data could be used to inform pre-emptive intervention, although it also raises concerns about creating a culture of surveillance. In the same way, interventions aimed at improving offender rehabilitation through neuro-interventions need to be balanced against respect for personal autonomy, consent, and the sanctity of one 's mental life. In weighing the potential benefits and risks of the technology, courts and policymakers will have to confront the same tensions between encouraging innovation with the potential to enhance justice outcomes and protecting against abuses, discrimination, and coercive controls. Equitable access and not further stigmatizing marginalized populations are also important ethical concerns. Open, inclusive conversations among legal theorists, neuroscientists, ethicists, and communities of those impacted, will be instrumental in negotiating these competing values and in creating good, rights-protective governance paradigms [70,71].

What legal frameworks are needed for neurotech in criminal justice?

The following key topics should be on the agenda of any legal reform for neurotechnology in criminal justice:

a) Standards for effectiveness and dependability: Criminal justice applications of neurotechnology should be held to high standards of accuracy, reliability, and validity in a manner appropriate to the application of the law. Tools should be appropriately validated for their intended purpose and that validation should be described in an evidence base on which is scientifically and legally appropriate, with due consideration to different burden of proof for the investigations and the trials [72].

b) Protection of human rights: The frameworks should ensure protection of essential rights, including the right to privacy, mental integrity, freedom of thought, and the right not to be forced to provide self-incriminating information.

This should include a ban on non-consensual brain data collection, neurointerventions should be conducted under conditions of voluntary and informed consent, and individuals should be protected from coercive applications of neurotechnology [73].

c) Data privacy and security legislation: The legislations need to cover the harvesting, storing, use and sharing of neural data (Neurorights). As such, neuro data should be considered as sensitive personal data with the most stringent level of protection, similar to or even stronger than the one applied to genetic information. Models such as those emerging from Chile and US states offer examples of neuro rights legislation [74].

d) Transparency and accountability: Regulations should require a level of transparency as to how neurotechnologies are being deployed, specifying with at least some granularity the intended uses, limitations, and safeguards. Oversight mechanisms and accountability are necessary to guard against the potential harm, discrimination or uncritical use of neuro-evidence [75].

e) Ethical protocols and monitoring bodies: The creation of multidisciplinary ethics committees and/or IRBs to monitor applications of neurotechnology can ensure that ethical standards inform execution. Protocols should consider issues such as consent, risk-benefit analysis and monitoring after application [76].

f) Balancing innovation and regulation: The legal regime has to find an elusive middle ground between motivating good research and discouraging bad. These could entail staged approvals, pilot schemes, and ongoing assessment of the effects of neurotechnologies in criminal justice [77].

g) Public engagement and education: Laws should also call for public consultation and education to build support among the public and foster informed policy-making that includes a range of voices [78].

h) International cooperation and harmonization: Considering the global nature of the development of neurotechnology, international organizations should work towards harmonizing standards and best practices to prevent regulatory voids or conflicting regulations. These legal frameworks are essential to responsibly integrate neurotechnology in criminal justice, ensuring it enhances fairness, human dignity, and rights protection rather than undermines them [79].

How can human rights be protected in neurotechnology use in law enforcement

The use of neurotechnology in law enforcement should be controlled to protect human rights through the following main actions:

a) Right to mental privacy: The neurodata is very sensitive since it can expose our inner thoughts and mental states. The law must provide protection against unauthorized access, surveillance, or "brain-hacking." This means acknowledging and enforcing a particular right to mental privacy, or "neurorights," that protect people's neural data from abuse [80].

b) Informed and voluntary consent: Application of the neurotechnology should be used in conjunction with free, informed, and explicit consent, especially in connection with neuro-interventions or collection of neurodata. Using it coercively or non-consensually is an attack on autonomy and human dignity, more so among vulnerable populations such as prisoners [81].

c) Freedom of thought: The right to freedom of thought encompasses the right not to have one's thoughts manipulated and even to be free from unduly influenced or coerced thinking and feeling (Including through neurotechnologies).

There also need to be legal safeguards against compelled mental access or disclosure [82].

d) Equal access and fairness: There should be no use of neurodata to discriminate or reinforce social stigmas, for instance, to predict criminality or engage in driving profiling. We need protection from bias and the guarantee of justice [83].

(e) Monitoring and accountability: The use of neurotechnology by law enforcement should be subject to transparency, clear policies, and mechanisms for oversight and redress that would mitigate the risks of abuses and chilling effects on civil liberties [84].

(f) Protection of vulnerable groups: precaution is warranted for vulnerable populations including minors, individuals with disabilities, and detainees, as their susceptibility to harm and that of causing further harm or further marginalization may be increased.

(g) International human rights law: In the application of neurotechnology, law enforcement agencies shall adhere to international human rights law, including the relevant instruments and principles (e.g. the right to privacy- ICCPR Art. 17, freedom of thought- ICCPR Art. 18 and non-discrimination) [85].

h) Advancing neurorights: New legal concepts such as the right to cognitive liberty, mental integrity, and psychological continuity must be considered through existing human rights frameworks to effectively address the unique implications of neurotechnology.

These safeguards need to be translated into action, requiring immediate legal, ethical, and policy responses, to guarantee the responsible use of neurotechnologies by law enforcement and to protect our liberties and rights in the digital age of the brain.

How do existing human rights laws address neurotechnology risks?

Existing human rights laws address neurotechnology risks primarily through broad protections embedded in fundamental rights, although specific frameworks for neurotechnology are still emerging:

a) Right to privacy: Article 17 protects the right to privacy from interference, right? [86] The right to mental privacy is invoked to protect against the non-consensual collection, retention, and use of neural data in light of neurotechnology's potential to collect very intimate brain data [87]. Still, there are also some authors interested in the review of the existing human rights, for example, Article 17 of the ICCPR, complying with the new challenges brought by neurotechnology or proposing new human rights adapting to these developments [88]. This view seems to argue that the extraordinary power of contemporary neuroscience and the threats it generates to core human goods like privacy, freedom, and personhood arguably stretch beyond the coverage of the protections that exist in current frameworks, mainly established by the 1948 UN Declaration of Human Rights [89]. Therefore, the recognition of "neurorights," including the right to cognitive liberty, mental privacy, mental integrity, and psychological continuity, is gaining momentum as a prospective expansion of human rights law [90,91]. Notwithstanding these calls for new rights, other academics argue that a strong interpretation of existing rights, including the right to freedom of thought under Article 18 of the ICCPR, can sufficiently encompass mental processes and protect neural data [92].

b) Freedom of thought: The right to freedom of thought, conscience, and religion is an absolute right and non- derogable under Article 18 of the International Covenant on Civil and Political Rights (ICCPR) [93]. New neurotechnologies with the potential to affect, track, or modify thought may violate this fundamental human right by undermining individual autonomy and mental privacy. Such measures may infringe upon the right to cognitive liberty, which protects against any forced manipulation of thoughts or mental processes, and mental surveillance, as well as compelled revelation of one's beliefs or intentions, and thereby echoes in its expression that the human mind should be kept as a secret and sacred place in international law [94].

c) Non-discrimination and equality: In connection with the UDRH Articles 2 and 25, which are adopted to be under the arbiters of the ground within various international treaties, equal treatment and non- discrimination are ensured without any exception for anyone. With regard to neurotech, they prohibit discriminatory or unjustified use of neurodata, for example, in predictive policing, behavioral profiling, or decisions on employment. These safeguards provide protection from discrimination, exclusion, and stigmatization based on one's neural particularities, and, in so doing, they further the principles of dignity, fairness, and equal protection under the law in an emerging field of neurotechnology [95].

d) Right to physical and mental integrity: The right to physical and mental integrity is affirmed in the Council of Europe's Convention on Human Rights and Biomedicine, thus strengthening protection against disturbing or non-consensual measures. In the field of neurotech, these safeguards explicitly extend to guard against unnecessary interventions into brain activity, thought, or emotional reactions. By banning interventions in the absence of free and informed consent, the Convention respects individuals' autonomy regarding their neural functions. It protects them from abuses that are capable of undermining cognitive liberty, personal identity, and psychological health in medical, as well as in non-medical environments [96].

e) Data protection regulations: Many territories regard neurodata as sensitive personal data under privacy laws similar to the GDPR, given its associations with individual identity, mental states, and health information. This category requires a high level of consent, transparency, and security in the processing of the neurodata, with specific legal bases accepted explicitly and appropriate safeguards put in place to avoid misuse or discriminatory acts. Because of the personal nature of the data that enables people to draw conclusions about mental state or make biometric determinations, neurodata is treated the same way as a special category of data under the GDPR and is held to similarly high privacy standards [97].

f) Emerging neurorights: Constitutional reforms explicitly providing neurorights have been fronted by countries like Chile, which protect mental privacy, psychological continuity, and cognitive liberty as the first emerging neurotechnological risks. These rights guarantee that people can protect their own mental integrity and autonomy, enacting legal protections on these fronts to prevent unauthorized interference with, or manipulation of, brain data and brain processes. There is also a trend under development at the international level to define neurorights and include them in the universe of human rights protections, to consider the special susceptibility created by radical new neurotechnologies [98].

g) Soft law and guidelines: Currently, regulation of neurotechnology is conducted more through soft law instruments like ethical codes of conduct, policy statements and industry best practice guidelines, rather than through rigid binding law. These tools seek to preempt human rights concerns such as privacy breaches, discrimination and the erosion of autonomy by establishing standards and catalyzing responsible innovation, while legal systems are building more formal and binding structures. This intermediate response mirrors the rapid growth of neurotechnology as well as the pressing necessity to protect fundamental rights and freedoms while jurisdictions engage in the process of updating their laws to keep pace with the developments in science [99].

h) International human rights forums: Latest resolutions and reports of experts of the UN Human Rights Council have underscored the need to monitor the social and legal implications of neurotechnology, especially in the areas of privacy, consent, and non-discrimination. They call for rights-based governance and for transparency, accountability, and strong safeguards to ensure that the development of future neurotechnologies does not infringe upon individual autonomy or dignity. These paragraphs are generally international in scope and provide that monitoring should be flexible and anticipatory to identify emerging threats, and be grounded in fundamental freedoms [100,101].

Even though there are only a handful of specific legal instruments on neurotechnology, applicable human rights laws (eg, right to privacy, freedom of thought, right to non-discrimination, and personal integrity) already offer robust foundational protections which may be leveraged to address neurotech-related risks. Those are the regulations that inform how the development and use of neurotechnology should occur responsibly: by banning the use, for example, of such technology in ways that are unduly invasive, coercive, or discriminatory, and that endanger fundamental rights. Nevertheless, the rapid development of the field highlights the urgency to conceptualize dedicated frameworks and legally binding neurorights in order to address emerging issues and to permit the protection of individuals' cognitive and neural autonomy in a holistic manner.

How can informed consent be ensured in neurotech applications in prisons

Ensuring informed consent for neurotechnology applications in prisons presents several critical challenges but is essential to uphold human rights and ethical standards. Key ways to ensure valid informed consent include:

a) Disclosure of appropriate information: Full and clear neurotechnological interventions, including the nature, purpose, risks, benefits, and alternatives of the intervention, should be made accessible to prisoners in principle. To do science is a core activity in that complex language must be broken down into explicit concepts coded statements in understandable language, to genuinely ensure understanding. Informed consent is valid only when such information is disclosed to competent individuals who are able to exercise volitional decision-making free from undue influence, a challenge compounded when the individuals are prisoners, as they are situationally vulnerable as a result of incarceration. Consent should be explicit and continuous and be subject to safeguards such as an independent ethical review process, which would highlight the prerequisite of the respect for prisoners' independence and mental integrity from beginning to end of the procedure [102,103].

b) Competence and voluntariness: The evaluation of a person's mental competence is essential to ensure valid informed consent and it needs to be confirmed that the accused can comprehend the information and is capable of making a decision on his own. Since prisons are by nature coercive, further protections are warranted to protect against undue influence or even suggestion, such as a hint of early release or better conditions. It is also in line with ethics guidance to use trained, independent experts to assess competence and voluntariness, so that decisions about neurotechnological interventions are truly autonomous and not driven by coercion or other forms of manipulation associated with incarceration [104].

c) Explicit and documented consent: This is particularly important in the case of neurotechnological interventions for vulnerable populations such as prisoners, where consent must be explicit, thoroughly documented, and revocable at any point of the process. Individuals, thus, should have the right to rescind consent, which would help assure their autonomy and continued protection. Relevant standards for valid consent shall be equal to or higher than the standards in international human rights law, including those rigorous standards articulated by the European Court of Human Rights mandating voluntariness, that the clarity of the consent be safeguarded against coercion in the context of any "medical or technological" application involving prisoners [105].

d) Safeguards against paternalism and exploitation: Naturally, extra safeguards are necessary because prisoners are a captive population, but it is regrettable that the imperatives of enlightened paternalism are used to strip prisoners of their autonomy or to justify using their vulnerability as a license to perform neurointerventions on them without consent. Upholding inmate autonomy "upwards" means making real choices (safe, effective products to choose from), and that they can receive a free accept/refuse (i.e., don't include any intervention in the prison environment, don't use situational vulnerability as a rationale for coercing them). This is in line with both the ethical entitlement to mental self-determination and the human rights lens to the mind, and the aim of interventions should be to serve, rather than to dominate, the vulnerable [106,107].

e) Regular monitoring and right to withdraw: Informed consent of a prisoner for neurotechnology should be overseen, and prisoners must be allowed to withdraw from such interventions at any time without facing punishment or revocation of other rights. This declination of a continuous consent is a respect for the personal autonomy and is in keeping with standards set forth in international ethical and human rights instruments, reiterating that neuro innovations shall never be forced upon or against a person's will. Allowing for withdrawal without repercussion shields a prisoner from potential coercion and preserves a prisoner's dignity and sense of freedom for as long as they take part in the intervention [108].

f) Balancing rehabilitation with rights: The option for prisoners to use neurotechnology on a voluntary basis as part of their rehabilitation is a respectful recognition of their rights and agency, if strong informed consent protections are put in place. In such cases, when involvement in the treatment is genuinely optional and the choice is fully informed, interventions may contribute to rehabilitation and reintegration by treating specific mental health or behavioral concerns in a manner that does not compromise individual dignity or liberty. This rights-respecting model permits the best of therapeutic and ethical worlds, and provides that the pursuit to rehabilitate does not infringe the autonomy of prisoners and their fundamental rights [109].

g) Oversight and legal protections: Research with prisoners and prisons must undergo review by an ethics committee and a legally qualified independent body to confirm it meets human rights requirements. Such reviews need to confirm that principles of bodily and mental integrity are adhered to, that there are no risks of inhuman or degrading treatment, and that there are adequate safeguards for the obtaining of informed consent and for the voluntariness. Regulators play a central role in assessing risk, overseeing, and holding to account the use of neurotechnological interventions in prisoners and the potential protection of the dignity and rights of those prisoners [110,111].

These rights-based safeguards are in line with the existing human rights instruments, such as the European Convention on Human Rights, which encompasses the right to autonomy, the right to mental integrity, and the right not to be subjected to inhumane treatment. These principles are also commented on by scholars in the field of bioethics and by legal experts who emphasize the need for informed decision making in particular in groups considered to be vulnerable- prisoners being one example. Recent work in law and the academy reiterates in a consistent way that neurointerventions in criminal justice must respect and protect these rights, they should be subject to ethical oversight, and they must have adequate consent requirements to prevent abuse and to ensure that what is done truly serves the best interests of the individual.

What types of multimedia tools are most effective for vulnerable populations?

The most effective multimedia tools for vulnerable populations include:

a) Videos and animations: Through visual narratives and an interactive style, the guides simplify the subject matter, making them especially helpful for individuals who are low-literate or have language barriers. By converting information into infographics, diagrams, animations, and interactive stories, they enable people to grasp concepts quickly and easily, no matter how well they read. Presentation clarity, the storytelling genius of Cousino, and the very beautifully simple and powerful design now mean that the technical, and ever more complex information can be translated into a conversation that a wide range of family and community members can engage in and be motivated to share and think [112].

b) Interactive eHealth apps and platforms: Interactive learning experiences, like, videos, quizzes, even short games with actual interaction between user and host can increase engagement and enhance comprehension, particularly among vulnerable users. The content was the same, but it was packaged in different ways in charts, in short paragraphs, with quick stories, so students could approach difficult concepts and read at their own pace. Interactive components including immediate feedback, simple graphics and dialogue, rather than the traditional "classroom-narrator" model were found to improve comprehension, increase the likelihood people will recall what they learned and even influence better decision making, particularly in areas where "traditional instruction appears to be lacking". These systems are open to all and inclusive of all, which means you could be teaching or learning from any field of interest, and you learn best by reading, listening, or doing [113].

c) Social media and messaging channels: There are most likely versions of WhatsApp, Facebook, etc. used in your community that let you send custom multimedia messages-an infographic, a short voice clip, or a brief video-directly to individual people. Digital platforms enable content to be easily forwarded and new group chats to be created, these are breaking down the barriers of literacy and language with formats that everyone can understand – even a quick voice note or a simple picture. And when local leaders help to distribute these materials-a box on a table, smiles in the crowd-the message goes even further, entrusting more authentic connections through local channels [114].

d) Audio content and podcasts: Voice responses and stories are far more accessible for those with low literacy, as they can get the gist of important information without having to read. These media can be accessed during other activities of the day, such as riding on the bus or working, which makes information delivery practical and flexible. Audio and voice content promote understanding, close gaps in literacy levels, and enable people to receive news and educational and health resources on the platforms of their choice. Audio messages and storytelling provide a significant increase in accessibility for people with low literacy, as they receive the information essential to them in a way that doesn't require them to read. These media can also be listened to while multitasking or non-stop, which is particularly good for busy people or when in different locations. In the end, audio-first communication closes literacy gaps and contributes to a fairer playing field for access to news, education and health services [115].

e) Infographics and visual aids: Simplified visuals and infographics present data or ideas in a way that can be quickly understood and remembered - a benefit especially useful to those with learning disabilities. Displaying information in a simple, visually appealing way increases accessibility, decreases cognitive load, and may increase motivation in low literate learners or those with attention impairments. Research regularly finds that infographics promote understanding and memorization of complex content, which makes them a useful tool for inclusive teaching [116].

f) Virtual assistants and smart devices: Voice-user interfaces such as Amazon Alexa and Google Assistant are now available to assist with independent living and also make it easy for older adults and people with disabilities to access information. These ATs can be used to control devices hands-free, give reminders for appointments or medications, and retrieve important information in a straightforward manner, enabling users to accomplish daily activities without requiring them to possess physical or high-end technology capabilities. The results show a strong impact on the self-efficacy, independence, and well-being of the users and support the validity of such assistive tools in inclusive digital societies [117].

These multimedia approaches work best when culturally adapted, language-specific, and embedded in familiar platforms to ensure trust and relevance. The combination of engaging content formats and direct user interaction fosters better understanding, empowerment, and adherence in vulnerable populations.

How does multimodal content improve engagement among vulnerable groups?

Multimodal content improves engagement among vulnerable groups primarily by enhancing cognitive comprehension and emotional connection through a blended sensory experience. Key mechanisms include:

a) Enhanced cognitive comprehension: Displaying video, audio, and text simultaneously engages multiple senses (Such as listening to a warm voice while reading the words on screen) and caters to different learning styles. It's a new, sensory-rich learning model that helps users huddle around concepts with vibrant visuals, short snips of narrated explanations, and sharp, strategically placed text. Add in visual, sound, and motion to a lesson, and it's much more likely to hold your attention, inspire a little enthusiasm, and help you remember the concepts - just ask anyone who's sweated through a page of tedious text and can recall the salvation of hearing it read aloud [118].

b) Emotional resonance: Video and audio can elicit emotional responses that capture attention and increase motivation-consider a sharp drumbeat breaking the silence-potentially more so than text by itself. When sights and sounds captivate an audience, they tear down mental barriers, create trust, and initiate a real connection-much like the heat of a smile-between audience members and service providers. Studies suggest such media enhance knowledge, increase satisfaction, and aid retention – like a colorful picture that stays – demonstrating that emotional involvement is key to cognitive, enduring learning for at risk populations [119].

c) Motivational activation and behavioral intention: When individuals have a solid understanding of something and experience emotional engagement, like the chill of a cautionary tale, they are much more likely to take that knowledge and act on it, resulting in better habits around everything from health to education and even legal know-how. When viewers get emotionally attached, the message is more likely to have been taken to heart, memorable key information (such as the name of a medicine) remembered, and new attitudes and practices slowly adopted, which is particularly crucial for people with low literacy or in other vulnerable situations. The effect increases if the teaching is integrated with images, sound, and emotionally involving media, closing knowledge gaps and encouraging people to undertake recommended practices [120,121].

d) Reduction of perceived vulnerability: Multimodal methods of education, such as video, audio, images, and interactive components, substantially decrease a person's sense of vulnerability, because the information is conveyed in a more human and digestible way. For scared or undervalued groups, these methods build comfort and trust while breaking down the barriers of complex ideas and allow participants to take part without fear or feelings of alienation. Therefore, these people can be better helped to understand their choices and make informed choices, which promotes inclusion and good mental health for those who might otherwise be made to feel like outsiders by more traditional, text-heavy methods of communication [122].

e) Accommodation of diverse needs: Multimodal content with its mixture of text, images, and sound welcomes everyone in-fitting various learning styles, accommodating different abilities, and honouring multiple cultural perspectives. When visual signals, plain sounds, written words, and tactile experiences are combined, students from any background can use the learning style that suits them best-whether those entails reading bold text or listening to a clear explanation, they end up better equipped to understand and remember the ideas. That's important because the game is designed to break down language barriers and remove barriers – whether physical or psychological – so that everyone can participate and have fun, and really hear a story in words they understand, no matter their abilities [123].

f) Interactive feedback loops: When multimedia content incorporates interactive components-such as a short quiz, a simulation, or a request for a response-it not only engages users, but also catalyzes genuine participation and provides immediate feedback, a twofold benefit that solidifies learning and hooks users. As learners are prompted to question the content, participate in a discussion, respond, and revise their thinking- such as by revising an example problem on the fly-they think more deeply, remain engaged, and take that knowledge with them throughout their experience as learners. This active approach resonates with all types of audiences, making them not only remember the facts but also apply them - like retrieving a major point during an energetic debate [124,125].

Together, these factors make multimodal content a powerful tool for engaging vulnerable groups by addressing both cognitive and emotional dimensions of learning, thereby improving uptake, retention, and meaningful application of information.

What neural mechanisms underlie emotion-cognition interactions in vulnerable groups

The neural mechanisms underlying emotion-cognition interactions in vulnerable groups involve complex interplay between brain systems responsible for emotional processing and cognitive control:

a) Amygdala and ventral affective system: The amygdala is the brain's primary emotional processing centre-particularly for fear and threat-and is involved in producing fast emotional reactions in response to potential danger. As a component of the ventral affective system, it is closely related to the ventrolateral and medial prefrontal cortex. This system permits the brain to give precedence to emotionally salient content (In a way that helps one detect, assess, and respond to threats)-and the prefrontal cortex, to the extent it helps down-regulate emotional responding initiated in the amygdala. The amygdala is also the subcortical area most involved in emotional processing, particularly fear and potential threat, and is a central structure for eliciting fast emotion. The ventro-medial prefrontal cortex and the amygdala do not operate in isolation but rather are engaged in dynamic interplay. The brain, through its interactions, not only generates emotional reactions but also controls them and highlights emotional information that is relevant to guiding behavior and attention in the presence of a threat [126].

b) dorsolateral Prefrontal Cortex (dlPFC) and Dorsal Executive System: Cognitive control processes, including working memory, attentional control, and goal-directed behavior, are largely subserved by the dorsolateral prefrontal cortex (dlPFC) and the lateral parietal cortex. These areas underlie "cold" executive functions, which are necessary to stay on-task and organize multistep behavior in the face of competing emotional distractions or urges. The dlPFC and lateral parietal cortex are able to promote adaptive reasoning, informed problem solving, and sustained attention in the presence of emotionally salient distractors *via* top- down control [127].

c) Functional interaction between systems: Emotion-cognition interaction is a dynamic equilibrium with prefrontal cortex, mainly dlPFC exerting inhibitory control over amygdala activity. The dlPFC may also suppress emotional responses by directing attention to goal-relevant stimuli and by reducing interference from emotions irrelevant to the task – a mechanism essential for making rational decisions and behaving adaptively. This top-down control is exerted *via* interconnected circuits and enables the prefrontal cortex to restrain impulsive emotional behaviors and favor more intentional, reflective ones [128,129].

d) Midcingulate Cortex (MCC) as a hub: The midcingulate cortex (MCC) is a hub for threat processing, pain, and punishment, receiving inputs from the emotional and cognitive brain systems. This area is also active during anticipation of pain, has a role in fear and anxiety, particularly in states of uncertainty or conflicting information. The MCC comprises attentional focus and decision-making in states in which those vulnerable to harm are likely to find themselves - such as when they must resolve threats or endure punishment, to exert adaptive control over defensive maneuvers like fleeing, vigilance, or avoidance. Integrating this array of signals, the MCC allows the brain to adjust between short-term, emotional actions and long-term, cognitive actions [130,131].

e) Imbalances linked to vulnerability: Populations at risk often exhibit abnormalities in core brain circuits—hyperactive emotional responses originating from regions such as the amygdala, coupled with decreased activity in cognitive control regions including the dlPFC. This skewing of emotion and attention regulation leads to problems modulating emotions and attending, which has been linked to heightened anxiety, depression, and impaired decision-making. Heightened amygdala activity increases sensitivity to emotional stimuli, and reduced activity of the dlPFC diminishes top-down regulation making it more difficult to distract from intrusive feelings and to sustain rational, goal-directed thought while experiencing emotional distress [132,133].

f) Recurrent neural networks: Emotion-cognition communication is based on a complex anatomical network consisting of recurrent circuits that link cortical areas and the thalamus with microcircuits inside the amygdala. Through such integrated routes, a continuous two-way modulation between emotional and cognitive systems is possible, and the amygdala and the prefrontal cortex, as well as thalamic relays, can dynamically influence one another. This simple recurrent architecture has been argued to play an essential role in the flexible adaptation of behaviour (Such as the regulation of affective state), as it provides a substrate for motivational salience to be 'online' integrated with perception, attention, and goal-oriented actions. In summary, emotion-cognition interactions in vulnerable groups depend on the functional balance between emotionally reactive brain regions (e.g. amygdala) and regulatory cognitive control areas (e.g. dlPFC, MCC). Disruptions in this balance underscore many challenges faced by vulnerable populations in regulating emotions and maintaining goal-directed cognition [134].

Practical frameworks and recommendations

To ensure responsible integration of neurotechnology, legal frameworks should embody:

a) Rigorous validation: We propose that the neurotechnologies in question, and their purveyors before anything else, be subject to mandatory certification to confirm that they are trustworthy, scientifically sound, and legally admissible [135]. Certification would be based on the most current scientific knowledge and consensus, use a common set of test methods, and involve accreditation in accordance with internationally recognized guidelines (e.g., ISO/IEC 17024). Certification programs contribute to quality control by certifying that products and practitioners of neurotechnology attain particular levels of performance, accuracy, and ethical standards that are required for use in forensic applications, thereby making the greatest reduction in the potential for the application (or misapplication) of these technologies to influence legal judgment. This aligns with further guidance for forensic science, which seeks to enhance the reliability and reproducibility of evidence employed in the criminal justice system [136].

b) Interdisciplinary ethics review: The creation of dedicated neurotechnology ethics committees is broadly advocated internationally, with recommendations highlighting a multidisciplinary model [137]. These groups, made up of neuroscientists, legal experts, and ethicists, would perform pre-deployment assessments with a laser focus on informed consent, risk-benefit analysis, and long-term tracking of neurotechnological interventions [138]. This inclusive composition allows for all pertinent knowledge to be applied to the ethical, scientific, and societal implications, and also facilitates transparency in decision making, the protection of human rights, and meticulous scrutiny of the effect on persons and communities continually [139].

c) Transparency requirements: It is increasingly accepted that developers, as well as law enforcement, have a responsibility to publicly disclose the capabilities, limitations, and operational parameters of neurotechnologies and other sophisticated digital tools [140]. This duty is supported by international policy entities, and resonates with global calls for transparency, a critical factor in fostering public trust and enabling stakeholders to evaluate potential risks and mitigations [141]. Transparency allows for continued oversight from civil society, helps deter abuse, and underwrites accountability for the developers and users, whether in law enforcement or criminal justice [142].

d) Data protection laws: Neural data is now being considered sensitive personal data, entitling it to strong legal protection and rights on the part of individuals, along the lines of templates such as the GDPR and new neurorights legislation [143]. These are provisions that entail obligations, such as data minimization only collecting what is necessary and very rough access controls to ensure that no one can use or view the neural data without being authorized [144]. Enforceable disposal regulations ensure that neural data is erased when its purpose is fulfilled, thereby providing an additional layer of privacy and autonomy for the subject of the data, both in clinical and forensic contexts [145].

e) Public consultation: Established channels for community participation and education are necessary to help ensure that governance of neurotechnologies is informed by the values and expectations of the community [146]. These mechanisms will be formalized through a new system of public engagement- including citizen assemblies, focus groups, interactive educational campaigns, and consultations with various stakeholders-to build meaningful two-way dialogue and transparency on the risks and benefits of neurotechnology [147]. Converging ethical, legal, and social implications in educational programs, and facilitating easy access to communication platforms for information exchange, contribute to enhancing neuro-literacy and enable the public to influence governance decisions on technology development in a manner acceptable to societal needs [148].

f) Capacity building: Specialized training for legal professionals and law enforcement officers is increasingly advocated to promote an interpretation and handling of neurotechnological evidence that is both ethical and effective [149]. They include the scientific basis of neurotechnology, suitable standards of evidence, data privacy responsibilities, and the ethical consequences of employing such evidence in court [150]. In promoting cross-disciplinary dialogue and critical evaluation of best practices, such training contributes to the accuracy, fairness, and accountable use of neurotechnological data in judicial determinations [151]. Phased implementation with pilot projects and continuous regulatory update provisions will foster innovation without compromising rights.

Conclusion

Advances in neurotechnology and genetics are transforming criminal law by providing far more information about behaviour-yet they also call into question our most basic values, such as free will and responsibility for one's actions, that serve as a foundation for the justice system. If knowledge of neuroscience or genetics is introduced as evidence, it may be argued that it diminishes the defendant's culpability, potentially lessening the punitive aspect of sentencing or even leading to full exoneration under conditions of extreme mental impairment.

However, courts have been increasingly turning to neuroscience to evaluate diminished capacity or mitigation, raising concerns about the degree to which biological accounts should influence assessments of legal responsibility. To exaggerate these findings in the legal sphere may risk shaping perspectives focused on seeing people as nothing but the products of their biology, which in turn could undermine the moral grounds for personal responsibility and justice. That debate means it is crucial to treat biological data as but one element in a more expansive context, contrasting with the principles of autonomy and choice that shape the legal system.

Progress in neurotechnology may make it possible not just to read thoughts or memories, but to modify memories or feelings, raising fundamental ethical and legal questions. If one could alter a person's memories or feelings, then the threat posed is not only to that person's personal autonomy but also to the reliability of their testimony, with consequences for the integrity of the legal process and, perhaps, for basic human rights. Legal scholars and human rights organizations are currently discussing the questions about whether new rights and safeguards are needed to protect mental privacy, and to prevent the forced or manipulative use of such technologies.

The incorporation of neurotechnology and genetics into criminal law, then, must be characterized by rigorous standards of reliability, clear ethical limitations, and perhaps even by the recognition of new rights protecting cognitive liberty and mental privacy. Lawmakers, scientists, and legal analysts should work in tandem to make the most of these beneficial technologies while preserving the foundational values of the justice system.

The law should actively anticipate the need for strong protections for mental privacy and personal autonomy from coercion as neurotechnology develops. This depends on a collective effort between scientists, ethicists, and policy- makers to begin designing ethical principles and concrete regulations. The new standards should treat transparency and accountability as paramount and accompany all the neurotechnological-related evidence/ intervention with a due diligence obligation in examining and supervising them. It is important that these increasingly powerful technologies do not give rise to invasive or manipulative applications to which individuals would be exposed, and so strong legal protections for cognitive liberty and mental privacy are required.

Attorneys cannot address these matters on their own – an interdisciplinary approach that includes neuroscience, ethics, medicine, and law is critical to making headway on these complex societal, scientific, and technological issues. Public officials have a duty to foster innovation while giving the public confidence that the sector will be well- managed: they need to listen to all sides and develop adaptive, responsive protections. Sensibly framed neurotechnology laws could enhance rehabilitation, deliver tailored interventions, and yield clearer, more reliable evidence in court. Ethical, responsible utilization of these advances ensures that justice remains humane and impartial while taking advantage of potent scientific breakthroughs.

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