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NEUROIMMUNOLOGY: EXPLORING THE NEUROLOGICAL BASIS OF CRIMINAL BEHAVIOR

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ABSTRACT

Neuroimmunology is a new field combining perspectives of neuroscience, psychology and criminology, which is beginning to start a foothold in social science, by examining the neurological and biological basis of criminal behavior believed to be connected to morality. By linking brain changes, biological influences, such as genetics and the neurochemical processes occurring in the brain and body, and morals/neuroscience, neuroimmunology wants to provide a better understanding of the relationship between biological characteristics which could be linked to impulsive, pathological motivators. This article reports on structural and functional brain abnormalities associated with criminality, genetic and epigenetic influences on behavior, neurochemical influences such as neurotransmitters and hormones, psychiatric disorders that are frequently linked with acts of criminality, and the legal and ethical ramifications associated with the inclusion of neurobiological evidence in the criminal justice system including rehabilitation and prevention strategies.

Keywords: *Neuroimmunology, criminal behavior, brain imaging, aggression, antisocial personality disorder.*

INTRODUCTION

Neuroimmunology is defined as the scientific study of the biological and neurological bases of criminal behavior. It connects neuroscience and criminology in order to clarify how individuals might be predisposed to engage in criminal or antisocial behaviors as a result of dysfunctions in brain structure and functionality [1]. Historically, neurocriminology was grounded in the ideologies of biological determinism, though, due to advances in technology, most importantly neuroimaging, the exploration of biological determinants of behavior as a science has begun to emerge [2].

Neuroradiologists are currently studying the different brain regions involved in decision-making, how neurochemical imbalances affect impulse control, aggression, and moral reasoning, as well as the genetic influences on antisocial behavior. Neurocriminologists engage in studies such as brain scans and longitudinal studies that support that the brain contains specific areas, specifically the prefrontal cortex and amygdala where abnormalities are consistently cited in individuals who engage in violent or antisocial behavior, not just for criminals, but for other social and psychological dysfunctions as well [3].

While there are useful insights to be gleaned through neurocriminology there are complicating ethical, legal, and philosophical questions about it. Is criminal behavior a free will mechanism, or is it in some way biologically predetermined in some individuals? To what degree should neuroscientific evidence be considered in a courtroom? These debates demonstrate that neurocriminology is not merely a science but a multidisciplinary discussion incorporating multiple approaches of law, ethics, public policy, and rehabilitation sciences. While the field is still developing, research in this area will eventually change the way forensic science and the criminal justice system will be approached [4].

2. Neuroanatomy of Criminal Behavior

2.1 The Prefrontal Cortex and Executive Dysfunction

The prefrontal cortex is important for a variety of executive functions (e.g., decision-making, impulse control, moral reasoning, and social behavior). There is evidence for impaired prefrontal activity or structure in individuals who are violent or antisocial [5]. Damage or developmental impairment to the prefrontal cortex may prevent individuals from being able to predict the consequences of their action, to control their impulses, or to distinguish right from wrong, which are all functions necessary for being law-abiding [6].

Neuroimaging studies have indicated that dysfunction in the dorsolateral prefrontal cortex and ventromedial prefrontal cortex has a predictive relationship with increased aggression and impulsivity. Lesion studies show that individuals who have lesions of the aforementioned areas may have normal intelligence, all while having poor judgment and are very likely to engage in criminal behavior. Overall, these studies demonstrate the influence of executive brain dysfunction on behavioral patterns that deviate from societal expectations [7].

2.2. The Amygdala and Emotional Regulation

The amygdala is engaged in the processing of fear, anger, and pleasure, and is a critical component of emotional learning and memory. Deviations in amygdala volume or are often apparent in psychopathy or violence-prone individuals [8]. The hypo-activity of the amygdala may prevent individuals from empathizing and noticing others fear (or affect). Conversely, hyperactivity of the amygdala causes fear responses and responses disproportionately to perceived threats, causing potentially impulsive violence [9].

We can associate amygdala dysfunction with lack of remorse, emotional coldness, and morality in violent offenders based on biological evidence including fMRI and other neuroimaging studies. In particular the connection between the amygdala orth lobes of the medial prefrontal cortex appears to be diminished in violent offenders exhibiting personality disorder or psychopathy forcing ensuing aggressor or criminal behaviors due to decreasing emotional regulation and acting morally [10].

2.3 Limbic System and Moral Decision-Making

The limbic system as a whole (hippocampus, hypothalamus, and cingulate cortex) participates in emotional expressiveness and motivation, stress responsiveness, etc [11]. When there are dysregulations in the limbic system, it will impact moral judgement and increase the individual's reactive tendencies to increasing levels of stressors, which may lead to dangerous or reckless behavior. Research has suggested that the anterior cingulate cortex contributes to error detection (wrong-doing) and impulse control (effective decision-making), both of which are salient for adaptive social behavior [12].

If limbic system activity is not regulated appropriately by the executive functions of the prefrontal cortex, aggressive urges, impulses, and poor emotional regulation may emerge. Such conditions become particularly hazardous in unconstitutional or unhealthy less-than-ideal external environments and psychiatric states. Neurocriminological studies support that limbic-prefrontal connectivity are more important for empathy, constraint and moral reasoning; skills that inhibit criminality when strike the balance of unhealthy in conditions [13]s.

3. Neuroimaging and Brain Abnormalities in Offenders

3.1 Functional Magnetic Resonance Imaging (fMRI)

Functional MRI has become a standard measure of the function of the brains of criminals. Research has shown that violent offenders demonstrate decreased blood flow to the prefrontal cortex, with the orbitofrontal segment exhibiting the greatest deficits. The orbitofrontal cortex helps us make decisions, assess risks, and inhibit impulsive behaviors; behaviors that may predispose individuals to behave antisocially or aggressively [14].

Furthermore, aside from decreased prefrontal cortex function (hypoactivity), fMRI research also

demonstrates disordered functional connectivity between the amygdala and frontal lobes, particularly in psychopathy, which creates abnormal connections found to drive poor emotional regulation, lack of empathy, and other common tendencies among many offenders. In conclusion, this and related research demonstrates strong evidence for the neurological basis for certain criminal behaviors [15].

3.2 Positron Emission Tomography (PET)

Position Emission Tomography scans detect glucose metabolism and gives researchers a view of metabolic activity in the brain. In studies of offenders with an offense history involving aggressive and violent behaviors, PET imaging often documented significant decreases in glucose metabolism in the pre-frontal and temporal lobes [16]. These lobes are critical for impulse management, emotional regulation, and social cognition. Impairment or abnormality in function or structure in these lobes could promote violent aggression and drive criminality [17].

Furthermore, PET research has found irregularities in the function of brain structures of the limbic system in violent offenders, specifically atypical emotional responses or inconsistent correlates between feelings of emotion and urges or automativtivities [18]. The offenders demonstrated a regcognition of appropriate emotional responses, but were unable to dampen heightened, automatic emotions through cortical regulation. Overall, these neurophysiological deficits and abnormalities in brain function are not limited to or restricted to those subjected to diagnosis of items in the Diagnostics and Statistical Manual of Mental Disorders (DSM), therefore brain dysfunction could also be considered a unique or independent risk factor in the engaging in criminal conduct [19].

3.3 Electroencephalography (EEG) and Brain Waves

EEG has demonstrated specific EEG characteristics of offenders and studies of the EEG have found specific abnormalities of electrical brain activity in offenders. In general, EEG studies have shown increased levels of theta and delta waves, which occur during states of drowsiness and significantly reduced levels of cortical arousal. Research implicates these MPAs as predictors of impulsivity, inappropriate self-regulation of attention, and diminished social adaptability; common characteristics in multiple forms of criminality [20].

EEG studies also observed delayed responses to stimuli in some violent offenders as well as abnormal waveforms. If the response latencies contribute as causal factors it might impede the individual's ability to respond in a socially desirable or tolerant way in an emotional and threatening situation, which may produce aggressive reactions. EEG studies convey the specific electrical brain activity indicates predispositions to behavioral characteristics [21].

3.4 Structural Imaging and Brain Volume Abnormalities

Structural imaging techniques, such as MRI and CT, show clear anatomical differences in the brains of many offenders. These differences may be significant [22]. For instance, there are recurrent notes of reduced volume in the areas of the brains that moderate the brain's executive function (the prefrontal cortex), affect (amygdala), and memory (hippocampus in perpetrators of antisocial or violent behaviors). The volumetric alterations themselves presumably arise from genetic predisposition and environmental factors, such as childhood abuse or traumatic brain injury [17].

Similarly, structural imaging studies show cortical thinning and some loss of gray matter density in the areas of the brain that elicit respect for one's self, empathy for others, impulse control, or moral decision making. Therefore, it is fair to argue that structural imaging studies have revealed abnormalities that are not merely correlational, but are increasingly seen as ingrained developmental causes of overt criminal behavior from a neurological perspective. The growing knowledge base from structural neuroimaging provides a firm framework for considering how morphological considerations of the brain interact with antisocial behaviors [23].

4. Genetic and Epigenetic Influences on Behavior

4.1 Heritability of Antisocial Behavior

Twin and adoption research has established a clear link between antisocial and criminal behavior and heritability. In the case of monozygotic twins raised apart, twin studies found a higher concordance of criminality across similar conditions for both twins than for dyzygotic twins [24]. This monzygotic twin study demonstrated a strong genetic component to criminality. Twin studies show that genetics can contribute to behavioral factors such as impulsiveness, aggression, and risk-taking behavior that link to criminal behavior [25].

Adoption studies have made it clear that children born to criminal biological parent, reared in a non-criminal family, also exhibit higher rates of criminality than children born to non-criminal biological parents,

reared in a non-criminal family. It is important to note that heredity cannot determine the behavior or behavior patterns of an individual; rather that heredity interacts with the environment to create the behavioral consequence. Understanding this interaction is important to understanding the development of criminal tendencies [26].

4.2 MAOA Gene and Aggression

Monoamine Oxidase A (MAOA) gene, known as the "warrior gene," is one of the most studied genes in neurocriminology. The MAOA gene helps break down neurotransmitters such as serotonin, dopamine, and norepinephrine [27]. Research indicates that variations of the MAOA gene, specifically the low-activity variation (MAOA-L), have been linked with aggressive and antisocial behavior and that this may be more prominent in males who experienced trauma or maltreatment as a child [28].

Some studies have demonstrated that the MAOA-L genotype was associated with a higher risk for violent behavior for individuals in the right (or wrong) environmental circumstances. The gene–environment interaction has significant implications for understanding and studying criminal behavior. Importantly, these genetic variants do not force you to commit a crime, but describe scenarios in which you are more likely to be vulnerable to committing crime, given certain conditions (including social context) [29].

4.3 Epigenetics and Environmental Modulation

Epigenetics means any change in gene expressing not directly in the DNA sequence. Some mechanisms of epigenetic change include DNA methylation and histone modification which will silence and activate genes in following signal from the environment [30]. In the field of neurocriminology, exposure to early life stressors such as abuse, neglect, or violence can lead to epigenetic change. These epigenetic mechanisms can change brain structure and function related to behavior regulation [31].

Research reports that those with a history of maltreatment in their childhood have altered methylation on genes involved in stress regulation and emotion regulation [32]. These epigenetic processes may lead to higher rates of aggression, poor impulse control, and emotional dysregulation traits that are often associated with criminal behavior. The field of epigenetics would provide enhanced representation for the complex interaction between biology and environment to better understanding behavior [33].

5. Neurotransmitters and Hormonal Influences

5.1 Dopamine and Serotonin Regulation

Dopamine and serotonin are two principal neurotransmitters that influence mood, impulse control and reward processing. Dopamine dysregulation has been associated with risk taking, reward seeking behavior and addiction; behaviours often exhibited in people who commit crimes. For example, more dopamine activity could heighten risk seeking behaviors and result in impulsive decision making which could contribute to offending behavior [34].

Conversely, low levels of serotonin have been associated with aggression, impulsivity and emotional instability. A vast amount of research demonstrates people having lower serotonin activity, particularly in the prefrontal cortex region, were more likely to engage in violent and antisocial behavior. Moreover, serotonin deficit has been associated with limited ability for empathy and reasoning, which again demonstrates the importance of studying both naturally occurring transmitters and their association with human behaviours [35].

5.2 Hormones and Aggression (Testosterone, Cortisol, etc.)

Testosterone, the main male sex hormone, is commonly explored regarding aggression and dominance behavior. Elevated testosterone levels have been associated with physical aggression especially those with underlying antisocial predispositions [36]. While a significant factor, testosterone is not a direct cause for crime, rather high testosterone is associated with exacerbating aggressive reactions especially human-directed aggression when provoked with difficult human to human scenarios or during emotional situations where the person is predisposed to become aggressive [37].

Like testosterone, cortisol the human body's main stress hormone can also play a role in regulating aggression. Interestingly, lower baseline cortisol levels may actually relate to higher risk for antisocial behavior [38]. This form of hypoarousal may be driven by adrenaline-seekers wanting stimulation through higher risky or violent actions who are only risky, violent, or extreme actions could get them feeling something again; as well are needed greater distilled fuel to create arousal in themselves. The balance or imbalance of cortisol and testosterone could be a good biometric to detecting patterns of aggression in aggressive behavior [39].

5.3 Neurochemical Dysregulation in Offenders

Offenders often display neurochemical imbalance patterns that are larger than simply single neurotransmitters or hormones. As an example: unhealthy functioning of gamma-aminobutyric acid (GABA), an inhibitory neurotransmitter, can result in poor impulse control and more aggressive irritability. Additionally, the contributions of norepinephrine as deficits in attention and emotional regulation, both key aspects of lawful social behavior are impaired [40]. In many violent offenders, the combination of elevated dopamine, reduced serotonin, along with GABA/norepinephrine will yield neurochemical markers that predispose the individual to reactive aggression and adverse judgment as a consequence of higher environmental stresses. Such biochemical terrain cannot be divorced from environmental stresses and genetic make-up that shape their adaptation to behavior and outcomes; neurochemical signatures may have potential for developing pharmacological solution for high-risk subjects [41].

6. Psychiatric Disorders and Criminality

6.1 antisocial personality disorder (ASPD)

Antisocial Personality Disorder (ASPD) is the psychiatric disorder that has the largest association with crime. Those diagnosed with ASPD have a persistent pattern of disregard for social rules, impulsivity, deceitfulness, and a propensity toward not feeling remorse after they have harmed others [42]. These traits fit chronic offenders and others who commit similar crimes in patterns. ASPD is commonly diagnosed in institutionalised populations showing its utility for forensic assessments.

Neurologically, those with ASPD show arrhythmias in neurological areas linked to impulse inhibition, feelings for others, and basic morality, which is the prefrontal cortex and the amygdala. Research has shown there are lower grey matter volumes and functional deficits in the frontal (behavioural control) and limbic (impulsivity and aggression) areas. The biological and behavioural aspects of ASPD offer an exciting target for neurocriminologists who are looking to understand what biological predisposes habitual offending [43].

6.2 Psychopathy and Criminal Behavior

Psychopathy poses an extreme state of personality disorder; in which superficial charm, manipulation, emotional detachment, and superficiality of feeling characterize the individual. While there are psychopaths who are not violent or criminal, certain studies have said an estimated 20 percent of violent offenders, and most serial offenders, qualify under psychopathy categorizations [44]. Psychopathy is a difficult phenomenon to measure, but it is done so through the use of the Hare Psychopathy Checklist-Revised (PCL-R) and through affective, interpersonal, and behavioural impairment [45].

Neuroimaging research in psychopathic individuals suggests that there is, in some part, hypoactivity in regions of the brain associated with emotional processing and social behaviour, namely the amygdala and ventromedial prefrontal cortex. These aspects of neural functioning explain their diminished fear response, deficient moral reasoning and incapacity for genuine attachment to others (with many acts of crime swept free of guilt, shame or inhibition). It is interesting to begin to understand the neurological basis of how some individuals carrying out acts of crime can be so cold, calculating or callous [46].

6.3 Other Psychiatric Conditions and Crime

In addition to ASPD and psychopathy, some other psychiatric disorders, schizophrenia, bipolar disorder, and substance-induced psychosis, can also be related to crime, but sometimes in very different ways. For example, if untreated, if someone with schizophrenia develops a delusion or hallucination and is provoked, they could act violently or irrationally. It is important to note that most people with mental illness will not act violently and it is not ethically right to characterize psychiatric disorders as criminal [47].

Mood disorders and substance disorders are commonly seen with crime, especially when they can affect judgment or increase inhibition. Dual diagnosis (both a mental disorder and substance use disorder) people are at even greater risk of impulsive or aggressive behavior. Therefore, a comprehensive psychiatric evaluation is important to determine the offender's mental state, and to distinguish between criminality and insanity, as well as to determine a reasonable legal response and/or therapeutic approach [48].

7. Applications in Rehabilitation and Prevention

7.1 Neurorehabilitation and Cognitive Training

Neurocriminology has a promising avenue for application, with neurorehabilitation programs geared towards improving the cognitive and emotional deficits present in offenders. Cognitive training programs that emphasize working memory, regulation of emotions, and impulse control have demonstrated success in changing behavioral patterns and reducing

recidivism. Targeting functions of the brain that are known to be impaired (including being governed by the prefrontal cortex), these neurorehabilitation programs seek to improve decision-making and reduce violence [49].

Neurofeedback therapy is another promising new approach used in forensic situations. This type of therapy enables individuals to view their brain activity in real-time, and intentionally manipulate their activity, to encourage individuals to use healthier types of neurological functioning. By reinforcing healthier neural wiring, neurofeedback can also produce healthier self-regulation of emotion and lower levels of impulse control. Though it is still being studied, the early studies suggest that the therapies may provide long-term impact for individuals with criminal histories based on the premise of neutral dysfunctions [50].

7.2 Early Identification and Risk Assessment

Neurocriminological instruments can also help identify individuals predisposed toward antisocial behaviors early in life. Neuroimaging, genetic screening, and assessments of behavior can be combined to create risk profiles more accurately, especially for juvenile offenders with symptoms of conduct disorder and emotional dysregulation. Early intervention programs can be applied to stimulate cognitive comprehension, promote empathy development, and reinforce social cognitive skills before antisocial behavior tendencies become habitual [51].

For clarity, the aim is not to stigmatize individuals because of genetic or neurological predispositions; rather, it may be that we can feasibly intervene with a subset of individuals and systematize supports that assist those individuals by preventing the onset of criminal behavior patterns. For example, we may be able to help children showing underactivity in certain brain regions associated with moral reasoning through moral education and behavioral therapy. This preventive model may be facilitated through schools, juvenile criminal justice programs, and child welfare services in a more proactive, large-scale crime prevention model [52].

7.3 Personalized Interventions Based on Neurological Profiles

As our comprehension of how neurologically based deficits contribute to criminality improves, there is a growing realization for the possibility of personalizing rehabilitation strategies. The prospect of personalizing rehabilitation through an individual's neurobiological profile, could improve treatment outcomes. For example, offenders with deficits in their emotional processing could benefit from an emphasis on empathy training than offenders who have deficits in executive functioning and may benefit from a cognitive-behavioural approach to improve planning and impulse control [53].

Pharmacological interventions may also be included as adjunctive therapies. In a few cases, medication to alter neurotransmitter functionality i.e., selective serotonin reuptake inhibitors (SSRIs) or antipsychotics have been used to reduce aggression and impulsivity. But, again these have to be prescribed cautiously and appropriately considering the individual health profiles of offenders, and risks involved with dependency or deleterious side effects. Using biological, psychological, and social interventions, presents an optimistic glimpse of a more effective and compassionate rehabilitation model [54].

7.4 Community-Based and Policy-Level Initiatives

Aside from individual interventions with offenders, neurocriminology has implications for community and policy initiatives for crime reduction. When viewing crime prevention from a public health standpoint, there are particular areas of importance for violence prevention, early childhood education, and community development where findings from the neurocriminological sciences can be applied. For instance, areas of high early life adversity associated with poverty, trauma and neglect may benefit from increases to mental health services, parenting support and developmental support services [55].

At the policy-level, there are possibilities for integration with criminal justice reform using new neuroscientific knowledge; we might advance towards more equitable and effective punishment administration in criminal justice systems. Rather than pragmatic knowledge through punitive sentencing, courts and corrections can apply rehabilitative knowledge through a rehabilitative justice framework using diversions, and conditional sentencing options that review cognitive rehabilitation options. In conclusion, there is a science of neurocriminology that gives opportunity for separating not only punitive but also healing justice systems [56].

8. Conclusion

Neurocriminology has improved our understanding of the biological components associated with criminality.

The exploration of brain dysfunctions, genetics, and neurochemical abnormalities has begun to explain the basis of the predisposition to aggression, impulsivity, and antisocial behaviours. Studies involving neuroimaging and genetics have consistently shown that there are significant structural and functional brain differences (again, especially in the prefrontal cortex and limbic system) that predispose some people to indiscretionary decision-making and insufficient regulation of destructive behaviour.

Neurocriminology appears to hold genuine possibilities for prevention, performance, rehabilitation, and for legal purposes. The application of neurocriminology also raises utilitarian and ethical concerns about free will, societal responsibility, and the impact of biological data in our notion of justice. It is also apparent that we must continue to combine the knowledge from neuroscience with social and psychological approaches to develop well-rounded and effective programs. To that end, we hope to use this knowledge to make our communities safer and our penal systems kinder.

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