

## The Effects of Behavioural Neurology on Individuals

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**ABSTRACT:** Behavioural neuroscience is an interdisciplinary field that examines the causal relationships between the central nervous system and human behaviour. This review article examines the effects of subregions of the prefrontal cortex, the limbic system and the mirror neuron system on an individual's cognitive, emotional and social functions in the light of the empirical literature. The findings reveal that cortico-limbic dysregulation paves the way for personality changes, impairments in executive function and deficits in empathy. The existence of neuroplasticity and epigenetic mechanisms demonstrates that psychotherapeutic interventions can lead to measurable structural changes in the brain and that the neurological underpinnings are not an immutable destiny. Consequently, a biopsychosocial approach that considers the biological, psychological and social dimensions of human behaviour in unison appears indispensable.

**KEYWORDS:** behavioural neurology, prefrontal cortex, neuroplasticity, emotion regulation, executive functions, social cognition.

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### INTRODUCTION

The endeavour to understand the biological foundations of human behaviour is rooted in a long-standing intellectual tradition stretching from the mind-body dualism of ancient Greek philosophy to the present day. This inquiry underwent a qualitative transformation in the final quarter of the 20th century with the development of neuroimaging technologies. Methods such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET) and high-resolution electroencephalography (EEG) have made it possible to examine the neural correlates of mental processes in the brain at a measurable level (Logothetis, 2008).

Thanks to this technological revolution, behavioural neuroscience has crystallised as an integrated scientific discipline investigating the relationships between brain structures and human behaviour. The field aims to unravel the neuroanatomical underpinnings of complex behaviours such as decision-making, moral judgement, empathy and social adaptation (Mesulam, 2000). It has been empirically confirmed that deep neurobiological dysregulations underlie psychopathologies such as major depressive disorder, attention deficit hyperactivity disorder (ADHD), post-traumatic stress disorder (PTSD) and antisocial personality disorder (Insel, 2010).

This study aims to systematically examine the multidimensional effects of behavioural neurology on an individual's cognitive, emotional and social functions. The functions of subregions of the prefrontal cortex, the limbic system and the mirror neuron network are discussed in the light of theoretical and empirical literature, including mechanisms of neuroplasticity and epigenetic transformation.

### METHOD

This study is a qualitative review based on a systematic review of the theoretical and empirical literature in the field of behavioural neurology. Data obtained from international peer-reviewed journals and key reference works, primarily from the PubMed, ScienceDirect and PsycINFO databases, have been classified using thematic analysis. The findings are presented within an integrated framework across cognitive, emotional, social and neuroplasticity dimensions. fMRI and PET-based experimental data have been adopted as the primary sources in this study.

### THEORETICAL FRAMEWORK

#### Historical Development and Paradigm Shifts

The historical trajectory of the relationship between behaviour and the brain has been shaped by a dialectical tension between localisationism and holism. Paul Broca's identification in 1861 of the region controlling motor speech production in a patient with damage to the left frontal gyrus constituted one of the first concrete findings regarding the brain's functional asymmetry (Broca, 1861). This debate has now been synthesised under the concepts of the 'connectome' and 'neural network models': behaviours arise not from individual centres, but from dynamic networks of connections between brain regions (Logothetis, 2008).

The most striking case reinforcing the foundation of this understanding is the 1848 Phineas Gage experiment. Gage, who sustained

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damage to his ventromedial prefrontal cortex in an accident, permanently lost his personality structure and moral judgement mechanism, despite his motor and sensory functions remaining intact (Damasio et al., 1994). This observation has become one of the foundational references of modern behavioural neurology by demonstrating that human character is based on a concrete neural infrastructure.

### **The Prefrontal Cortex and Executive Functions**

The prefrontal cortex (PFC) is the central coordinating unit that integrates executive functions such as working memory, planning, attention management, abstraction and impulse inhibition. It is divided into three subregions that differ functionally from one another. The dorsolateral prefrontal cortex (DLPFC) governs ‘cold’ cognitive processes that are relatively independent of emotions (Curtis and D’Esposito, 2003). Damage to this region leads to perseveration, mental rigidity and a breakdown in organisational skills.

The orbitofrontal cortex (OFC) ensures an individual’s compliance with social norms by undertaking ‘hot’ cognitive functions such as reward-punishment assessment and impulse inhibition; when damaged, a picture of acquired sociopathy is observed (Rolls, 2004). The ventromedial prefrontal cortex (VMPFC) plays a central role in emotion-based decision-making and moral judgement. According to Damasio’s (1994) Somatic Markers Hypothesis, this region enables intuitive decisions by reading the bodily traces of past experiences; when damaged, individuals begin to make socially destructive decisions.

### **The Limbic System and the Neurobiology of Emotional Regulation**

The limbic system is a complex of subcortical structures that regulates the motivational, emotional and homeostatic components of human behaviour. In a healthy brain, the prefrontal cortex suppresses the amygdala’s excessive responses via inhibitory GABAergic pathways; when this top-down control is disrupted, limbic dominance and emotional dysregulation come to the fore (LeDoux, 2012). The amygdala triggers immediate responses by detecting signals of environmental threats without awaiting cortical processing (LeDoux, 1996). Chronic stress and early childhood trauma lead to structural hypertrophy in the amygdala, fuelling a state of chronic hypervigilance.

The hippocampus, meanwhile, records the contextual framework of emotional experiences; cortisol-induced dendritic atrophy reduces the volume of this region, paving the way for the involuntary flashbacks observed in PTSD (Sapolsky, 2000). The insular cortex, as an interoceptive centre that transforms visceral sensations into emotional experience, also plays a critical role in processes of empathy and self-awareness (Craig, 2009).

### **The Mirror Neuron System, Social Cognition and Empathy**

Mirror neurons are motor neurons that show simultaneous activation both when performing an action oneself and when observing the same action (Rizzolatti and Craighero, 2004). The existence of an extensive mirror neuron system in the human brain has been confirmed by fMRI and transcranial magnetic stimulation studies (Iacoboni, 2009). This system forms the neurobiological basis for social learning, imitation and empathy. Empathy comprises two fundamental components: affective empathy involves physically sensing another person’s emotional experience and is mediated by the simultaneous activation of the anterior insula and the anterior cingulate cortex (Singer et al., 2004). Cognitive empathy, on the other hand, involves understanding the mental states of another person at a logical level and is regulated by the medial prefrontal cortex and the temporo-parietal junction (Frith and Frith, 2003).

Whilst weaknesses in the mirror neuron network and insular connectivity lead to difficulties with social adaptation in autism spectrum disorder (Ramachandran, 2011), in antisocial personality disorder, whilst cognitive empathy is largely preserved, the circuits involved in affective empathy lose their functionality.

### **Neuroplasticity and Epigenetic Mechanisms**

Neuroplasticity is the brain’s capacity to reorganise its structural and functional organisation in response to learning experiences, environmental changes and trauma. It has been demonstrated that new neuron production continues throughout life in the adult hippocampus (Eriksson et al., 1998). Epigenetic mechanisms underpin this plastic transformation: therapeutic experiences modify gene expression without altering the DNA sequence, thereby increasing the production of the neurotrophic factor BDNF and supporting neural growth (Eriksson et al., 2007).

These findings demonstrate that psychotherapy is a biological treatment method. Following Cognitive Behavioural Therapy (CBT), an increase in prefrontal cortex metabolism and a reduction in amygdala hyperactivity were observed in patients with depression (Goldapple et al., 2004); whilst EMDR therapy triggered an increase in hippocampal volume in patients with PTSD (Bossini et al., 2012).

## **FINDINGS**

### **Cognitive Effects: Executive Networks and Memory**

Hypometabolism in the DLPFC leads directly to impaired executive function in areas such as planning, cognitive flexibility and sustained attention. In ADHD, meanwhile, dysfunction in the dopaminergic pathways between the DLPFC and the striatum disrupts attention and organisational skills (Arnsten, 2009). Functional disconnections in large-scale networks associated with the prefrontal cortex have been documented through neuropsychological testing as causing severe difficulties in perseveration and impulse control in individuals (Curtis and D’Esposito, 2003). In cases of bilateral damage to the hippocampal formation, it has been observed that recent events cannot be transferred to long-term memory and that contextual memory processes break down entirely (Sapolsky, 2000).

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### **Emotional Effects: Cortico-Limbic Dysregulation**

Meta-analyses of functional neuroimaging reveal that, in anxiety disorders, there is marked hyperactivity in the amygdala and insular cortex, whilst there is concurrent hypoactivity in the VMPFC and anterior cingulate cortex (Etkin and Wager, 2007). This pattern implies a dysfunction in the individual's capacity for emotional inhibition and a loss of control over limbic responses. Prolonged high cortisol levels under chronic stress cause a significant reduction in hippocampal volume, ranging from ten to fifteen per cent; when this volume loss is combined with a decrease in BDNF, it leads to learned helplessness, anhedonia and intense dysphoria (Sapolsky, 2000).

Findings showing that CBT and EMDR can correct cortico-limbic imbalance at the cellular level in patients with depression and PTSD (Goldapple et al., 2004; Bossini et al., 2012) demonstrate that these treatment processes are not purely psychological but involve direct biological changes. Similarly, Eriksson et al. (1998) demonstrated that successful treatments can re-trigger hippocampal neurogenesis and that volume loss can be partially reversed.

### **Effects on Social and Personality Functioning**

Clinical observations of individuals with orbitofrontal cortex lesions strikingly demonstrate that whilst intellectual intelligence is preserved, social and emotional intelligence can collapse due to biological damage (Damasio, 1994). Individuals who previously led ethical and respectable lives exhibit a lack of empathy, social disinhibition and impaired moral judgement following the lesion (Damasio et al., 1994). fMRI studies on moral reasoning show that moral dilemmas require intense synchronisation in the VMPFC (Greene and Cohen, 2004). Patients with damage to the VMPFC approach these dilemmas solely through utilitarian logic, excluding the emotional dimension (Greene et al., 2001).

How impairments in the mirror neuron system disrupt social cognition can also be assessed in this context. Ramachandran's (2011) 'broken mirror' hypothesis explains the neural basis of social disconnection in individuals with autism; whilst Iacoboni's (2009) studies demonstrate that the capacity for empathy in healthy individuals is directly linked to the functionality of this system. Meanwhile, the fMRI findings of Singer et al. (2004) revealed that the networks activated when witnessing another person's pain largely overlap with the structures engaged when the individual experiences their own pain.

## **DISCUSSION**

The findings discussed here demonstrate that human behaviour cannot be explained independently of its biological underpinnings. Clinical evidence ranging from the case of Phineas Gage to modern neuroimaging studies shows that brain damage can completely transform one's moral compass and personality (Damasio et al., 1994). This observation opens up the concepts of free will and individual responsibility to legal debate and is accelerating the emergence of the discipline known as neurolaw (Greene and Cohen, 2004).

Findings on neuroplasticity, however, provide a strong counter-argument to this deterministic approach. The brain is not a fixed piece of hardware, but a dynamic system that can be rewritten through environmental experiences and psychotherapeutic interventions. Findings showing that CBT and EMDR can correct cortico-limbic imbalance at the cellular level in patients with depression and PTSD (Goldapple et al., 2004; Bossini et al., 2012) demonstrate that biology is not an immutable destiny. In this context, epigenetic mechanisms also play a critical role: therapeutic processes modify gene expression, thereby increasing BDNF synthesis and supporting neural growth (Ericsson et al., 2007).

The characterisation of a broad clinical spectrum—ranging from anxiety to autism spectrum disorders—as connectivity defects within brain networks emphasises the need to shift psychiatric classifications from purely behavioural observations to objective neuroanatomical parameters (Etkin and Wager, 2007). Consequently, it is insufficient to reduce human reality to either a purely biological machine or to treat it as an abstract mind detached from physical reality; a bio-psycho-social holistic framework appears inevitable.

## **CONCLUSIONS AND RECOMMENDATIONS**

The key findings of this study can be summarised under three headings. Firstly, cognitive, emotional and social behaviours are underpinned by the synchronised functioning of specific brain structures—such as the prefrontal cortex, the limbic system and the mirror neuron network—and the dynamic connections between these structures (Logothetis, 2008; Mesulam, 2000). Secondly, cortico-limbic dysregulation and neurological damage lay the groundwork for profound pathologies that may lead to personality changes, impairments in executive function and deficits in empathy (Etkin and Wager, 2007; Damasio et al., 1994). Thirdly, neuroplasticity and epigenetic mechanisms demonstrate that the neurological infrastructure is a flexible and modifiable starting point (Eriksson et al., 1998; Ericsson et al., 2007).

Based on these findings, various recommendations can be developed. The inclusion of neuropsychological tests in clinical assessment batteries will enhance the objectivity of diagnosis and treatment planning. It is recommended that interventions targeting neuroplasticity, such as CBT, EMDR and neurofeedback, be more widely adopted in clinical settings (Goldapple et al., 2004; Bossini et al., 2012). Given the damaging effects of amygdala hyperactivity and hippocampal atrophy, the development of early intervention programmes for at-risk children is of critical importance (LeDoux, 1996; Sapolsky, 2000). Updating the legal and education systems in line with findings from behavioural neuroscience is also emerging as an interdisciplinary imperative (Greene and Cohen, 2004).

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