

Biological Constraints and Human Agency: Neurotransmitter Systems in the Free Will Debate

Biyolojik Belirleyiciler ve İnsan İradesi: Özgür İrade Bağlamında Nörotransmitter Sistemlerin Rolü

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Abstract

Recent advances in neuroscience have intensified debates about free will and determinism. In particular, neurotransmitter systems such as dopamine and serotonin play important roles in motivation, emotion, learning, and self-control, raising questions about how much our decisions are biologically determined. This paper reviews evidence on how neurochemical systems influence reinforcement learning, moral judgment, executive function, and behavioral flexibility. Genetic differences and large-scale brain networks are also considered. The available evidence shows that neurotransmitters shape tendencies and influence decision-making processes. However, their effects are generally probabilistic rather than strictly deterministic. Neurochemical states can bias certain choices, but they do not make alternative actions impossible. Furthermore, neuroplasticity, environmental context, and even beliefs about free will contribute to behavioral outcomes. Overall, current neuroscience does not support the view that human agency is an illusion. Instead, biological systems appear to constrain behavior while still allowing flexibility. Continued dialogue between neuroscience and philosophy remains essential for clarifying the relationship between brain chemistry and free will.

Keywords: Free will; Dopamine; Serotonin; Determinism; Decision-making; Neuroethics

Özet

Nörobilim alanındaki güncel gelişmeler, özgür irade ve determinizm arasındaki ilişkinin yeniden değerlendirilmesine zemin hazırlamıştır. Dopamin ve serotonin başta olmak üzere nörotransmitter sistemlerin motivasyon, duygu, öğrenme ve özdenetim süreçlerinde önemli rol oynaması, insan kararlarının ne ölçüde biyolojik mekanizmalar tarafından belirlendiği sorusunu gündeme getirmektedir. Bu çalışma, nörokimyasal sistemlerin pekiştirmeli öğrenme, ahlaki yargı, yürütücü işlevler ve davranışsal esneklik üzerindeki etkilerine ilişkin mevcut bilgileri değerlendirmektedir. Genetik farklılıklar ve geniş ölçekli beyin ağları da bu bağlamda ele alınmaktadır. Mevcut bulgular, nörotransmitterlerin davranışsal eğilimleri şekillendirdiğini ve karar verme süreçlerini etkilediğini göstermektedir. Bununla birlikte, bu etkiler çoğunlukla katı biçimde deterministik değil, olasılıksal niteliktedir. Nörokimyasal durumlar bazı seçimleri belirli yönlerde eğilimli hale getirebilir; ancak alternatif eylemleri olanaksız kılmaz. Ayrıca nöroplastisite, çevresel koşullar ve özgür iradeye ilişkin bireysel inançlar da davranışsal sonuçlar üzerinde etkili olabilmektedir. Genel olarak, güncel nörobilimsel bulgular insan iradesinin bir yanılsama olduğu görüşünü desteklememektedir. Bunun yerine, biyolojik sistemlerin davranışı belirli ölçülerde yönlendirdiği, ancak yine de esnekliğe olanak tanıdığı görülmektedir. Beyin kimyası ile özgür irade arasındaki ilişkinin açıklığa kavuşturulması için nörobilim ve felsefe arasındaki disiplinler arası diyalogun sürdürülmesi önem taşımaktadır.

Anahtar Kelimeler: Özgür irade; Dopamin; Serotonin; Determinizm; Karar verme; Nöroetik

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INTRODUCTION

The concept of free will has historically been examined within metaphysics, ethics, and theology. However, in recent decades, empirical neuroscience has begun to inform this longstanding debate. Determinist interpretations often suggest that if human behavior can be explained by neurobiological mechanisms, then agency may be illusory. In contrast, compatibilist perspectives argue that causal explanation does not necessarily negate meaningful autonomy [1,2].

Neuroimaging research has shown that neural activity predictive of certain choices can be detected prior to conscious awareness [3,4]. These findings have been interpreted by some as evidence that unconscious neural processes determine behavior before conscious deliberation occurs. However, others caution that predictive accuracy remains probabilistic and does not imply inevitability [5]. Importantly, neural readiness potentials may reflect preparatory biases rather than final commitments.

While much of this debate has focused on temporal precedence of neural signals, neurotransmitter systems provide a deeper biochemical layer of analysis. Neurotransmitters regulate neural excitability, network communication, and plasticity [6]. Therefore, exploring their role may offer a more nuanced understanding of how biological constraints interact with subjective experience.

Dopamine and Reinforcement Learning

Dopamine has been widely implicated in reinforcement learning and motivational salience. The reward prediction error model proposes that dopaminergic neurons encode discrepancies between expected and actual outcomes, thereby guiding behavioral adaptation [7]. This suggests that current decisions are influenced by prior reinforcement histories embedded in dopaminergic signaling. However, dopaminergic influence is neither uniform nor absolute. Balleine and O'Doherty [8] differentiate between goal-directed and habitual systems, indicating that behavior results from the interaction of parallel circuits. Recent behavioral studies in humans and rodents show that decision-making performance relies on two distinct learning systems. One system learns the link between actions and their consequences (goal-directed learning). The other forms stimulus-response associations that support habitual behavior.

Dopaminergic modulation in the prefrontal cortex follows an inverted U-shaped relationship with cognitive performance [9]. Both hypo- and hyperdopaminergic states may impair executive control. In Parkinson's disease, dopaminergic replacement therapy has been associated with impulse control disorders in some individuals [10]. Yet variability across individuals suggests that neurochemical modulation alone does not dictate behavioral outcomes. Environmental context,

personality traits, and cognitive strategies appear to mediate these effects. Addiction illustrates how dopaminergic plasticity can alter decision-making architecture. Repeated substance exposure induces neuroadaptations within mesocorticolimbic circuits that bias valuation processes toward drug-related cues while diminishing the salience of alternative rewards. This shift reflects a redistribution of reinforcement weighting rather than a simple increase in reward sensitivity. Over time, control may transition from goal-directed to habitual systems, constraining behavioral flexibility [11].

Serotonin and Moral Cognition

Serotonin contributes to affect regulation and social evaluation [12,13]. Reductions in serotonergic system function have been associated with increased impulsivity and altered harm aversion [14]. These findings suggest that neurochemical states may bias moral judgments.

However, the magnitude and consistency of neurochemical effects on moral judgment vary across studies. Moral reasoning engages distributed cortical networks that integrate affective and cognitive processes. Experimental manipulation of serotonin levels has been shown to increase harm aversion in personal moral dilemmas, suggesting that serotonergic modulation influences affective weighting rather than rigidly determining moral conclusions [14,15].

Glutamate, GABA, and Executive Regulation

Decision-making depends on inhibitory control mechanisms supported by the balance between glutamate and GABA. Prefrontal circuits require coordinated excitation and inhibition to sustain working memory and suppress impulsive responses [9].

Active inference frameworks propose that behavior emerges from probabilistic predictions updated via error signals [16]. Neurotransmitter systems influence the precision weighting of these signals. This computational perspective suggests that decisions arise from dynamic Bayesian updating rather than deterministic sequences. Such models align with constrained flexibility. Neurochemical states bias probability distributions of potential actions but do not collapse them into singular inevitabilities. In other words, decisions are not the product of a fixed and inevitable biological chain; they are the result of constantly evolving probabilities. Neurochemical states may make some options more likely, but they do not eliminate all alternatives. Therefore, biology guides behavior, but it does not reduce it to a single inevitable outcome.

Genetic Polymorphisms and Behavioral Diversity

Genetic variants influencing neurotransmitter systems contribute to individual variability [17-19]. A well-characterized example is the COMT Val158Met polymorphism, which alters prefrontal dopamine metabolism and has been

linked to differences in executive performance [20]. Variations in dopamine receptor genes have likewise been associated with individual differences in reward sensitivity [21]. Nonetheless, this topic lacks clarity, and gene-environment interactions significantly contribute. What we can say is that genetic predispositions shape behavioral tendencies, not behavioral outcomes, and thus are in support of a probabilistic model of behavioral influence.

Network-Level Integration and Emergence

Research in large-scale brain networks shows that thinking and emotions do not come from a single molecule or one isolated brain area. Instead, they emerge from many interconnected brain regions working together as a system [22]. Emotional salience, executive monitoring, and value computation interact across networks.

Emergentist perspectives propose that higher-order properties may arise from but not be reducible to molecular events. Under this view, agency may reflect integrated network dynamics operating within biological constraints.

Comparative Interpretation of Evidence

Some scholars argue that neuroscientific findings undermine traditional libertarian notions of uncaused choice [23]. Others maintain that compatibilist frameworks remain intact because agency can be defined as action arising from internal psychological processes—even if those processes are biologically instantiated.

Empirical data show that neurotransmitter systems influence motivational and cognitive parameters. Yet no study demonstrates that a specific neurochemical configuration renders alternative choices impossible in ordinary conditions. Variability, plasticity, and context sensitivity remain pervasive.

Additionally, belief in free will itself appears to influence behavior [24]. Experimental studies have shown that when individuals are exposed to deterministic messages that cast doubt on free will, they are more likely to engage in cheating, display reduced self-control, and behave more aggressively compared to those whose belief in free will is affirmed. Conversely, strengthening belief in free agency has been associated with greater prosocial behavior, improved task persistence, and enhanced moral accountability. These findings suggest that beliefs about free will function as psychologically active constructs that shape motivation, norm compliance, and self-regulation. Agency, therefore, is not merely a byproduct of molecular or neural mechanisms; it is also sustained by socially embedded belief systems and self-concepts that influence how individuals interpret and guide their own behavior.

DISCUSSION

Taken collectively, the literature suggests that neurotransmitter systems establish probabilistic constraints rather than deterministic mandates. Dopamine biases reward valuation; serotonin modulates affective sensitivity; glutamate and GABA regulate inhibitory control. Genetic variation introduces additional diversity. However, multi-level integration prevents reduction to a single explanatory layer.

Moreover, neuroplasticity complicates deterministic interpretations. Learning, therapy, and environmental restructuring can modify synaptic strength and motivational priorities [25-27]. If neural circuits remain adaptable, agency may be constrained but not extinguished.

A strictly reductive biochemical determinism would require demonstrating that neurochemical states fully and inevitably determine specific behaviors. Current evidence does not meet this standard. Instead, findings are compatible with a model of constrained agency operating within biological systems.

Future research integrating computational modeling, longitudinal neuroimaging, and interdisciplinary philosophy may further clarify these relationships.

CONCLUSION

Brain chemistry plays an important role in how we make decisions. It affects our motivation, emotions, and ability to control our behavior. However, current neuroscience does not support the idea that human behavior can be explained only by chemical processes in the brain.

Our biology influences what we do, but it does not completely determine it. It sets certain limits, yet within those limits there is still room for change and flexibility. For this reason, understanding free will requires continued discussion between neuroscience and philosophy rather than relying on biology alone.

Ethical Statement

This study is a narrative review based on previously published literature and does not involve human participants or animals. Therefore, ethical approval was not required.

Conflict of Interest

The author declares no conflict of interest.

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Author Contribution

T.B. conceptualized the study, conducted the literature review, and drafted the manuscript. H.B.S. contributed to the theoretical framework, critically revised the manuscript for intellectual content, and supervised the study. Both authors approved the final version of the manuscript.

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