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Mini Review

How Drug Addiction Affects the Brain

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Abstract

Drug addiction is a chronic relapsing brain disorder characterized by irresistible drug seeking and use regardless of harmful repercussions. It results from repeated exposure to psychoactive substances that alter the structure and function of neural circuits involved in reward, motivation, memory and executive control. These neurobiological changes compromise decision-making, increase craving and reduce an individual's ability to control drug use. This mini-review summarizes the effects of drug addiction on the brain, focusing on the neural pathways involved, neurotransmitter alterations, structural and functional brain changes and the long-term repercussions of addiction.

Introduction

Drug addiction is a major global public health challenge that affects millions of people worldwide. It is now recognized as a chronic brain disease rather than merely a behavioral problem. Repeated exposure to addictive substance such as opioids, cocaine, methamphetamine, nicotine, cannabis and alcohol produces lasting changes in brain function that contribute to dependence, tolerance, withdrawal and relapse [1]. Advances in neuroscience have provided valuable insights into the mechanisms through which addictive drugs alter brain circuity, offering new opportunities for prevention and treatment.

The Brain Reward System and Addiction

The rewarding effects of addictive drugs primarily involve the mesolimbic dopamine pathway, which includes the Ventral Tegmental Area (VTA), Nucleus Accumbent (NAc) and Prefrontal Cortex (PFC). Under normal conditions, dopamine is released in response to natural rewards such as food and social interactions. However, addictive drugs cause a much larger and prolonged increase in dopamine levels, producing intense feelings of pleasure [2]. Repeated stimulation of the reward pathway results in neuroadaptations that reduce the brain's sensitivity to natural rewards while increasing responsiveness to drug-related cues. Consequently, individuals become increasingly motivated to seek drugs while experiencing diminished satisfaction from everyday activities [3].

Neurotransmitter Alterations

Although dopamine plays a central role in addiction, several other neurotransmitter systems are also affected. Glutamate regulates learning, memory and synaptic plasticity and contributes to drug craving and relapse through alterations in corticosteroid pathways. Gamma-aminobutyric acid (GABA) influences inhibitory control while serotonin affects mood regulation and impulsivity.

Chronic drug exposure also disrupts endogenous opioid and endocannabinoid systems, father contributing to dependence and withdrawal[1].

These widespread neurotransmitter changes produce an imbalance between reward processing and cognitive control, making abstinence increasing difficult.

Structural And Functional Brain Changes

Long-term drug use causes significant structural and functional changes in several brain regions. Neuroimaging studies have demonstrated reduced gray matter volume in the prefrontal cortex, a region responsible for judgment, planning, impulse control and decision-making [2]. Damage to this region weakens an individual's ability to resist drug cravings despite awareness of negative consequences.

The amygdala, which regulates emotional processing becomes hypersensitive to stress and drug-related cues, increasing vulnerability to relapse. The hippocampus involved in learning and memory strengthens associations between environmental cues and drug use, allowing even minor triggers to provoke intense cravings [4].

Chronic exposure to addictive substances also alters synaptic plasticity by changing neuronal connectivity and receptor expression. These persistent neuroadaptations may remain long after drug use has stopped, explaining why relapse can occur months or even years after recovery.

Cognitive and Behavioral Consequences

The neurological alterations associated with addiction produce significant cognitive impairments. Individuals often show poor attention, impaired working memory, diminished executive function and reduced cognitive flexibility. Decision-making becomes increasingly biased toward immediate drug rewards despite long term adverse effects [1].

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