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Addiction Risk, Decision Making, and Mood Regulation: The Impact of Nicotine and Cannabis on Adolescent Brain Development

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Abstract

Adolescent nicotine and marijuana use has been shown to increase risk for addiction, impair decision-making, and disrupt mood regulation—heightening susceptibility to future substance use disorders. Nicotine and cannabis affect the brain's circuits in different ways, but their overall impact on the adolescent brain is remarkably similar. A literature review was conducted to understand the mechanisms and implications of nicotine and cannabis use. Data from 2003 to 2024 from PubMed, PsychINFO, and SCOPUS were collected using key words such as adolescent, nicotine, cannabis, brain development, and mental health. Since adolescence is a time of brain development, consumption of a drug during this time can lead to long-term consequences. Addiction risk and impacts on decision making and mood regulation are among the most concerning consequences. Teenagers who use cigarettes and marijuana acquire heightened risk of mood and anxiety disorders, as these chemicals interfere with the brain's processes for regulating stress. Additionally, initiation of drug use is highly associated with social isolation, low self-esteem, and suicidal thoughts, especially for teenagers with risk factors for mental health. Research is developing new therapeutic approaches and evaluating the effects of nicotine and cannabis on adolescent brain health. This report offers a comprehensive overview of studies investigating adolescent brain development.

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1. Introduction

Marijuana and tobacco are the most used substances among adolescents and young adults. In fact, the 2023 results from the FDA's Annual National Youth Tobacco Survey showed that 2.8 million (roughly 10%) middle and high school students reported current use of any tobacco product.[1] Ranging from ages 10 to 20, adolescence is a particularly influential period for neurodevelopment. Young individuals are more often put in positions of heightened peer influence, increasing their chances of developing long lasting habits and addictions to substances. According to the World Health Organization, tobacco use has declined over the past 20 years from one-third of the adult population to one-fifth in 2022.[2] However, in recent years, the rise of vape pens and e-cigarettes (which were introduced with the goal of minimizing tobacco use) has only increased the number of nicotine users with particular focus on adolescents. In 2024, more than 38.4% of youth e-cigarette users reported using e-cigarettes for 20 out of a 30 day period.[3] Furthermore, 2023 statistics shows that 89.4% of adolescent e-cigarette users prefer flavored e-cigarettes, which increases the appeal and likelihood of sustained use by masking the harshness of nicotine and enhancing the sensory experience.[4] The greatest use of cannabis and nicotine occurs in teenagers. Studies show that more than one-third of twelfth graders have ever used cannabis, and 78% of those who have started to use report between the ages of 12 and 20.[5]

Comprehending drug abuse among adolescents entails going into the history of studies that aimed to unpack adolescent brain development. Research has shown that neurodevelopmental asynchrony marks adolescence by earlier maturation of limbic systems (which drive reward-seeking and emotion) relative to slower-developing prefrontal regions (which regulate judgment and self-control).[6] This imbalance heightens emotional sensitivity and impulsivity, especially in high-stress or peer-influenced environments. The conceptualization of such a framework has extensively captured the vulnerability of the adolescent brain to substance abuse.

From a pharmaceutical perspective, both nicotine and cannabis target specific neuromodulatory systems, namely the dopaminergic and endocannabinoid pathways. These substances significantly disrupt neurological processes that are critical to adolescent brain maturation, such as synaptic pruning, myelination, and receptor regulation. This impairs the efficiency of neural communication, weakens the brain's executive functioning, and compromises its ability to regulate emotion, impulses, and cognition. As a result, some of the most common and concerning effects induced by nicotine and cannabis are risk of addiction, change in mood control, and impairment of decision making– core functions essential for academic, social, and psychological development. These three factors significantly contribute to an increased risk of substance use disorders in later life.

Understanding how these pharmacological agents alter neurodevelopmental trajectories is essential not only for clarifying addiction risk, but also for informing therapeutic strategies and policy. This paper reviews current literature on the neurobiological impact of adolescent nicotine and cannabis use, with particular attention to addiction risk, decision-making deficits, and mood dysregulation—areas of high priority for clinical intervention and future research.

2. Significance

The goal of this paper is to provide a comprehensive review of the effect of cannabis and nicotine use on adolescent brain development, highlighting several studies and research projects that exhibit how these substances directly impact important neurological pathways. In this review, we highlight 3 specific areas that are particularly impacted by early use of cannabis and nicotine–addiction risk, decision making, and mood regulation–and how that affects future susceptibility of mental disorders. Furthermore, the paper explores current and emerging research regarding the impact of substance use as well as therapies aimed at reversing its effects or supporting adolescents in overcoming addiction. It also examines the effectiveness and successes of these interventions. This paper is intended for adolescents seeking

to understand the effects of substance use, researchers looking for a comprehensive overview of the topic, and clinics aiming to raise awareness about its impact on adolescent health.

3. Effect of Cannabis and Nicotine Use on Adolescents

3.1 Neurobiological Foundations of Addiction Risk

Adolescence is a neurodevelopmental period where one is highly susceptible to the effects of addictive drugs.[7] It is because brain regions develop asynchronously—most notably, the prefrontal cortex, which has executive functions like decision-making and restraint of impulses, and develops behind the faster-developing limbic system, which is responsible for seeking rewards and emotion regulation.[8,9,10] Such desynchrony heightens teenagers' predisposition to risk-taking behavior, including drug taking, while deteriorating their resistance to the same.

Exposure to nicotine and marijuana early in life during this period of vulnerability disrupts brain circuit development responsible for the regulation of reward and stress, priming susceptibility to addiction later in life.[11,12,13] Repeated nicotine exposure has been reported to trigger structural and functional brain alterations, including upregulation and desensitization of nAChRs, especially the $\alpha 4\beta 2$ subtype, a major component of the dopamine reward system.[14,15] These receptor-level changes augment sensitivity to dopamine release, facilitating drug-seeking behavior and propensity to further transition to other drugs of abuse.[16,17,18] Repeated substance exposure during adolescence causes persistent alterations in reward processing and stress regulation circuits, making the brain less responsive to natural rewards and more reactive to drug-related cues—conditions that heighten addiction susceptibility.

Nicotine, the primary addictive component of e-cigarettes, targets developing nAChRs in the adolescent brain.[2] This overstimulation amplifies dopamine signaling in the nucleus accumbens and prefrontal cortex, hijacking the reward system and encouraging the risk of long-term drug-seeking behavior.[3,4,5]

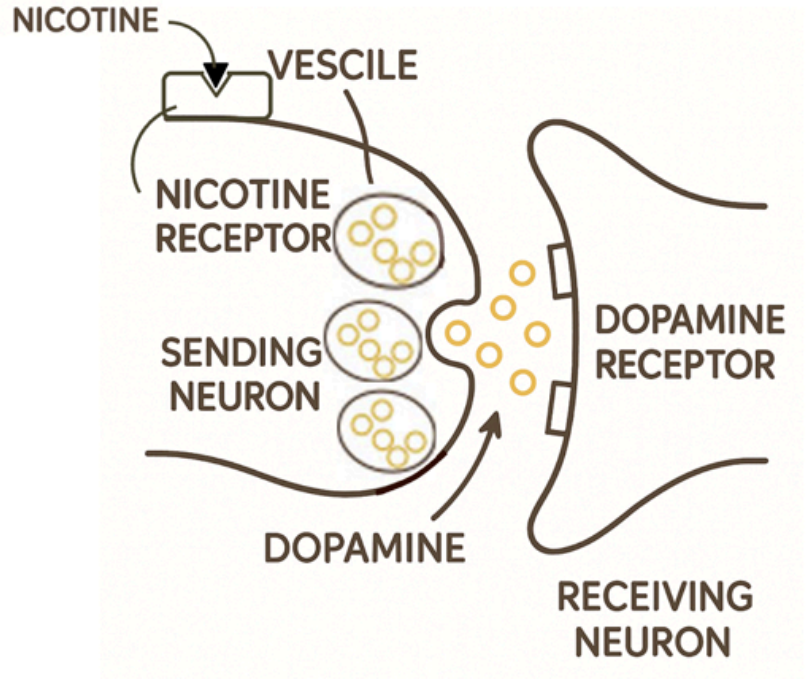

Figure 1: Nicotine binds to nicotinic acetylcholine receptors on the presynaptic (sending) neuron, releasing dopamine from vesicles into the synaptic cleft. Dopamine then binds to receptors on the postsynaptic (receiving) neuron, reinforcing reward-related behaviors and setting the stage for addiction.

Longitudinal epidemiological studies support this mechanism: early nicotine exposure significantly enhances the risk of adult polysubstance dependence, including alcohol, cannabis, and opioids.[6,7,8]

Teenage cannabis use interferes with important neurodevelopmental processes such as synaptic pruning and myelination, both of which are essential for emotional regulation and cognitive efficiency.[9,10] The interference has been linked to long-term deficits in affective control, attention, and memory. Perhaps most importantly, adolescent onset of cannabis use strongly predicts continued and dependent patterns of use throughout adulthood. [11,12]

A 2012 study showed that nicotine exposure during the adolescent period disrupts normal synaptic plasticity by impairing

spike-timing-dependent plasticity (STDP), a mechanism necessary for learning and memory.[13] Undeveloped cognitive control further results in poor impulse regulation and emotional instability, both of which increase the risk for addiction.[14,15] This is especially concerning among adolescents with a previous psychiatric disorder, such as depression or behavioral disorders, who are at higher risk of using substances as maladaptive coping strategies.[16,17]

Nicotine and marijuana also interfere with the hypothalamic-pituitary-adrenal (HPA) axis—the brain's mechanism for responding to stress—resulting in heightened sensitivity to emotional stress, enhanced cravings, and more rapid routes to substance dependence.[18,19] This dysregulation also weakens the brain's resilience to stress, leaving it more susceptible to substance abuse during times of duress.

Strong evidence indicates that initiation of e-cigarette and cannabis use in early life is linked with higher risk of substance use disorders and psychiatric problems during adulthood, such as depression, anxiety, and impairment of cognitive functioning.[20,21,22] These findings support the urgent need for interventions and policies targeting limitations on youth access to habit-forming substances.

3.2 Disruption of Decision-Making Circuits

Adolescent substance use significantly compromises brain systems that are required for rational decision-making and self-control. Nicotine and marijuana, when consumed during adolescence, interfere with the structural and functional maturation of the ventral striatum and prefrontal cortex—subcomponents of the mesocorticolimbic circuit required for cost-benefit analysis, response inhibition, and future planning.[23,24] Interference leads to heightened impulsivity, reduced capacity for delayed gratification, and heightened likelihood of engaging in high-risk behavior.

Nicotine acts on nicotinic acetylcholine receptors (nAChRs) to stimulate dopaminergic pathways in the ventral striatum. Repeated stimulation of these pathways during adolescence across a period of

years dysregulates reward anticipation and sensitizes animals to present reward.[25] This could be the reason for youth initiation of nicotine use being strongly associated with future use of alcohol and marijuana, a correlation widely referenced to support the gateway hypothesis. Concurrently, exposure to cannabis impairs synaptic pruning and myelination of the prefrontal cortex, which lowers executive control and alters the approach adolescents use to assess risks and consequences.[26,27] The resulting neural changes undermine their ability to make thoughtful, future-oriented decisions.

These neurobiological findings are supported by behavioral studies where nicotine- and marijuana-using teens performed significantly more poorly on decision paradigms such as the Iowa Gambling Task[28] and Go/No-Go paradigms[29], which examine both risk-taking and inhibitory control.[30] Each of these paradigms, in which adolescent users tend to seek short-term gains at long-term cost, evidence compromised reward evaluation and self-regulation.[31]These impairments are not temporary; instead, initial drug use is linked with long-term impairments in attention, working memory, and response inhibition.[32,33]

The consequences of impaired decision-making extend to the larger community. Early initiation of substance use places young people at higher risk for having unprotected sex, driving while intoxicated, being injured accidentally, and encountering legal or disciplinary trouble.[34,35] In addition, impaired decision-making caused by drugs has been found to lead to poor school outcomes, increased school dropout, and decreased educational attainment.[36] In the long term, these trends frequently are cumulative and result in disadvantage patterns that persist well into adulthood.

Cumulatively, the data reveal the intensity of the implications of initial nicotine and marijuana use. As they impact essential brain systems, these substances undermine adolescents' ability to control behavior and think through consequences.

3.3 Altered Mood Regulation and Emotional Processing

During adolescence, individuals tend to transition from relying on parents and guardians for support and develop independent emotional regulation strategies influenced by peers to manage their emotions. This developmental stage is marked by improvements in cognitive self-regulation, which includes greater use and flexibility in applying strategies like cognitive reappraisal.[37] Mood regulation is defined as the process of modulating the occurrence, duration, and intensity of internal states of feeling, positive or negative, and emotion-related physiological processes.[38] Dysregulation of emotional regulation is a key determinant of well-being during adolescence and can lead to severe mental health consequences. Emotional regulation deficits have been frequently linked to depressive symptoms, and therefore mood regulation emerges as an immediate target when trying to promote adolescent mental health. Both cannabis and nicotine have been shown to interfere with emotional processing directly at this vulnerable stage of brain development.

In "The Interaction of Oxytocin and Nicotine Addiction on Psychosocial Stress: An fMRI Study," researchers looked at how nicotine addiction alters the brain's response to stress, specifically through the hormone oxytocin, a hormone involved in mood regulation. Non-smokers and smokers were administered oxytocin and instructed to perform an anxiety-provoking task while being observed using fMRI imaging. The right superior gyrus anterior (rSTG) region, responsible for emotion and the right middle frontal gyrus (rMFG) which plays a role in decision making were scanned while conducting the experiment. The functional interaction between these regions is especially of significance since emotional information from the rSTG directly determines the decision-making process of the rMFG. Findings confirm that nicotine plays a significant role in brain regions and hormones influencing mood regulation. While oxytocin significantly reduced craving and stress in healthy subjects, it had very little effect on smokers, who continued to show high stress levels and abnormally high activity in the anterior right superior temporal gyrus. Furthermore, while oxytocin facilitates communication between the rSTG and rMFG, there was no difference in communication for smokers.

Cannabis also adversely affects emotion regulation in adolescents and studies evaluate the impact of the two primary components of cannabis, THC and CBD, on brain activity.[39] THC, also known as delta-9-tetrahydrocannabinol, is a compound found in the Cannabis sativa plant known to cause the "high" while CBD or cannabidiol, also part of the cannabis plant, is widely known to cause more feelings of relaxation.[40,41] Together, these compounds have been claimed to improve mental health problems, but the reality is that these compounds in cannabis have no real impact in decreasing mental health disorders such as obsessive-compulsive disorder and anxiety.[42]

The limbic striatum, a key structure for emotion regulation, mature strongly in adolescence and is particularly sensitive to THC, which disrupts salience network and limbic system activity, impairing emotional processing and inducing anxiety, mood changes, and psychotic-like symptoms. The study finds that contrary to popular belief, CBD does not mitigate the negative effects of THC on brain network connectivity and in some cases even aggravates distortions in emotional regulation. Regulation of mood as well as acquiring the ability to regulate emotions is a core part of adolescence, and early cannabis and nicotine use have direct implications for mechanisms for emotional regulation. Continued disturbances in emotional regulation have also been associated with teen depression and anxiety. In fact, the ages 18 to 19 years appear to be most vulnerable to the onset of depressive symptoms caused by cigarette, e-cigarette, and cannabis use.[43]

Recent evidence also shows that cigarette-related stimuli retain the ability to process attention and emotion even after cessation. In a 2015 study using event-related potentials, Robinson et al. found that although all participants, which included past, never, and current smokers, demonstrated early attentional responses to cigarette images. However, only current smokers displayed heightened late positive potential responses, which indicates strong motivational salience. Former smokers showed neural responses like never smokers, which suggests that there is some normalization of neurocognitive function over time. Conversely, cigarette stimuli persisted attentional

engagement across groups, implying that even visual exposure to smoking cues activates emotional processing systems regardless of use history, supporting the view that nicotine's neurological impact influences how adolescents and former users emotionally respond to triggers, contributing to relapse vulnerability or emotional dysregulation.[44]

At this critical juncture of emotional development, when adolescents are just beginning to acquire skills in managing and navigating through their feelings, substance use can have particularly long-lasting and negative consequences.

3.4 Long-Term Vulnerability and Future Susceptibility

When adolescents are exposed to nicotine or cannabis, their brains may become more vulnerable to addiction later. Nicotine, for example, affects the mesolimbic reward system, which controls how we experience pleasure. It increases dopamine activity in this area and makes the brain more likely to seek that same reward again.[45] Over time, this can make teens more likely to try other substances, like alcohol or opioids, even if they didn't originally intend to.[46] The brain gets used to that level of stimulation, and even if the person stops using nicotine, the system can stay more reactive to other drugs.

Cannabis works differently but has a similar outcome by interfering with the endocannabinoid system, which plays a major role in regulating mood, decision-making, and stress. During adolescence, this system helps the brain organize and "prune" connections that aren't needed anymore. But if THC is present, this process can be disrupted, which might make it harder for teens to manage stress and control their emotions. This could be one reason why people who start using cannabis young are more likely to develop cannabis use disorder later in life.[47]

Functional neuroimaging studies have shown that chronic cannabis use is associated with altered blood flow and activation in regions critical for executive functioning and attention regulation.[48] A systematic review of 41 neuroimaging studies found that while

structural brain differences were inconsistently reported, functional alterations, particularly reduced prefrontal metabolism during resting states and altered activation during cognitive tasks, were much more common.[49] Other studies show that regular users show increased activation in compensatory regions during cognitive tasks, while abstinence and intoxication are associated with decreased and increased activity, respectively, particularly in the cerebellum and frontal lobes.[50]

Long-term studies highlight the neurotoxicity of early and consistent cannabis use. In a 20-year longitudinal birth cohort study published in 2012, individuals who started their cannabis-use during adolescence, continuing regularly into adulthood, experienced a significant decline in neuropsychological functioning, including executive function, memory, and processing speed. The most persistent adolescent-onset users lost an average of 8 IQ points from age 13 to 38, a decline unable to be reversed even after quitting. These findings reinforce that adolescent cannabis exposure can cause enduring cognitive impairments that persist well into adulthood.[51]

Early use also affects the parts of the brain involved in thinking and planning. The prefrontal cortex, which helps with judgment and self-control, is still developing during adolescence. Nicotine has been shown to slow that development, making it harder for people to adapt, focus, or make decisions in the future.[52] Cannabis can also interfere with brain communication, which may lead to longer-term struggles with memory, focus, or impulse control.[53,54] These effects can last even after someone quits. A cross-sectional study of adolescent marijuana users aged 16 to 18 found that they exhibited slower processing speed, along with impairments in verbal learning, memory, and sequencing abilities.[55]

All of this shows that early use of nicotine and cannabis doesn't just create a short-term risk — it can shape how the brain functions for years to come. Teens who use these substances may find it harder to stop later and more likely to return to them under stress. That's why it's important to start prevention efforts early and make sure teens

have accurate information about how these substances can affect them, not just now, but in the future.

4. Current Research and Studies

4.1 Investigating Treatment and Neurodevelopment through Clinical Trials

Ongoing studies are still discovering the impact of nicotine and marijuana on the adolescent brain, in terms of addiction as well as brain function. One ongoing clinical trial at the American University of Beirut, "Assess the Influence of Nicotine Flux and Nicotine Form on Subjective Effects Related to Dependency", examines how the rate of nicotine delivery, also known as flux, influences craving, addiction potential, and overall user behavior as shown in Figure 2.[56]

Additionally, the researchers explore how nicotine forms (protonated vs. freebase) affect typical results of nicotine addiction such as the ongoing urge to smoke and increased satisfaction. In the study, 130 participants are exposed to various e-cigarette conditions with varying amounts of nicotine per second. The preliminary findings indicate that increased levels of nicotine delivery and protonated nicotine are more efficient in reducing craving. These findings suggest that adolescent risk for drug addiction is not simply based on the amount of nicotine consumption but also on speed of penetration into the system. [57]

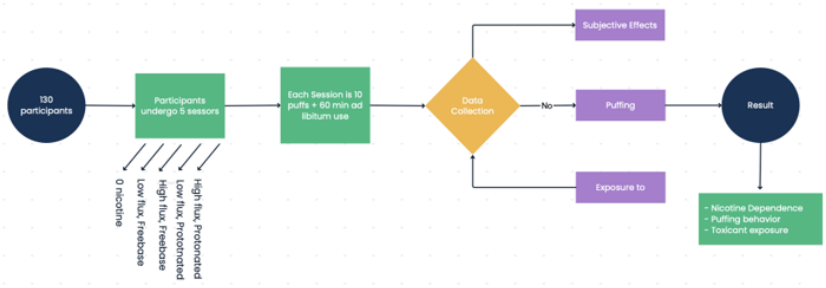

Figure 2: Flowchart depicting the study design of the clinical trial "Assess the Influence of Nicotine Flux and Nicotine Form on Subjective Effects Related to Dependency".

A total of 130 participants underwent five sessions using different levels of nicotine flux rates and forms. The results were then observed through subjective effects, puffing behavior, and exposure to toxicants.

Another ongoing clinical trial, "Determining the Effect of Six Weeks of Cannabis Abstinence on Fronto-Striatal fMRI Markers in Adolescents with Cannabis Use Disorder (ABSCAN)," examines how cannabis use affects the adolescent brain reward system. The research utilizes fMRI scans to examine how the brain reacts to reward and regions of the brain when resting, talking to each other. Cannabis and impulsivity are the focus area in the center, and the investigators find out how the drug affects self-regulation and reward response. Notably, the research also examines what happens to the brain after some time of abstention from cannabis, lessons regarding recovery capacity, and long-term impacts on teen cognitive performance and emotional regulation.[58]

4.2 Therapeutic Strategies for Adolescent Substance Use

As the long-term effects of adolescent nicotine and cannabis use become increasingly evident, scientists have focused on therapeutic treatments that can minimize or reverse neurobiological harm. Four evolving modes of treatment are typically utilized in accomplishing this, namely 1) neuromodulation, 2) varenicline, 3) abstinence-based recovery, and 4) cognitive behavior therapy (CBT). These treatments aim not only at the cessation of addictive behavior but also at recovery from cognitive and emotional deficits that arise because of early substance use.

4.3 Neuromodulation: Rewiring Dysregulated Brain Circuits

One interesting method involves neuromodulation, namely transcranial direct current stimulation

(tDCS). In a second study following up on an fMRI study of stress regulation in smokers, researchers applied tDCS to the anterior right

superior temporal gyrus, which is implicated in emotional processing and craving. Participants who received tDCS had reduced stress and craving levels, suggesting that stimulation of this area may normalize dysfunctional brain circuits in adolescent substance users.[59] This technique might be particularly beneficial for adolescents who have difficulty regulating their emotions or who relapse when under stress.

4.4 Varenicline: Pharmacological Targeting of Nicotine Dependence

Another approach that is gaining attention with regards to smoking cessation is a pharmaceutical called varenicline. A recent human study has demonstrated that varenicline significantly reduces receptor activity in important brain regions that are involved in reward processing such as the thalamus and the ventral striatum. Varenicline not only blocked those receptors but also decreased the typical dopamine release that is triggered by nicotine use. The dampening of the reward system is believed to reduce the addictive effects of smoking, lowering cravings and withdrawal symptoms.[60]

Another study was conducted in 2021, which proved the specific effects of varenicline. The study was conducted on mice, investigating varenicline's specificity in blocking mesolimbic circuit activation in response to nicotine. Using in vivo fiber photometry, researchers were able to observe that varenicline pretreatment enhanced the prevention of nicotine-evoked dopamine release in the nucleus accumbens by reducing the force of dopamine neuron activity in the ventral tegmental area. As a result, varenicline did not affect dopamine release in response to natural rewards such as food intake or exercise, highlighting its specificity in targeting nicotine-induced reward pathways.[61]

A randomized clinical trial involving adolescents aged 12–19 years assessed high-dose and low-dose varenicline versus placebo. The study found no significant advantage in abstinence rates with varenicline compared to placebo. However, the safety profile was consistent with adult data, showing no new tolerability issues.[62]

Pharmacological interventions that target the dopamine and endocannabinoid systems show promise for treating adolescent substance dependence. However, due to the ongoing maturation of the adolescent brain, these therapeutic methods pose significant risks. As Lee et al. (2014) emphasize, adolescence is marked by critical neurodevelopmental changes, particularly in regions of reward and self-regulation, leading this period to be both a window of opportunity and vulnerability for therapeutic intervention.[63]

4.5 Abstinence-Based Recovery: Harnessing Neuroplasticity

Another approach targets abstinence-based recovery, as was shown by the ABSCAN study through the observation of adolescents with cannabis use disorder across a six-week abstinence period. Researchers used fMRI to measure fronto-striatal activity prior to and following abstinence. The results showed alterations in the interaction of brain areas that oversee self-regulation and reward processing, and neuroplasticity can potentially be reversible with time following abstinence from cannabis use. The findings suggest that although early cannabis use can result in long-term impairments, the brain can have a finite capacity to recover, particularly if intervention is initiated early.[64]

This was also completed in another research study where adolescent marijuana users who had abstained for 28 days still showed abnormal fMRI activation patterns during spatial working memory tasks, including decreased dorsolateral prefrontal activity and increased posterior parietal recruitment. This suggests compensatory neural strategies, signifying that while abstinence may not immediately normalize brain function, it can initiate a trajectory of neurocognitive reorganization, supporting the potential for recovery if addressed early.[65]

4.6 Cognitive Behavioral Therapy: Strengthening Emotional and Executive Control

Along with biological interventions, cognitive behavioral therapy (CBT) is among the most prevalent and successful psychological interventions for adolescent substance use. CBT aims to identify cognitive processes underlying drug-seeking behavior and teaches coping skills for managing craving, stress, and social pressure.[66] One strategy of CBT is cognitive reappraisal, an adaptive regulatory strategy where individuals aim to alter their response to a situation by adjusting the way in which they consider the situation.[67] For example, if someone struggles with anxiety related to academics or examinations, rather than thinking, 'If I fail this test, my life is over' they can train themselves to understand that one test does not define them or their capabilities, and that they can learn from their mistakes and do better next time. Similarly, if an individual experiencing withdrawal changes their thought process from "I need to smoke right now or I won't be able to calm down" to "This craving is temporary, and there are healthier ways to cope with my stress," their addiction can shift from feeling uncontrollable to being manageable.

Although CBT does not actively address neurological damage, it has the advantage of enhancing emotional regulation and decision-making capacities that are typically compromised due to exposure to substances.[68] Some researchers are investigating pharmacological interventions, albeit with limited options at present. Medications that alter dopamine levels or affect the endocannabinoid system are being tried to assess their efficacy in decreasing cravings or mood stabilizing in adolescents in recovery from substance dependence. More research is necessary, however, before such medications could be available on a large scale to adolescent groups. In general, adolescent nicotine and cannabis smokers' treatment modalities are evolving. The combination of behavioral treatments with neurobiological interventions like tDCS or structured abstinence would be the most suggested way to go. Early intervention still remains important since the adolescent brain is still able to change if the right support mechanisms are introduced.

5. Discussion

Current literature reveals a consistent and disturbing trend: teen nicotine and marijuana use strongly erode the neurological, cognitive, and emotional processes on which healthy development depends. The adolescent brain, continuing in critical development—namely, the prefrontal cortex, limbic system, and mesocorticolimbic circuitry—is especially vulnerable to exogenous chemical disruption. Nicotine exposure enhances dopaminergic transmission and derails the control of reward anticipation, and cannabis derails the endocannabinoid system, synaptic pruning, and myelination. These neurobiological alterations cumulatively impair executive function, increase impulsivity, and decrease stress management ability.

These neurodevelopmental deficits have direct implications for real-world behavioral and psychological outcomes. Research shows that adolescents users score lower on tests of decision-making and inhibition that correlate with their greater risk to engage in risk behaviors such as unprotected sex, driving under the influence, and polysubstance use. In addition, earlier exposure foretells ongoing cognitive deficit, emotional dysregulation, and heightened susceptibility for psychiatric disorders such as depression and anxiety. Such repercussions not only affect the person involved but also come with societal impacts in general—e.g., lower educational achievements, increased costs for healthcare, and diminished national productivity.

Whereas earlier investigations have largely reviewed structural and functional brain alterations, current studies are only beginning to investigate interventions meant to reverse or forestall the consequences. Neuromodulation techniques, such as transcranial direct current stimulation (tDCS), and abstinence-based treatment regimens are now investigated for their potential to assist in the restoration of self-regulatory processes among adolescent substance users. Prevention, however, remains the most effective intervention. Education, restriction of access policy led by policy, and targeted behavioral interventions among high-risk youth are critical in reducing early exposure and its long-term consequences.

6. Conclusion

Marijuana and nicotine use during the early years of life have a strong correlation with both cognitive and behavioral impairment. These impairments are more likely to present poor performance on tasks that require sustained attention, impulse control, and executive function—abilities especially important during adolescence when pressures at school and socially increase. The adolescent brain in development is vulnerable to disruption from early use of these substances that continues.

Teenage marijuana use increases the risk of psychological damage such as depression, anxiety, and suicidal thoughts. The effects are not merely emotional—there are actual brain changes. Marijuana and nicotine both disrupt vital brain circuits responsible for mood control, including the prefrontal cortex, amygdala, and reward circuitry. Such disruption makes stress and emotional responding harder for adolescents to manage and puts them more at risk of psychiatric disease. In more developed cases, prolonged use in adolescence will lead to mood change that mimics psychotic symptomatology—paranoia, delusional ideation, and extremely unstable affect. These effects are especially dangerous because they are likely to go unnoticed or slip by undetected as a normal "teenager" reaction. Adolescents may therefore not receive proper intervention or support until such symptoms have reached advanced stages.

The long-term consequences of early marijuana and nicotine use can extend into adulthood. Although many users have stopped using, they continue to experience difficulties with attention, memory, emotional control, and motivation. Such issues impact school, job, and social relations. Because of this, early prevention, education, and access to mental health services are required. Early detection of the hazards can protect teen brain development along with the chances of more intense consequences down the line in life.

Ultimately, the adolescent brain is especially vulnerable to the negative effects of nicotine and marijuana. Both interfere with critical processes like emotion regulation, decision-making, and susceptibility to

addiction, increasing future risk for mental illness and other drugs. This article overviews how early drug exposure can lead to permanent changes of neurological development, particularly in regions such as the prefrontal cortex, limbic system, and mesocorticolimbic pathway, leading to heightened risk for addiction, cognitive dysfunctions, and psychiatric disease such as anxiety and depression. These do not happen in isolation but instead affect more general psychosocial influences, ultimately yielding greater long-term risks. As science continues to evolve, newer treatments such as neuromodulation, abstinence-based treatment, cognitive behavioral therapy, and pharmacologic treatments such as varenicline have the promise to reverse some of the early drug exposure neural compromise. Prevention, however, remains to be the best solution. Adolescent education, restriction of access to addictive drugs, and early incorporation of mental health services are the solutions to neuroprotection and reducing society's negative impact from drug disorders. Early detection is not only beneficial but also vital to the continued well-being of future generations.

References

1. Talih S, Hanna E, Salman R, et al. Influence of nicotine form and nicotine flux on puffing behavior and mouth-level exposure to nicotine from electronic nicotine delivery systems. *Drug and Alcohol Dependence*. 2024;254:111052. doi:10.1016/j.drugalcdep.2023.111052

2. Bogdanov VB, Wenzel J, Bar KJ, et al. Effects of nicotine on oxytocin-induced attenuation of psychosocial stress: an fMRI study. *Transl Psychiatry*. 2024;14(1):66. doi:10.1038/s41398-024-03016-5

3. Steinberg L. Risk taking in adolescence: new perspectives from brain and behavioral science. *Psychol Bull*. 2003;112(1):64-69. doi:10.1037/0033-2909.112.1.64

4. Squeglia LM, Jacobus J, Tapert SF. The influence of substance use on adolescent brain development. *West J Emerg Med*. 2009;10(3):216-224. doi:10.5811/westjem.2019.7.41661

5. Spechler PA, Allgaier N, Chaarani B, et al. Cannabis use in early adolescence: evidence of amygdala hypersensitivity to signals of threat. *J Adolesc*. 2021;90:57-65. doi:10.1016/j.adolescence.2021.07.001

6. Zilverstand A, Parvaz MA, Moeller SJ, Goldstein RZ. Cognitive interventions for addiction medicine: understanding the underlying neurobiological mechanisms. *Prog Brain Res*. 2016;224:285-304. doi:10.1016/bs.pbr.2015.07.008

7. Hindocha C, Freeman TP, Schafer G, et al. Acute effects of delta-9-tetrahydrocannabinol, cannabidiol, and their combination on facial emotion recognition: a randomized, double-blind, placebo-controlled study in cannabis users. *CNS Neurol Disord Drug Targets*. 2013;12(1):126-132. doi:10.2174/13816128113199990426

8. Casey BJ, Jones RM, Hare TA. The adolescent brain. *Ann N Y Acad Sci*. 2008;1124:111-126. doi:10.1196/annals.1440.010

9. Substance Abuse and Mental Health Services Administration (SAMHSA). *National Helpline*. https://www.samhsa.gov/find-help/helplines/national-helpline. Accessed April 18, 2025.

10. Pearlson GD, Yip SW, Scheinost D, et al. Cannabis use disorder and the brain: a scoping review of neuroimaging findings. *Neuropsychopharmacology*. 2024. doi:10.1038/s41386-024-01738-1

11. Zhornitsky S, Potvin S. Cannabidiol in humans-the quest for therapeutic targets. *Pharmaceuticals (Basel)*. 2012;5(5):529-552. Published 2012 May 21. doi:10.3390/ph5050529

12. Francesco Versace PhD. Vaping and your brain: What to know. *MD Anderson Cancer Center*. Accessed February 3, 2025. https://www.mdanderson.org/cancerwise/vaping-and-your-brain-what-to-know.h00-159696756.html.

13. Jacobus J, Tapert SF. Effects of cannabis on the adolescent brain. *Curr Pharm Des.* 2014;20(13):2186-2193. doi:10.2174/13816128113199990426

14. World Health Organization. (2024, January 16). *Tobacco use declines despite tobacco industry efforts to jeopardize progress*. World Health Organization. https://www.who.int/news/item/16-01-2024-tobacco-use-declines-despite-tobacco-industry-efforts-to-jeopardize-progress

15. Birdsey, J., Cornelius, M., Jamal, A., Park-Lee, E., Cooper, M. R., Wang, J., Sawdey, M. D., Cullen, K. A., & Neff, L. (2023). Tobacco Product Use Among U.S.

Middle and High School Students - National Youth Tobacco Survey, 2023. *MMWR. Morbidity and mortality weekly report*, *72*(44), 1173–1182. https://doi.org/10.15585/mmwr.mm7244a1

16. McGrath-Morrow SA, Gorzkowski J, Groner JA, et al. The effects of nicotine on development. Pediatrics. 2020;145(3):e20191346. doi:10.1542/peds.2019-1346

17. Wonnacott S, Sidhpura N, Balfour DJK. Nicotine: from molecular mechanisms to behaviour. Curr Opin Pharmacol. 2005;5(1):53-59. doi:10.1016/j.coph.2004.12.002

18. Markou A. Neurobiology of nicotine dependence. Philos Trans R Soc Lond B Biol Sci. 2008;363(1507):3159-3168. doi:10.1098/rstb.2008.0095

19. Dani JA, Heinemann S. Molecular and cellular aspects of nicotine abuse. Neuron. 1996;16(5):905-908. doi:10.1016/S0896-6273(00)80112-9

20. Le Foll B, Piper ME, Fowler CD, et al. Tobacco and nicotine use. Nat Rev Dis Primers. 2022;8(1):19. doi:10.1038/s41572-022-00346-w

21. Young KS, Sandman CF, Craske MG. Positive and Negative Emotion Regulation in Adolescence: Links to Anxiety and Depression. Brain Sci. 2019;9(4):76. Published 2019 Mar 29. doi:10.3390/brainsci9040076

22. Y. Fombouchet, "The development of emotion regulation in adolescence ...," The development of emotion regulation in adolescence: What do we know and where to go next?, https://onlinelibrary.wiley.com/doi/10.1111/sode.12684 (accessed May 9, 2025).

23. Bataineh BS, Wilkinson AV, Sumbe A, et al. The Association Between Tobacco and Cannabis Use and the Age of Onset of Depression and Anxiety Symptoms: Among Adolescents and Young Adults. *Nicotine Tob Res*. 2023;25(8):1455-1464. doi:10.1093/ntr/ntad058

24. McCaul ME, Wand GS, Kuwabara H, Dannals RF, Wong D, Xu X. The Relationship of Varenicline Agonism of α4β2 Nicotinic Acetylcholine Receptors and Nicotine-Induced Dopamine Release in Nicotine-Dependent Humans. *Nicotine Tob Res*. 2020;22(6):892-899. doi:10.1093/ntr/ntz080

25. "Assess the Influence of Nicotine Flux and Nicotine Form on Subjective Effects Related to Dependency," Clinicaltrials.gov, https://clinicaltrials.gov/study/NCT05430334?term=Nicotine+flux&rank=1 (accessed May 9, 2025).

26. "Determining the Effect of Six Weeks of Cannabis Abstinence on Fronto- Striatal fMRI Markers in Adolescents With Cannabis Use Disorder (ABSCAN)," Clinicaltrials.gov, https://clinicaltrials.gov/study/NCT06124846?term=ABSCAN&rank=1 (accessed May 9, 2025).

27. Yang J, Mejia MC, Sacca L, Hennekens CH, Kitsantas P. Trends in Marijuana Use among Adolescents in the United States. *Pediatr Rep*. 2024;16(4):872-879. Published 2024 Oct 15. doi:10.3390/pediatric16040074

28. Zevin S, Gourlay SG, Benowitz NL. Clinical pharmacology of nicotine. Clin Dermatol. 1998;16(5):557-564.

29. Kyerematen GA, Vesell ES. Metabolism of nicotine. Drug Metab Rev. 1991;23(1-2):3-41.

30. Haass M, Kübler W. Nicotine and sympathetic neurotransmission. Cardiovasc Drugs Ther. 1997;10:657-665.

31. T. Ng, "Tetrahydrocannabinol (THC)," StatPearls [Internet]., https://www.ncbi.nlm.nih.gov/books/NBK563174/ (accessed May 9, 2025).

32. M. Peter Grinspoon, "Cannabidiol (CBD): What we know and what we don't," Harvard Health, https://www.health.harvard.edu/blog/cannabidiol-cbd-what-we-know-and-what-we-dont-2018082414476 (accessed May 9, 2025).

33. Kayser RR, Haney M, Raskin M, Arout C, Simpson HB. Acute effects of cannabinoids on symptoms of obsessive-compulsive disorder: A human laboratory study. *Depress Anxiety*. 2020;37(8):801-811. doi:10.1002/da.23032

34. Schweinsburg AD, Nagel BJ, Schweinsburg BC, Park A, Theilmann RJ, Tapert SF. Abstinent adolescent marijuana users show altered fMRI response during spatial working memory. *Psychiatry Res.* 2008;163(1):40-51. doi:10.1016/j.pscychresns.2007.04.018

35. Robinson JD, Versace F, Engelmann JM, et al. The motivational salience of cigarette-related stimuli among former, never, and current smokers. *Exp Clin Psychopharmacol.* 2015;23(1):37-48. doi:10.1037/a0038467

36. Goldstein N, Carty JRE, Betley JN. Specificity of Varenicline in Blocking Mesolimbic Circuit Activation to Natural and Drug Rewards. *Neuroscience*. 2022;483:40-51. doi:10.1016/j.neuroscience.2021.12.016

37. Yuan M, Cross SJ, Loughlin SE, Leslie FM. Nicotine and the adolescent brain. *J Physiol.* 2015;593(16):3397-3412. doi:10.1113/JP270492

38. Goriounova NA, Mansvelder HD. Nicotine exposure during adolescence alters the rules for prefrontal cortical synaptic plasticity during adulthood. *Front Synaptic Neurosci*. 2012;4:3. Published 2012 Aug 2. doi:10.3389/fnsyn.2012.00003

39. Spear LP. The adolescent brain and age-related behavioral manifestations. *Neurosci Biobehav Rev.* 2000;24(4):417-463. doi:10.1016/s0149-7634(00)00014-2

40. Coronado C, Wade NE, Aguinaldo LD, Mejia MH, Jacobus J. Neurocognitive Correlates of Adolescent Cannabis Use: An Overview of Neural Activation Patterns in Task-Based Functional MRI Studies. *J Pediatr Neuropsychol.* 2020;6(1):1-13. doi:10.1007/s40817-020-00076-5

41. Silvers JA. Adolescence as a pivotal period for emotion regulation development. *Curr Opin Psychol.* 2022;44:258-263. doi:10.1016/j.copsyc.2021.09.023

42. Volkow ND, Koob GF, McLellan AT.

Neurobiologic advances from the brain disease model of addiction. *New England Journal of Medicine*. 2016;374(4):363-371. doi:10.1056/nejmra1511480

43. Meier MH, Caspi A, Ambler A, et al. Persistent cannabis users show neuropsychological decline from childhood to midlife. *Proc Natl Acad Sci U S A.* 2012;109(40):E2657-E2664. doi:10.1073/pnas.1206820109

44. McHugh RK, Hearon BA, Otto MW. Cognitive behavioral therapy for substance use disorders. *Psychiatr Clin North Am.* 2010;33(3):511-525. doi:10.1016/j.psc.2010.04.012

45. Lee FS, Heimer H, Giedd JN, et al. Mental health. Adolescent mental health--opportunity and obligation. *Science*. 2014;346(6209):547-549. doi:10.1126/science.1260497

46. Martín-Santos R, Fagundo AB, Crippa JA, et al. Neuroimaging in cannabis use: a systematic review of the literature. *Psychological Medicine.* 2010;40(3):383-398. doi:10.1017/S0033291709990729

47. Quickfall J, Crockford D. Brain neuroimaging in cannabis use: a review. *J Neuropsychiatry Clin Neurosci.* 2006;18(3):318-332. doi:10.1176/jnp.2006.18.3.318

48. Li X, Lu ZL, D'Argembeau A, Ng M, Bechara A. The Iowa Gambling Task in fMRI images. *Hum Brain Mapp.* 2010;31(3):410-423. doi:10.1002/hbm.20875

49. Lesage E, Sutherland MT, Ross TJ, Salmeron BJ, Stein EA. Nicotine dependence (trait) and acute nicotinic stimulation (state) modulate attention but not inhibitory control: converging fMRI evidence from Go-Nogo and Flanker tasks.

50. Gray KM, Rubinstein ML, Prochaska JJ, et al. High-dose and low-dose varenicline for smoking cessation in adolescents: a randomised, placebo-controlled trial. *Lancet Child Adolesc Health.* 2020;4(11):837-845. doi:10.1016/S2352-4642(20)30243-1

51. National Youth Tobacco Survey. Results from the annual National Youth Tobacco Survey (NYTS). U.S. Food and Drug Administration. January 22, 2025. Accessed May 11, 2025. https://www.fda.gov/tobacco-products/youth-and-tobacco/results-annual-national-youth-tobacco-survey.

52. World Health Organization. (2024, January 16). *Tobacco use declines despite tobacco industry efforts to jeopardize progress*. World Health Organization. https://www.who.int/news/item/16-01-2024-tobacco-use-declines-despite-tobacco-industry-efforts-to-jeopardize-progress

53. National Youth Tobacco Survey. Results from the annual National Youth Tobacco Survey (NYTS). U.S. Food and Drug Administration. January 22, 2025. Accessed May 11, 2025. https://www.fda.gov/tobacco-products/youth-and-tobacco/results-annual-national-youth-tobacco-survey.

54. Birdsey, J., Cornelius, M., Jamal, A., Park-Lee, E., Cooper, M. R., Wang, J., Sawdey, M. D., Cullen, K. A., & Neff, L. (2023). Tobacco Product Use Among U.S. Middle and High School Students - National Youth Tobacco Survey, 2023. *MMWR. Morbidity and mortality weekly report*, *72*(44), 1173–1182. https://doi.org/10.15585/mmwr.mm7244a1

55. Yang J, Mejia MC, Sacca L, Hennekens CH, Kitsantas P. Trends in Marijuana Use among Adolescents in the United States. *Pediatr Rep*. 2024;16(4):872-879. Published 2024 Oct 15. doi:10.3390/pediatric16040074

56. Casey BJ, Jones RM, Hare TA. The adolescent brain. *Ann N Y Acad Sci*. 2008;1124:111-126. doi:10.1196/annals.1440.010

57. Spear LP. The adolescent brain and age-related behavioral manifestations. *Neurosci Biobehav Rev.* 2000;24(4):417-463. doi:10.1016/s0149-7634(00)00014-2

58. Steinberg L. Risk taking in adolescence: new perspectives from brain and behavioral science. *Psychol Bull*. 2003;112(1):64-69. doi:10.1037/0033-2909.112.1.64

59. Squeglia LM, Jacobus J, Tapert SF. The influence of substance use on adolescent brain development. *West J Emerg Med*. 2009;10(3):216-224. doi:10.5811/westjem.2019.7.41661

60. Zevin S, Gourlay SG, Benowitz NL. Clinical pharmacology of nicotine. Clin Dermatol. 1998;16(5):557-564.

61. Squeglia LM, Jacobus J, Tapert SF. The influence of substance use on adolescent brain development. *West J Emerg Med*. 2009;10(3):216-224. doi:10.5811/westjem.2019.7.41661

62. McGrath-Morrow SA, Gorzkowski J, Groner JA, et al. The effects of nicotine on development. Pediatrics. 2020;145(3):e20191346. doi:10.1542/peds.2019-1346.

63. Kyerematen GA, Vesell ES. Metabolism of nicotine. Drug Metab Rev. 1991;23(1-2):3-41.

64. McGrath-Morrow SA, Gorzkowski J, Groner JA, et al. The effects of nicotine on development. Pediatrics. 2020;145(3):e20191346. doi:10.1542/peds.2019-1346

65. Wonnacott S, Sidhpura N, Balfour DJK. Nicotine: from molecular mechanisms to behaviour. Curr Opin Pharmacol. 2005;5(1):53-59. doi:10.1016/j.coph.2004.12.002

66. Squeglia LM, Jacobus J, Tapert SF. The influence of substance use on adolescent brain development. *West J Emerg Med*. 2009;10(3):216-224. doi:10.5811/westjem.2019.7.41661

67. McGrath-Morrow SA, Gorzkowski J, Groner JA, et al. The effects of nicotine on development. Pediatrics. 2020;145(3):e20191346. doi:10.1542/peds.2019-1346

68. Wonnacott S, Sidhpura N, Balfour DJK. Nicotine: from molecular mechanisms to behaviour. Curr Opin Pharmacol. 2005;5(1):53-59. doi:10.1016/j.coph.2004.12.002