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IN BRIEF
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Chronic Substance Use and Cognitive Effects on the Brain: An Introduction

Frequent use of a psychoactive substance (or substances) over an extended period, or *chronic substance use,* can negatively affect many aspects of a person's life and well-being. Although many body systems may be harmed by chronic substance use, this *In Brief* addresses ways in which the brain may be affected, with a particular focus on cognitive processes.

Psychoactive substances produce their effects by modifying chemical signaling in the brain, affecting feelings, perceptions, thought processes, and behavior. This can produce long-lasting alterations in the neural circuits responsible for normal learning and memory processes.[1] The cognitive effects of chronic substance use may abate relatively quickly with abstinence, resolve after weeks or months of abstinence, abate only with extended abstinence, or not abate at all.

This *In Brief* provides information for health and human services practitioners who may encounter clients with cognitive deficits related to chronic substance use. Awareness of the potential cognitive effects of chronic substance use is important because:

- Cognitive effects may make it more difficult for clients to engage in and benefit from health care and other services.
- Effects on *executive functions* may make clients in recovery from substance use, mental, or medical disorders particularly vulnerable to relapse.

Executive functions are the cognitive processes that regulate, control, and manage:

- Planning.
- Working memory.
- Attention.
- Problem-solving.
- Verbal reasoning.
- Inhibition.
- Mental flexibility.
- Task switching.
- Initiating/monitoring actions.

- Problems with cognitive functioning affect the quality of life of clients and may create additional social problems.

The *In Brief* will discuss ways in which chronic substance use may affect the brain, variables that can influence the effects, and some ways in which professionals can help clients who have substance-related cognitive impairments.

Ways in Which Chronic Substance Use May Affect the Brain

The process of addiction

Addiction is a chronically relapsing disorder characterized by a compulsion to take a substance, loss of control in limiting intake, and the development of a negative emotional state when the substance cannot be obtained.[2,3]

The process of addiction creates profound changes in the brain. The process is complex, and specific changes to the way the brain works can vary depending on the substance used. Brain reward circuits are often mentioned when discussing the effects of addictive substances and substance misuse. Addictive substances activate these circuits, resulting in pleasurable effects; because of this positive reinforcement, a person may be motivated to use such substances again. However, the process of addiction is functionally and structurally multifaceted, and motivation for continuing to use an addictive substance involves more than positive reinforcement.

One way of looking at how brain structures and systems are affected as addiction develops is to divide addiction into three stages:

1. Binge/intoxication
2. Withdrawal/negative affect
3. Preoccupation/anticipation (craving)

Each stage changes the brain in specific ways, and these changes interact with one another as addiction develops.[2,3] The following descriptions note the primary brain area or areas involved in each stage, but the descriptions are not exhaustive.

The first stage, binge/intoxication, is mediated in large part by neurocircuitry within the basal ganglia, a structure critical to the reward circuits.[3] Addictive substances create artificial pleasure signals that are stronger and longer lasting than normal pleasure signals, altering neurotransmitter signaling. The resulting enhanced reinforcement of substance effects can increase an individual's motivation to repeat use of the substance.[3,4]

The second stage, withdrawal/negative affect, involves two processes. First, there is continued disruption of reward circuits (particularly in the ventral striatum). Non-substance-use activities now have a diminished effect in activating reward circuits when compared with the effect they had before the onset of substance use. Second, the brain's stress systems are recruited into the process of addiction, with the extended amygdala playing a key role. At this point, *not* using the substance causes stress; an individual's use of the substance is now motivated more by negative reinforcement (avoidance of aversive effects of *not* using the substance) than by positive reinforcement.

The final stage, preoccupation/anticipation, or craving, involves impairment of executive functions by way of prefrontal cortex circuits. Loss of executive function in the prefrontal cortex can have adverse effects on both impulsivity and compulsivity. Along with the gradual changes in the reward system and increased stress sensitivity, this loss of executive function can further perpetuate the addiction cycle.[2,3]

The process of addiction includes the development, over time, of tolerance, meaning that greater amounts of a substance are needed to get the desired effects. Mechanisms similar to those involved in the development of tolerance can eventually lead to profound changes in neurons and brain circuits.[4] The regions and processes of the brain involved in addiction, particularly as the disorder becomes increasingly severe, significantly overlap with those involved in learning, memory, attention, reasoning, and impulse control.[5] These processes are particularly affected by chronic substance use.[4,5]

Physical damage

Although intoxication effects are short-lived, intoxication may indirectly lead to longer lasting negative effects on the brain—for example, via physical trauma caused by intoxication-related auto crashes, falls, or violence. Alcohol use, particularly among young adults, is especially correlated with

trauma.[6] A review article noted that up to three-quarters of patients diagnosed with traumatic brain injury tested positive for alcohol at the time of admission, and approximately half were intoxicated.[7] Negative effects on the brain may also be caused by physical damage related to substance use (e.g., damage due to stroke or vitamin deficiency).

Mental disorders

Substance use, including withdrawal from substance use, may also induce mental disorders. Substance-induced mental disorders may be temporary and abate quickly (typically within 1 month of abstinence). However, some substance-induced mental disorders are of long duration and abate only with extended abstinence or not at all (e.g., inhalant- or alcohol-induced neurocognitive disorder).[8] Substance-induced mental disorders can also negatively affect cognition.

Variables That Influence the Effects of Chronic Substance Use

The effects of chronic substance use can vary considerably across individuals. A substance's effects on the brain also depend to a great degree on the overall substance dosage, including the length of time a person has been using the substance, the frequency of use, the typical amount used, and the route of administration. Not surprisingly, the longer and heavier the use, the more likely it is that a substance will have negative effects on the brain.

Two additional factors appear to play significant roles in how and to what extent an individual's brain will be affected: age of substance use onset and genetics. Early substance use can have particularly deleterious effects on the human brain. The brain continues to develop throughout adolescence, and particularly important neural pathways are established during this period. For example, the prefrontal cortex of the brain is still maturing during adolescence. This part of the brain is involved in assessing situations, making sound decisions, and keeping emotions and desires under control.[4] In addition, during adolescence the brain is particularly malleable. Substance use during these years may seriously affect the normal course of brain development in long-lasting ways.[4,5] For example, a comprehensive review of the literature indicated that adults who routinely use cannabis and began using it before the age of 17 exhibit significantly more impairment in executive functioning than do adults who also routinely use cannabis but did not begin use until after the age of 17.[9] Heavy alcohol use during adolescence is also associated with cognitive impairments, particularly in memory and visuospatial processing (the ability to interpret visual information about where objects are in space).[10]

Advancing age might also increase vulnerability to the negative cognitive effects of substance use. For example, a pilot study that included age-matched controls found that older participants (ages 51–70)

> "Alcohol is especially toxic to the developing brain. Excessive alcohol use damages brain cells and the fibers that connect brain regions, shrinks certain brain regions, and stops new brain cells from maturing. Some brain regions, such as the ones involved in memory, continue to make new neurons during adolescence through the expansion of neural stem cells. But alcohol specifically targets neural stem cells, so its negative impact is magnified in adolescents.[11]

who were dependent on cocaine demonstrated greater impairment in psychomotor speed, attention, and short-term memory compared with younger participants (ages 21–39) who were dependent on cocaine.[12]

Genetic factors also play a role in how a substance will affect an individual. For example, according to a 2010 review article, several studies have found that certain variations in a particular gene (SLC6A3) are associated with increased risk of cocaine-induced paranoia and methamphetamine-induced psychosis.[13] Another example is the finding of increased risk of psychosis among adults who used marijuana in adolescence, but only among those who also carry a specific variant of the gene for catechol-O-methyltransferase.[14]

Clinical Implications of Neurological Effects of Chronic Substance Use

The neurological effects of chronic substance use may significantly affect a client's ability to remain abstinent and to manage other aspects of his or her life, such as developing a healthy lifestyle or recovering from a co-occurring medical or mental disorder. Deficits in information processing and other learning issues interfere with acquiring and applying coping and other skills needed for ongoing recovery from substance use, mental, or medical disorders.[9,15,16] Other cognitive issues that can further complicate recovery include:[17]

- Difficulties understanding complex instructions.
- Distractibility.
- Disorganized behavior.
- Lack of insight.

How Practitioners Can Help

Educate clients with cognitive deficits and teach life skills

Practitioners can talk with clients about the possibility of substance-use-related impairment and explain the ways in which it might interfere with treatment for substance use or mental disorders, health care, case management, or life goals.[9] When appropriate, practitioners can offer realistic reassurance that the impairment will be temporary and that there are ways of compensating for it.

Practitioners can further help clients with cognitive deficits better manage their lives by encouraging and teaching them to:

- Allow ample time to complete tasks.
- Check and recheck their work.
- Use memory aids such as calendars, diaries, pill containers, watches that beep, and sticky notepaper.
- Take advantage of smartphone features like alarms, voice recorders, calculators, and notepads.
- Establish and use cues to help remember skills and information.[9]
- Take some time before responding to situations; make lists and carefully weigh costs and benefits of actions instead of reflexively responding.[9]
- Develop routines for daily living.
- Ask for help when needed.

Provide or refer clients for treatment of co-occurring mental disorders

Mental disorders may bring their own cognitive deficits, which may exacerbate the deficits caused by chronic substance use. If a client shows signs of a mental disorder, such as depressive symptoms, suicidal thoughts or attempts, anxiety, paranoia, or auditory hallucinations, the client should be referred for psychological assessment. A qualified

mental health practitioner can monitor the course of the mental disorder over time and provide useful feedback to other service practitioners.

Adjust behavioral interventions to help compensate for deficits

Practitioners can help clients learn new information and skills in ways that can at least partially compensate for cognitive deficits. For example, practitioners can:

- Schedule shorter but more frequent sessions.[18]
- Use more than one modality (oral, graphic, video) to convey information;[18] provide written information in addition to verbal explanations.
- Use feedback-based learning approaches (e.g., frequent in-session rehearsal of skills);[17,18] provide specific, immediate, direct, and positive feedback.
- Repeat information frequently, in short and concise segments.
- Ask the client to repeat or paraphrase what he or she heard.
- Support a client's positive coping styles (e.g., actively addressing life problems as they arise, using humor to counteract stress, making time for enjoyable activities).

Refer clients for cognitive rehabilitation

Although cognitive rehabilitation programs may not be available or financially realistic, they can be very helpful for clients, particularly when the cognitive effects of substance use are likely to be long lasting. Practitioners should be aware of such programs where they are available and know the eligibility requirements, costs, and coverage options.

One such program is Goal Management Training (GMT), a validated, structured program for rehabilitating executive functions.[19] A pilot study examined the efficacy of a combination of GMT and mindfulness meditation with individuals with alcohol and polysubstance dependence along with deficits in executive functioning.[20] Clients who participated in a 7-week program that included GMT and mindfulness meditation significantly improved their performance on measures of working memory, response inhibition, and decision making. A matched control group of clients who did not receive the GMT and mindfulness program showed no significant improvement in executive functioning.

Coordinate with other care providers

Collaborative care teams can be particularly important for clients with cognitive deficits and/or substance-induced mental disorders. Teams can include physicians as well as practitioners who specialize in areas such as physical and neurological rehabilitation, substance-induced or co-occurring mental disorders, vocational rehabilitation, employment services, and family support services. Close collaboration among providers can help ensure consistent communication and facilitate meeting a client's complex needs in a coordinated and effective manner.

Summary

Chronic psychoactive substance use can affect the brain in a number of ways, both directly and indirectly. The effects depend in part on the type and quantity of substances used and the duration of their use. Individual factors such as genetics and the age of first use play a substantial role in determining the effects of chronic substance use on an individual's brain.

Cognitive effects of chronic substance use may make it more difficult for clients to engage in and benefit from treatment; make relapse to substance use, mental disorders, and physical disorders more likely; and make everyday life for clients more difficult.

Although most cognitive effects related to chronic substance use abate fairly quickly with abstinence,

others may take more time. Practitioners can help by understanding that cognitive deficits are common in clients who have substance use disorders, assessing clients for cognitive deficits, adapting behavioral interventions to help clients gain maximum benefit from treatment, teaching clients skills to help them navigate everyday life more efficiently, and, when appropriate and feasible, referring clients for cognitive rehabilitation.

Relevant Publications From SAMHSA

Substance Abuse Treatment Advisory: Treating Clients With Traumatic Brain Injury
http://store.samhsa.gov/product/Treating-Clients-With-Traumatic-Brain-Injury/SMA10-4591

Treatment Improvement Protocol (TIP) 29: *Substance Use Disorder Treatment for People With Physical and Cognitive Disabilities*
http://store.samhsa.gov/product/TIP-29-Substance-Use-Disorder-Treatment-for-People-With-Physical-and-Cognitive-Disabilities/SMA12-4078

Other Resources

National Institute of Neurological Disorders and Stroke
www.ninds.nih.gov

National Institute on Drug Abuse
www.drugabuse.gov

Society for Cognitive Rehabilitation
www.societyforcognitiverehab.org

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In Brief

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