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Neuroplasticity and Modern Addictions: The Brain's Response to Alcohol

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Abstract

Neuroplasticity is the brain's way of re-wiring itself due to repetitive actions. Neuroplasticity is the brain's neurons forming new connections allowing us to learn new things, forget a painful memory or adapting to new areas. Alcohol is a carcinogenic drug known for its toxicity on the brain's reward system. Alcohol increases the dopamine level in the brain and gives the drinker a feeling of pleasure and satisfaction telling the brain that the action is worth repeating. When taken repeatedly, the brain adapts to the high level of dopamine boost produced by alcohol and produces less dopamine on its own. This leads to a sense of dependence on alcohol as the producer of pleasure and satisfaction. The aim of this study serves to explore how alcohol affects the brain's adaptive structures reward, decision-making, and emotional control. This study will also discuss the consequences of acute and chronic alcohol use and abuse in personal life, work relationships and the society at large.

Keywords: neuroplasticity; alcohol; dopamine; neurons; addiction

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Introduction

1.1. Background Information

Neuroplasticity

Neuroplasticity also known as neural or brain plasticity is the ability of the brain to modify itself to fit or apply to changes to certain structures and functions in the presence of new stimuli.

Neuroplasticity is the brain's ability to form new neural connections thereby re-organizing itself. This allows for new learning experiences, adapting to new areas, recovering from illnesses.

Neuroplasticity goes further than childhood stage of life, employing itself in learning, memory, conditioned reflexes, recovery from brain damage by neurogenesis.

Neuroplasticity is the brain's response to external and internal insults rearranging its neural connections by creating more or weakening others to function properly. The response can be neutral (no change happens), positive (like restoration after after a brain injury such as stroke), or negative (pathological consequences or loss of a motor skill or memory).

Mechanisms of Neuroplasticity

1. **Neuronal Regeneration/ Collateral sprouting**

Neuronal regeneration involves the growth of injured axons to their original targets. The injured axons are guided back to their original targets by the Schwann cells.

Collateral sprouting refers to the sprouting of collaterals from neighbouring uninjured axons to the denervated area.

Although Neuronal regeneration is the primary mechanism for nerve reconnection, it is limited in the CNS due to inhibitory facts in the myelin sheath, leaving collateral sprouting as an important aspect of neuroplasticity, contributing to sensory and motor recovery.

While Ramon Cajal stated that adult brains had no more new neurons after the development of the brain, Josef Altman showed otherwise with convincing evidence of neurogenesis in adult rats (Puderbaugh M. & Emmady PD., 2023).

Neurogenesis is the generation of new nerve cells in the brain. The proposed sites for neurogenesis in adult humans is the olfactory bulb and the hippocampus, although not evidence-proven (Viel et al., 2020).

Synaptic plasticity is the ability of synapses to change their connections over time by either strengthening or weakening depending on the activity level of the neurons and neurotransmitter receptors involved.

This is as a result of the present synapses activity or the activity of synapses in another pathway (*Synaptic Plasticity (Section 1, Chapter 7) Neuroscience Online: An Electronic Textbook for the Neurosciences | Department of Neurobiology and Anatomy - the University of Texas Medical School at Houston, n.d.*).

An example could be forgetting how to manoeuvre directions in a town that you haven't been to for the past 10 years despite having grew up there or forgetting to drive properly after been off the wheel for years.

2. Functional Reorganization

This is the capacity of the brain to redistribute lost functions of a structure following brain damage or injury. The brain shift's activities from damaged or injured areas to unaffected regions.

1.2. BRAIN

The brain is one of the most important organs in the body as a person's survival depends largely on the brain. It is a complex organ that serves as a command center controlling every basic function in the body by the the information that comes into and leaves it in the form of stimulus.

The human brain makes up approximately 2% of the body mass and is made up of fat, water, carbohydrates, protein and salts. It weighs around 1.2kg in an adult female and 1.3kg in adult human males. The brain of a human baby weighs about 350-400g and is considered fully formed by the age of 25 (MSEd, 2023).

The external portion of the brain is grey matter while the internal region is white matter. Grey matter constitutes round central cell bodies and white matter is made up of mainly axons.

Mechanism of the Brain Function

The brain sends information and receives information by the use of chemical and electrical signals travelling throughout the body.

Information exchange occurs in the brain by the use of nerves. Neurons (nerve cells) are the foundational blocks of the nervous system.

1. Afferent nerve

Afferent neurons also known as sensory neurons carry information from the sensory receptors such as skin, and other organs to the central nervous system (CNS). examples of sensory information include vision, taste, sense of touch, temperature,smell, hearing.

2. Efferent nerve

Efferent neurons also known as Motor neurons transmit information away from the CNS (central nervous system) to the muscles and glands. The goal of efferent neurons serve to initiate an action. Example of information: retracting the hand after touching a hot object.

3. Interneuron

Interneuron, also known as the intermediate or association neurons act as a junction or a relay system between efferent and afferent neurons enabling information to be transmitted fully. They transmit signals from sensory neurons to motor neurons and other interneurons (Vandergriendt,2025).

1.3. *AIM*

The aim of this study serves to explore how alcohol affects the brain's adaptive structures reward, decision-making, and emotional control.

Effects of Alcohol on Brain Anatomy And Plasticity

2.1. Alcohol as a Substance Based Addiction

Alcohol, the main chemical ingredient in alcoholic beverages and drinks is classified as a central nervous system (CNS) depressant because it alters the brain chemistry. This means that it slows down brain functionality and neural activity affecting cognition, perception and emotion.

Alcohol use disorder (AUD) is a chronic brain disorder characterized by an compulsive urge to consume large quantities of alcohol despite the negative consequences and harm.

Alcohol addiction has a high relapse rate of over 50% in the first 3 months of trying to be sober due to environmental cues, stress, neurochemical triggers such as glutamate, GABA, opiods and dopamine systems.

Alcohol as an addiction is recognized as a chronic and relapsing disorder which directs neurochemical effects of ethanol on the brain's reward system despite harmful consequences on the body.

> *"There is no designated 'safe' level of drinking" ----- Amanda N. Donald, MD.* (Northwestern Medicine Staff & Northwestern Medicine, 2021).

Alcohol-based addiction causes change in brain structure and function in systems related to reward, motivation and self-control.

Alcohol addiction is marked by an intense urge for continual consumption, inability to limit use or behavior, needing more more for the same effect, withdrawal - physical or physiological symptoms when choosing to stop.

2.2. Acute vs Chronic Alcohol Use

Acute Alcohol Use

Acute alcohol use refers to the short-term intake of alcohol in a single episode. acute alcohol use can range from light drinking, binge drinking and accidental ingestion.

Acute alcohol use effects present as nausea, vomiting, slurred speech, loss of motor coordination, impaired judgement, drowsiness, increased risk of accidents and injuries.

Acute alcohol abuse refers to short-term, high intensity drinking, often in the form of binge drinking (consuming alcohol in less than 2 hours) to raise the concentration of the blood to greater than or equal to 0.08% (National Institute on Alcohol Abuse and Alcoholism [NIAAA], 2023).

Acute alcohol abuse which is usually binge or sporadic heavy drinking puts the drinker at heavy risk of intoxication, violence, hypoglycemia, acute gastritis, arrhythmias, alcohol poisoning, disinhibition, impaired judgement, respiratory depression, unsafe sexual activity, coma and even death.

While the body tries its best to absorb the copious amount of alcohol, it affects the;

- GABA-A receptors responsible for sedation and motor impairement
- NMDA glutamate recptors responsible for memory impairment.
- Dopamine release responsible for euphoria, lowered ininbition.

Chronic Alcohol Use

Chronic alcohol use refers to prolonged consumption of alcohol leading to lasting structural and functional damage to organs and psychological health.

Chronic alcohol users are considered heavy-drinkers as a result of their repeated and long-term consumption of alcohol from months to years.

Chronic alcohol use develops over consistent use over the years and has persistent negative effects on the health includes but are not limited to;

- Cirrhosis,
- Alcoholic hepatitis,
- Wernicke-Korsakoff syndrome (WKS),
- Dilated cardiomyopathy,
- Arrhythmias,
- Gastritis,
- Pancreatitis,
- Oesophageal varices,
- Depression,
- Anxiety,
- Memory impairment and
- Increased risk of cancer.

Abrupt withdrawal from chronic alcohol use can cause withdrawal symptoms in the form of seizures, tremors or delirum (Levesque et.al, 2023).

Chronic alcohol use affects the drinker's relationships with people, their jobs leading to possible social, financial and legal issues.

2.3. Short - Term Impairments vs Long Term Degeneration of Alcohol on the Body.

There are various effects of alcohol on the body. Some of the short-term effects listed below are based on the assumption that the drinker has a normal level tolerance to alcohol.

Heavy drinkers with a higher tolerance to alcohol can most times drink more without experiencing noticeable effects (NHS, 2022).

Short-term effects of alcohol on the body includes:

- Hangover,
- Dizziness
- Falls and injuries,
- Risky behaviour,
- Higher propensity to be violent,
- Lowered inhibitions,
- Alcohol poisoning,
- Frequent urination and dehydration,
- Stomach lining irritation,
- Hypoglycemia,
- Vasodilation of the blood vessels.

Long-term alcohol misuse can weaken the immune system of the body, increases high blood pressure, cholesterol levels, lead to dehydration and puts the drinker at a major risk for heart attack and stroke.

Long-term alcohol consumption contributes to over 200 types of different diseases and injury (Department of Health & Human Services, n.d.).

Heavy drinking of alcohol over several years takes a toll on the organs of the body such as the pancreas, heart and brain with the liver being more susceptible to alcohol intake of all the organs in the body (Thomes, 2021).

Long-term degeneration of the body associated with alcohol includes:

Weakened immune system

- Weak bones
- High blood pressure

- Stroke
- Pancreatitis
- Liver diseases such as cirrhosis, hepatitis
- Cancer of various organs (mouth, breast, liver, head, neck, mouth, bowel)
- Depression
- Dementia
- Reproductory organ issues such as erectile dysfunction, premature ejaculation, low sperm count.
- Suppression of the Brain and nervous system.

2.4. Affected Brain Areas

The brain like several organs in the body is affected by alcohol, however the level of brain damage and neurobehavioural deficit varies from person to person.

Alcohol affects the frontal lobe, limbic system, occipital lobe, cerebellum, hipocampus and brain stem. These regions of the brain are responsible for high-level thinking, motor coordination, decision-making, impulse control,memory formation, balance, cortical activity, speech, relaying sensory information and communication within the brain and hormone regulation.

- **Frontal Lobe**: The prefrontal cortex (PFC) is the anterior portion of the frontal lobe responsible for cognitive functions such as decision making, memory, personality and behaviour (Grujicic R.,Kenhub 2023).

Long-term alcohol use causes thinning of the prefrontal cortex in the dorsolateral and orbitofrontal regions and reduces it in volume leading to impaired reasoning, poor decision making, poorer impulse control. Chronic alcohol exposure over the years promotes neurodegeneration, disrupts myelination and slows communication between nerve cells (Prefrontal Cortex, 2023).

- **Cerebellum**: The cerebellum is vunerable to alcohol, both during fetal development and at adulthood.

Alcohol abuse leads to purkinje cell loss and white matter shrinking. This affects motor coordination and balance causing the 'staggering gait, slurred speech' that is easily associated with drunks. Chronic alcohol consumptionis associated with lasting lower limb tremors, increased risks of falls and cerebellar atrophy. (Mitoma H. et.al., 2021).

- **Hippocampus**: The hippocampus is known to function as the site of learning and memory and of spatial processing. Alcohol interefers with the glutamergic signaling and the Brain-Derived Neurotrophic Factor (BDNF) affecting the process of neurogenesis and causing a shrinking of the volume of the hipocampus (Mira et al., 2020).

Alcohol targets the hipocampus function of memory leading to difficulty in learning, reduced attention span and temporary 'blackouts'. Alcohol-induced blackouts are caused by high Blood alcohol content.

- **Brain Stem**: The brainstem consists of the mid-brain, pons and medulla oblongata . The medulla oblongata which is responsible for involuntary functions such as heart rate and breathing has a high level of vunerability to alcohol (Basinger & Hogg, 2023).

Chronic usage of alcohol depresses vital reflexes, causes neuronal apoptosis and hinders recovery in cardiovascular and respiratory centers.

- **Amygdala**: Alcohol causes an imbalance of GABA (Gamma aminobutyric acid) responsible for inhibiting chemical messages from travelling between nerve cells promoting a calming effect and glutamate which is responsible for permitting chemical messages travelling between neurons.

This reshapes the neuronal circuitry to favor alcohol-related pathways, heightening stress, anxiety and fear focused neuronal circuits.

Social Implications of Alcohol Use

3.1. Impacts on Mental Health; Depression, Anxiety, Cognitive Decline

Prolonged exposure of the body organs to alcohol exposes it to oxidative stress, inflammation and apoptosis in neural cells.

Alcohol disrupts synaptic plasticity and cognitive functions affecting the serotonin pathways responsible for mood regulation.

Alcohol acts as a depressant affecting the balance between the neurotransmitters (GABA and Glutamate) in the brain heightening anxiety, stress and poorer mood episodes in the drinker (Department of Health & Human Services, n.d.)

3.2. Societal Consequences

Reduced Productivity: Problematic alcohol consumption causes frequent missed deadlines, several careless mistakes, incomplete assignments, sleeping while working, reducing interest to work (LMFT, 2025).

Workplace performance decline: Alcohol use disorder leads to impairement of memory, behaviour and judgment. This leads to errors, accidents, absenteeism, and presenteeism which involves being physically present at work but poor work performance (Buvik, K., Moan, I. S., & Halkjelsvik, T. (2018).)

Economic burden: The World Health Organization mentions that alcohol-related productivity loss is a major contribution to the global economic cost of harmful drinking, which is estimated at **over 1% of GDP** in many countries (WHO, 2018).

Unemployment and job instability: Alcohol abuse constantly lead to the drinkers getting fired for their lack of productivity and strained relationship with workers to keep the work machine working properly.

Educational setbacks: For students, alcohol misuse can lead to poor academic performance, reduced learning capacity, and higher dropout rates.

Attention Disorders: Alcohol interferes with neurotransmitters involved in concentration, such as dopamine and acetylcholine. This disrupts focus, attention span, and information processing speed.

Alcohol-related neurodevelopmental disorders (ARND)**:** Prenatal exposure to alcohol can cause attention deficits in children (closely linked to fetal alcohol spectrum disorders).

Alcohol and ADHD (Attention Deficit Hyperactivity disorder): Individuals with attention-deficit/hyperactivity disorder (ADHD) are at higher risk of alcohol misuse, which in turn worsens their attention problems—a harmful cycle that burdens families and social institutions.

Conclusion

Neuroplasticity which is the brain's remarkable ability to rewire, re-position and regenerate itself works both for us and against us.

Alcohol, especially with repeated usage over a long period of years hijacks the positivity of neuroplasticity from the users, re-shapens neural circuitry in ways that reinforces alcohol tolerance, cravings and dependence.

While the effects of occasional alcohol use is reversible, chronic abuse of alcohol over a long period of time, affects the structural and functional aspects of the brain turning the power of neuroplasticity neurotic wiring the brain towards alcohol dependence.

Understanding the brain's power of neuroplasticity gives power to possibility.

Since every habitual consistent sip stands to train the brain and re-route its circuitry, the brain can also change in the direction of healing.

References

 doi:10.20944/preprints202509.1916.v1

1. Buvik, K., Moan, I. S., & Halkjelsvik, T. (2018). Alcohol-related absence and presenteeism: Beyond productivity loss. *The International journal on drug policy*, *58*, 71–77. https://doi.org/10.1016/j.drugpo.2018.05.005
2. Department of Health & Human Services. (n.d.). *How alcohol affects your body*. Better Health Channel. https://www.betterhealth.vic.gov.au/health/healthyliving/how-alcohol-affects-your-body
3. Mira, R. G., Lira, M., Tapia-Rojas, C., Rebolledo, D. L., Quintanilla, R. A., & Cerpa, W. (2020). Effect of alcohol on Hippocampal-Dependent plasticity and Behavior: Role of glutamatergic synaptic transmission. *Frontiers in Behavioral Neuroscience*, *13*. https://doi.org/10.3389/fnbeh.2019.00288
4. Mitoma, H., Manto, M., & Shaikh, A. G. (2021). Mechanisms of Ethanol-Induced Cerebellar Ataxia: underpinnings of neuronal death in the cerebellum. *International Journal of Environmental Research and Public Health*, *18*(16), 8678. https://doi.org/10.3390/ijerph18168678
5. *Neuroscience: The Brain in Addiction and Recovery | National Institute on Alcohol Abuse and Alcoholism (NIAAA)*. (2025, May 8). https://www.niaaa.nih.gov/health-professionals-communities/core-resource-on-alcohol/neuroscience-brain-addiction-and-recovery?utm_source=chatgpt.com
6. Puderbaugh, M., & Emmady, P. D. (2023). Neuroplasticity. In *StatPearls*. StatPearls Publishing.
7. World Health Organization. (2018). *Global status report on alcohol and health 2018*. https://apps.who.int/iris/handle/10665/274603
8. Levesque, C., Sanger, N., Edalati, H., Sohi, I., Shield, K. D., Sherk, A., Stockwell, T., Butt, P. R., & Paradis, C. (2023). A systematic review of relative risks for the relationship between chronic alcohol use and the occurrence of disease. *Alcohol Clinical and Experimental Research*, *47*(7), 1238–1255. https://doi.org/10.1111/acer.15121
9. Viel, T., Toricelli, M., Pereira, A. R., Abrao, G. S., Malerba, H., Maia, J., & Buck, H. (2020). Mechanisms of neuroplasticity and brain degeneration: strategies for protection during the aging process. *Neural Regeneration Research*, *16*(1), 58. https://doi.org/10.4103/1673-5374.286952
10. *Synaptic Plasticity (Section 1, Chapter 7) Neuroscience Online: An electronic textbook for the neurosciences | Department of Neurobiology and Anatomy - The University of Texas Medical School at Houston*. (n.d.). https://nba.uth.tmc.edu/neuroscience/m/s1/chapter07.html?utm_source=perplexity
11. Thomes, P. (2021b). Natural recovery by the liver and other organs after chronic alcohol use. *Alcohol Research*, *41*(1). https://doi.org/10.35946/arcr.v41.1.05
12. Northwestern Medicine Staff & Northwestern Medicine. (2021, March 30). *How alcohol impacts the brain*. Northwestern Medicine. https://www.nm.org/healthbeat/healthy-tips/alcohol-and-the-brain
13. Basinger, H., & Hogg, J. P. (2023, July 4). *Neuroanatomy, brainstem*. StatPearls - NCBI Bookshelf. https://www.ncbi.nlm.nih.gov/books/NBK544297/#:~:text=The%20brainstem%20is%20the%20structure,%2C%20pons%2C%20and%20medulla%20oblongata
14. *Prefrontal cortex*. (2023, October 30). Kenhub. https://www.kenhub.com/en/library/anatomy/prefrontal-cortex
15. MSEd, K.C. (2023, November 26). *The size of the human brain*. Verywell Mind. https://www.verywellmind.com/how-big-is-the-brain-2794888
16. LMFT, L. K. W. P. (2025, February 12). *Alcoholism in the workplace: Effects of alcohol in the workplace*. American Addiction Centers. https://americanaddictioncenters.org/alcohol/workplace?hl=en-US
17. Vandergriendt, C. (2025, August 1). *An Easy Guide to Neuron Anatomy with Diagrams*. Healthline. https://www.healthline.com/health/neurons
18. Website, N. (2025, August 27). *Risks*. nhs.uk. https://www.nhs.uk/conditions/alcohol-misuse/risks/#:~:text=After%20drinking%2010%20to%2012,reach%20toxic%20(poisonous)%20levels