Neurophysiology of Alcohol in Human Beings

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Abstract

This paper examines the neurophysiological changes that Alcohol brings in human body. Alcoholism is a weakening ill for the society and the individual. Alcoholism is associated with the related combination of environmental and genetic factors and is connected to brain defects and the changes in physiological and behavioral pattern. The studies about Alcoholism in association with neuroimaging, neuropathological and neuropsychological research has depicted that cerebellum and the limbic system are prone to more damages.

Excessive usage of alcohol will bring changes on the neural circuits and neural transmitters that control the sensitivity, stress and thought process in a human. As the exposure towards alcohol increases, the neural circuits adapts and the neuroadaptations brings changes in the sensitivity and tolerance level of the body. There is a stage of transition from alcohol consumption to alcohol dependence which is then associated with a withdrawal syndrome when there is a gap in the consumption of alcohol or an attempt to stop the usage. This study aims to analyze the changes that alcohol brings to the brain, nervous system and the resultant chemical structures that control the functions and activities of a human body.

Keyword: *Acetaldehyde, Neuroimaging, Limbic System, Neurogenesis, Cerebellar Ataxia, Excitatory, Inhibitory, Basal Forebrain.*

Chapter 1: Introduction

Alcohol and alcoholic beverages contain a psychoactive drug named ethanol, which is of an addictive potential and gives a relaxing and euphoric effect while consuming. Alcohol consumption leads to more than 60% of acute and chronic health conditions irrespective of the quantity consumed. Research and studies by scholars have suggested that intaking a small quantity of alcohol on a daily basis will help in preventing diseases such as diabetes, heart attacks but the studies have failed to pinout the **safe level** of consumption. The genetic and environmental factors have a role in the intake of alcohol to its transition to alcoholism. It differs from and individual to an individual on how one reacts to the consumption of the same quantity because it depends on the genetically passed neuro-chemical transmitters in the brain. There is a motivational factor behind consuming alcohol and the motivational factor is different from the initial stage of consumption to the regular stage as there is a change in the sensitivity towards alcohol.

When alcohol is broken down, one of the primary component product is **acetaldehyde** and it has a significant impact on the brain. Opiates are a drug derived from opium and it binds on to the opium receptors in the brain to produce a morphine effect. These opiates are produced by a chemical process named condensation which includes the involvement of dopamine and similarly certain studies shows that excessive consumption of alcohol will lead to the production of acetaldehyde in the brain which then will channel the process of condensation that will bind with the chemical receptors in the brain. Alcohol activates certain brain receptors which in turn stimulates certain chemical hormones in the body and these chemical hormones brings certain effects such as more courage, confidence and other traits as the subconscious mind is more active and the conscious mind goes to a dormant stage.

Around 25.5% of the alcohol produced and consumed are illegally and is not monitored in an effective legal manner which leads to consumption at an earlier stage because studies through geographical analyzation have revealed that the minimum age of the beginning of alcohol consumption is from the age of ‘15’. Certain studies also consider gender as a factor in the neurophysiology of alcoholism. Studies through **Neuroimaging** provide data that females are more prone to brain impairments compared to the males because of certain compositional tissue differences that occur because of the difference in gender.

1.2 OBJECTIVES OF THE STUDY.

- To understand the impact of alcohol on the central nervous system and the brain
- To analyze how the consumption of alcohol brings certain effects of intoxication associated with the the different parts of the brain.
- To Study the different factors that influence the alcoholic behaviour in an individual
- To analyze the different techniques and studies used to determine the damage caused by alcohol in human brain

1.3 SCOPE OF THE STUDY

The scope of the study is confined to individuals between the age group of 18-29 who consume alcohol. Data was collected and analyzed using an online survey and questionnaire developed with survey software. The subjects of the questionnaires are all college students and individuals between the age group of 18-29.

1.4 RESEARCH DESIGN

My research study titled 'Neurophysiology of Alcohol in Human Beings.' is a of research. It is a quantitative study due to its use of statistical tools. I have followed the process as listed above in carrying out the research study.

1.5 RESEARCH METHODOLOGY

My research study titled 'Neurophysiology of Alcohol in Human Beings.' has been prepared through both Primary and Secondary sources of information such as conducting interviews, questionnaires, articles and survey reports secondary sources of data, from published works, journals and YouTube videos to understand the effect of ethanol in depth.

1.6 SAMPLING TECHNIQUE

A sample is a mere representation of a larger universe. A universe / population in a research study is the whole set of observations of shared or common characteristics about which the researcher wishes to study. The universe with respect to my study would include College students and individuals between the age group of 18-29. My questionnaire has a sample size of 40 responders.

Statistical Tools for Research Study:

The most important statistical tools utilized in this study would be pie charts accompanied by tabular representation of data.

1.7 LIMITATIONS OF THE STUDY.

➢ The study was conducted during a short period of time hence a detailed assessment could not be prepared.

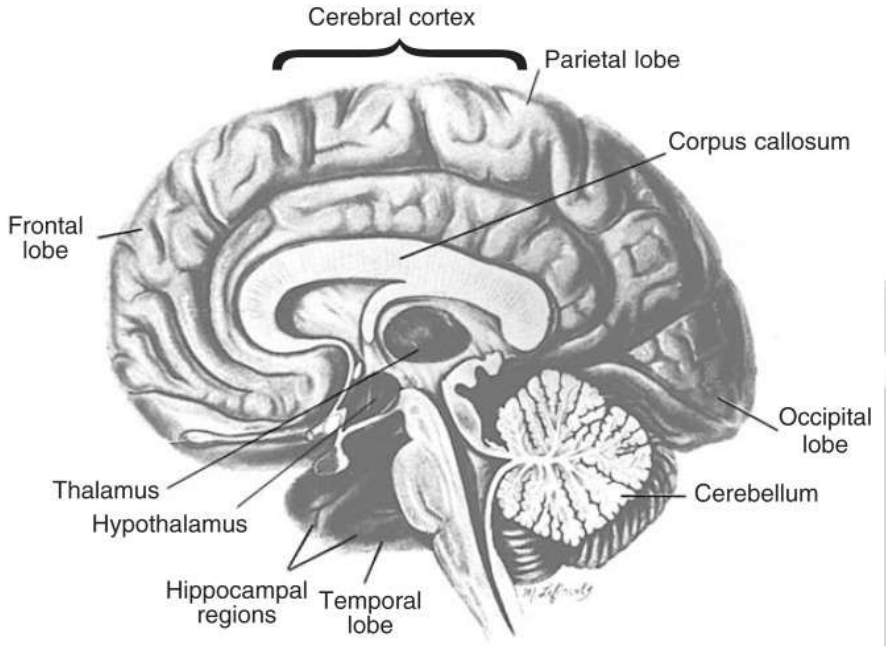
➢ Certain experiments could not be conducted as the experimentation on human beings with alcohol is risky and prohibited.

➢ Certain people were reluctant to cooperate with the interview as the research was based on alcohol.

Chapter 2: Parts of the brain it affects and how it affects

The effect of the consumption of alcohol differs from an individual to individual as it depends on many factors such as age, gender, genetics, family history of consumption, the age at which he/she started drinking and many

more. The brain has two parts i.e., gray matter and white matter. The Gray matter or the cerebral cortex is the part that controls the complex activities while the white matter or nerve fibres connects the different regions of the brain. Alcohol generally affects all the parts of the brain and it mainly has an impact on the **limbic system**, **Thalamus**, **Hypothalamus**, and **Basal forebrain.**



The above diagram shows the different parts of the brain that are prone to Alcohol intoxication damage.

CEREBRAL CORTEX: The cerebral cortex is the layer that is on top of the cerebrum and is the outermost layer of the brain. The cerebrum divides the brain into two hemispheres and the cortex consists around 14-16 billion nerve cells which are responsible for high level thinking functions of the brain. The cerebral cortex function on the basis of senses of a person and on the consumption of alcohol, it supresses the senses, decreases the capability of the functioning and increases the tolerance of pain. It is the cerebral cortex that coordinates high level functions such as decision making, speaking, thought processing, language one speaks, movement of the body and many more. One other effect is that people who generally speak less and are reserved by nature open up and talk confidently when they consume alcohol and that is because of the effect it has on the cerebral cortex. People tend to make poor decisions as their judgement and thought process are influenced because of the effect of alcohol.

CENTRAL NERVOUS SYSTEM: The central nervous system consists of the brain and the spinal cord. All the actions (muscular) or any that a person intends to do is done by the central nervous system. When a person intends to do, the thought process is done in the brain and the message is passed on to the nervous system which then coordinates the action. Alcohol affects the central nervous system by slowing down one's actions i.e. it slows down the hand-eye coordination, muscular movement, creates a troubled vision and many more. Prolonged and excessive consumption of alcohol can lead to the destruction of the brain cells and neurons. For example, a person will find it hard to drive after the consumption of alcohol and it is because of the lack of hand-eye coordination because of the toxic effect of alcohol.

HIPPOCAMPUS: The hippocampus or the hippocampal region is that part of the brain which is associated with the storage of memory and plays a crucial role in the process of learning and acquiring knowledge. When a person consumes alcohol and when it affects the hippocampus, one is subjected to face memory loss and will face a condition where he/she is unable to remember certain things such as his phone number, ATM pin or any other matter that the person has learnt recently. From my personal experience I can relate to this as I have had experiences where I had forgotten my ATM pin when I was intoxicated. Another adverse effect of alcohol on

hippocampus is that people tend to experience gaps in their memory on the events occurred while they were intoxicated.

The loss of memory is because of the effect of alcohol on the electrical activity of the neurons and it causes a delay in the firing of electrical activity and it some cases it inhibits the firing. There is also an important process that takes place in the hippocampus called the **Neurogenesis.** Neurogenesis is the process where new neurons are produced in the hippocampus and the alcohol will affect the neurogenesis after a certain stage which then will have an impact on an individual learning and knowledge acquiring capacity.

FRONTAL LOBES: Frontal lobes are a part of the brain which is also a part of the cerebral cortex. There are two frontal lobes, left frontal lobe and the right frontal lobe. The left frontal lobe controls the muscle movement in the right side of the body and vice versa. Both the frontal lobes control in an opposite manner. The frontal lobes are associated with the control of the emotions and also controls the muscular movement. Alcohol affects the frontal lobes by affecting the emotional control of a person and also by reducing the self-control. One will fail to recognize emotions in others and will have a change in the personality. The change in personality causes a change in the social behaviour of an individual as the alcohol affects intelligence level and the behavioural traits of a person because it is the frontal lobe that controls the person's body language, thought process and other components that form a character of a person. The actions and activities of the frontal lobe are somewhat similar to the **Cerebral Cortex** as it is a part of it.

CEREBELLUM: Cerebellum is a part of the brain that is located near to the spinal cord and at the back side of the skull. This part is responsible for the motor functions of the body and also the balance and posture. It has two hemispheres and both the sides control the muscular activity on the same side unlike in the frontal lobes.

Alcohol affects the cerebellum by affecting the posture and balance of an individual while walking and standing. In some cases, it has been observed that certain people find it difficult to analyse the size and distance of an object. Certain neuroimaging and neurotransmission studies have revealed that alcohol has led to the shrinkage of the cerebellum because of the loss of tissue. **Cerebellar Ataxia** is a condition which is caused by the excessive consumption of alcohol where an individual loses the balance and muscular controls of the body because of the intoxication. It is because of the effect of alcohol that people find hard to walk and stand after consuming alcohol and there is a loss in eye hand and eye foot coordination.

HYPOTHALAMUS: Hypothalamus is the part of the brain that Is like the main control centre as it coordinates the main vital functions of the body such as heart rate, hunger, Blood pressure, body temperature and many more. This part is the major actor in the release of hormones in the body by sending chemical signal to each gland as and when required. Its main job is to keep the body in a stable condition termed as "homeostasis" or a stable stage. It acts according to the chemical messages received from both the external and internal environment. Consumption of alcohol has an effect on the hypothalamus by increasing the hunger and blood pressure after the consumption.

Alcohol cause irregular menstrual cycle and also decreases the fertility in females because of the effect caused on the hormonal release and causes irregularity in the hormones. Even though alcohol increases the sexual desire, it decreases the sexual performance because of the hormonal irregularity which then causes an adversity in the genitals.

MEDULLA OBLONGATA: It is the part of the brain which is located at the bottom and controls all the necessary important functions of a human body such as breathing, heart beat and many more. It establishes a connection between the brain and the spinal cord and passes on information from the brain to the spinal. Medulla is responsible for the control of certain involuntary actions such as coughing, vomiting, sneezing etc.

When alcohol Is consumed, it affects the medulla by causing a delay in the passing of messages from the brain to the spinal cord and it blocks the passage of the communication. Another adverse effect is that some people tend to loose their consciousness and reaches a stage of passing out. When a large amount of alcohol is consumed, it takes the brain to an overdose stage where the medulla is totally affected by ethanol causing fatal consequences such as troubled breathing, irregular heart functioning and in some cases death.

Even though alcohol affects the brain, it doesn't affect everyone in the same manner as many factors such as the drinking environment, genetical factors, family drinking history, age from which he/she started drinking, age, sex and many other factors plays a vital role on how alcohol impacts the brain and the body. But it can be

understood from the above explanations that alcohol has a severe impact on the brain and has vital consequences as one is subjugated to the prolonged use of alcohol.

Chapter 3: Alcohols effect on neurons

The brain is a complex structure of billions of neurons and the consumption of alcohol has an adverse effect on the neurons. There are two neurons in the brain, **Inhibitory** neurons and **Excitatory** neurons. The neurons are functioned to relay chemical messages and coordinate activities and they are more functioning when they are positively charged and less when they are negatively charged. The excitatory neurons are functioned to pass on the electrical messages while the function of Inhibitory neurons is to reduce the responsiveness and to check whether any excessive firing happens in the neurons.

When a person starts to consume alcohol, the balance between inhibitory and excitatory neurons are disrupted. The level of the inhibitory neurons increases and the excitatory neurons decrease. There are GABA system and GABA receptors in the inhibitory neurons and when alcohol binds on to these GABA receptors, it induces the inflow of negatively charged ions into the neurons making it more negatively charged which in turn leads to less response. When alcohol binds on to the Glutamate receptor it induces the inflow of positively charged ions and then the brain reaches a state of **Adaptiveness** where the balance is restored. But when a person abstains from the consumption of alcohol, the brain will be damaged because of the excess production of **Calcium** by the glutamate receptor which was induced by the binding of alcohol.

Chapter 4: Studies in human beings related to alcoholism and its effects

Post-mortem Studies

The post mortem studies on the brains of alcoholics had revealed that the brain had undergone shrinkage compared to its actual size and also showed changes in the neurophysiological structure and physical structure (colour and complexity). It also revealed that people who consume a large amount of alcohol and less amount of food had more damage to their brains especially affecting cerebrum and thalamus.

Pneumoencephalography

Pneumoencephalography is one the oldest techniques used in the studies of determining the effect of alcohol. In this technique, a needle is inserted into a subject and then the fluid around the brain (cerebrospinal fluid) is removed and then air is inserted or at times other substitutes such as oxygen is filled. After the removal of the fluid, an x-ray image is taken to analyse the damage induced by alcohol by examining the shape and size of brain or the difference in the structure of the ventricles and other lobes.

This method only provides an x-ray image and fails to analyse the tissue and neuron damages.

MRI

Through MRI, the difference in the volumes and composition of the white matter and grey matter, especially the white matter is analysed which is caused by the influence of ethanol. Certain factors such as the age, drinking habits, quantity of alcohol consumed matters when it comes to MRI as it varies from person to person on the quantity of alcohol in taken into the body. But a general common result showed that people with more age tend to show lesser volume of grey matter and white matter as they had consumed more alcohol in their entire life but there are cases where this generalisation was not applicable.

Functional MRI

The other methods and techniques such as MRI and Pneumoencephalography, gives a structural image and volume differentiation with which conclusions or analysis are made to find out the impact of alcohol on the brain but fails to provide data on the functional changes of the brain. Functional MRI is a method through which the functional changes of the brain can be analysed. In this method, a subject is asked to perform certain functions and the part which is activated to perform the task is identified through scanning and how efficiently the task is carried out is found out.

It was observed through this method that people who consume alcohol activated a different part of the brain to perform a certain task compared to a person who doesn't and consume alcohol and the efficiency depended on the health of the neuron which then differed among alcoholics on the basis of certain characteristics such as drinking history, drinking habits, age and many other.

Chapter 5: Factors affecting an individual's relation to alcohol

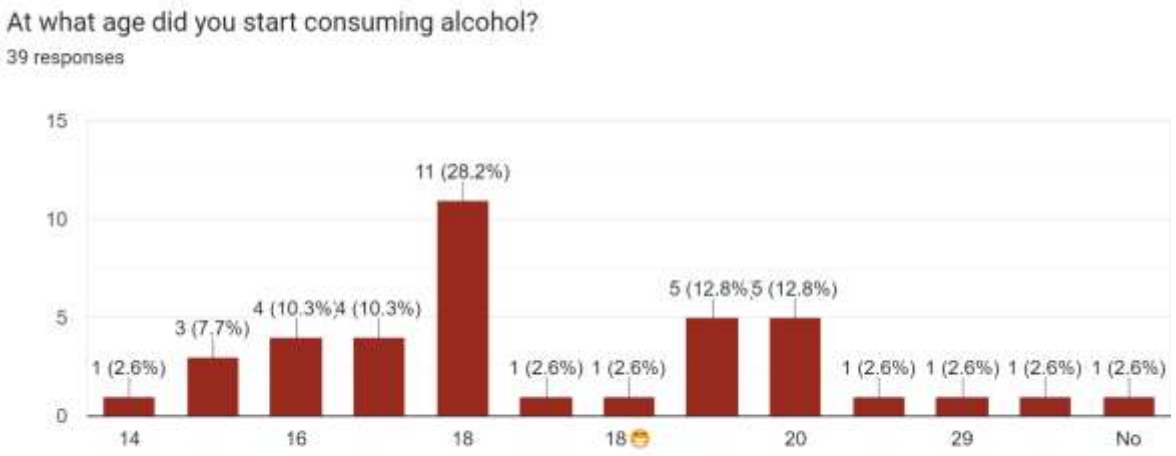
Age: Age plays a crucial and important factor in one's relation to alcohol. As an individual's age increases, the body undergoes certain biological changes which influences the effects that are caused by the consumption of alcohol. A person's body's capability to metabolize alcohol decreases as one ages and also the concentration of alcohol in the blood is found to be more in aged people compared to the youth. A person who drinks the same quantity of alcohol that he/she had consumed in her youth days will impact the brain in a different way at the older stage because of the change in the body's capability and will have more adverse effect on the brain.

Gender: Men consume more alcohol than women globally as they consider it as a sign to show their strength and tolerance capacity. Studies have revealed that women are more prone to alcohols impact than men because women's body capability to metabolise ethanol is less compared to men so the impact of alcohol also varies when it comes to gender. But Women stop the consumption of alcohol after a certain point and they restrict themselves from it compared to men who still continue the usage of alcohol as they get older.

Genetics: Genetics plays a crucial role in the effect of alcohol as there are receptors in the brain (GABA a) that react to the ethanol and the composition of these receptors varies from person to person depending on their genetical background. Several studies have been done on the chromosomes to find the alcohol related genes and their influence on how their body and brain reacts to ethanol.

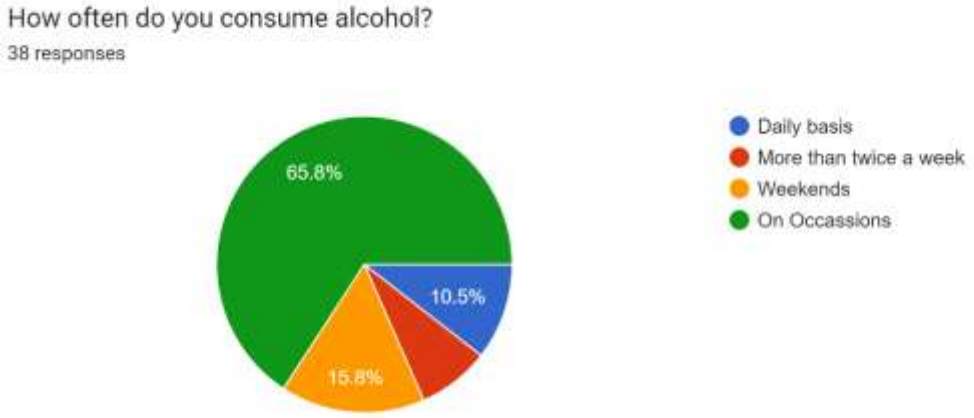
Chapter 6: Survey, Analysis & Interpretation

1. Out of a total of 39 respondents, 13 claimed that they started drinking at the age of 18. 5 respondents each selected 19 and 20 as the age they started consuming alcohol. 4 respondents each selected 16 and 17 as the age they started consuming alcohol. Late adolescence and peer pressure could be a reason for such results. The ages mentioned by the respondents range from 14 to 29 years. People who do not drink also filled out my survey.

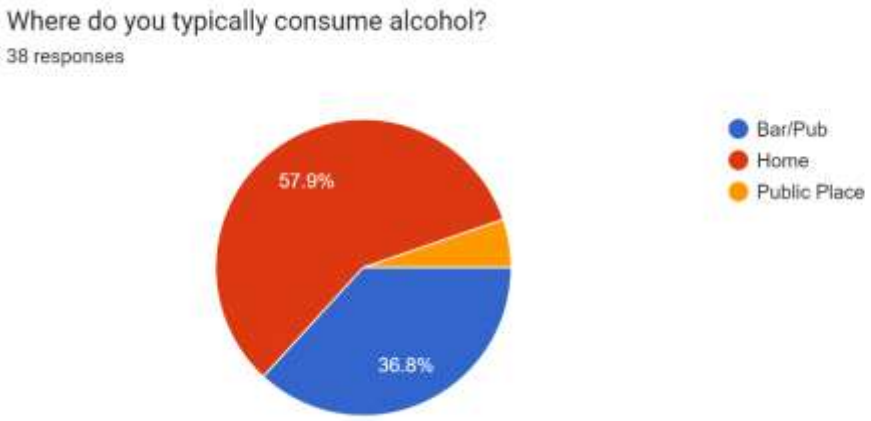


2. A majority of 25 respondents out of 38, cited that they consume alcohol occasionally. 6 respondents selected weekends as the time when they consume alcohol. 4 respondents claimed that they drink on a daily

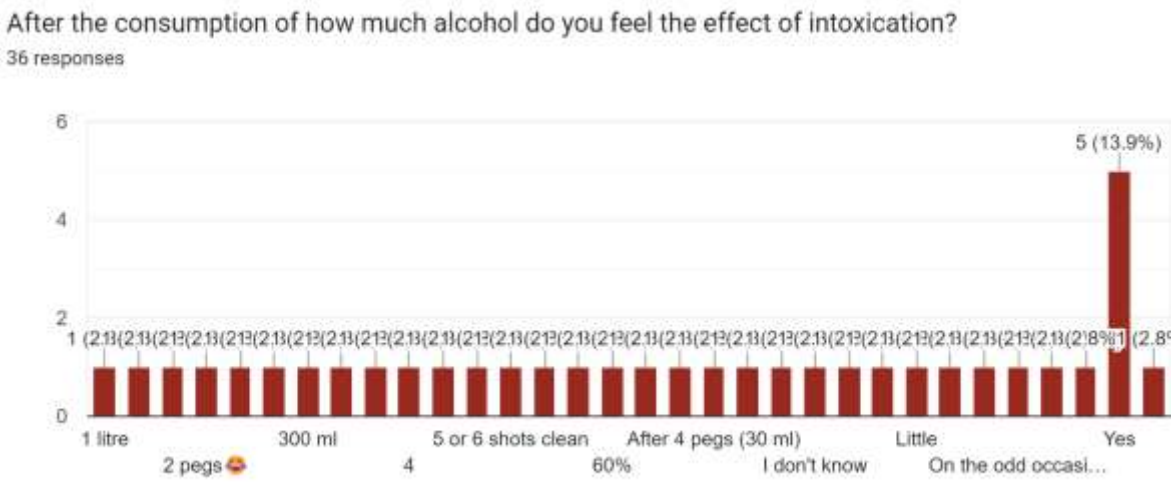
basis and 3 respondents claimed that they drink more than twice a week. We can infer from the results that people tend to consume alcohol as a part of social convention in social settings.



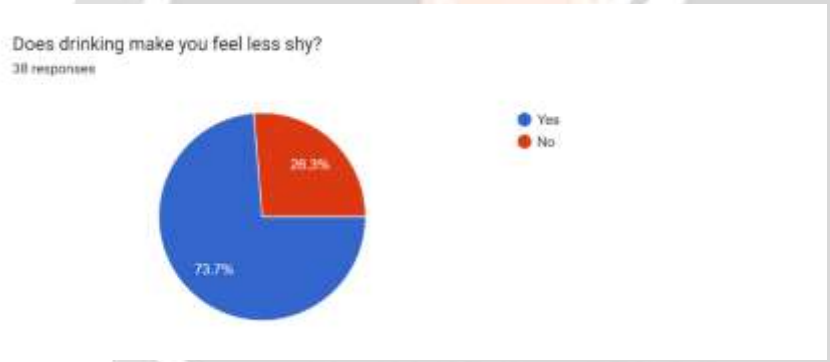
3. 22 out of 38 respondents said that they typically consume alcohol at home. 14 respondents said that they typically go to a bar/pub and a meagre portion of just 2 respondents said that they drink in public places. After having conversations with more people, it can be inferred that environment plays a crucial role in the way in which people get and act drunk. For example, in a public setting, people would feel conscious after drinking and they try to maintain an image around others. At home, when they drink the same amount, they tend to let loose as they feel comfortable and safe there. Thus, how the brain responds to a particular environment must be taken into consideration.



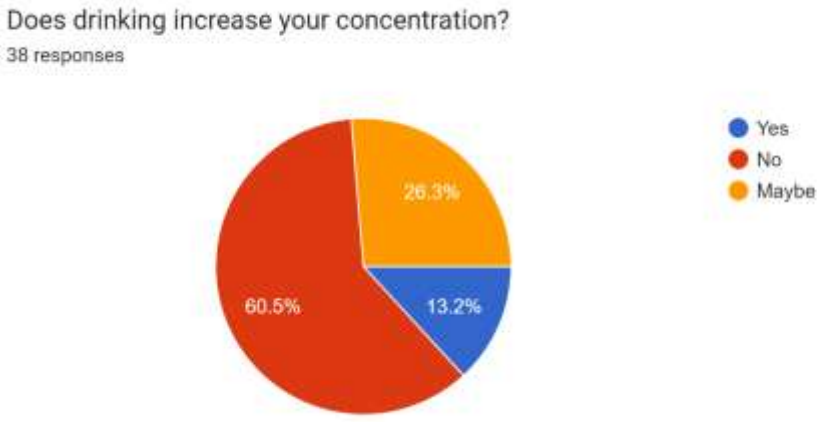
4.There were a variety of answers for this question. Different people have different tolerance level and it depends on the genetics, age, previous drinking habits, family's drinking history and many other factors. It also depends on the composition of the receptors in the brain that react to the ethanol.



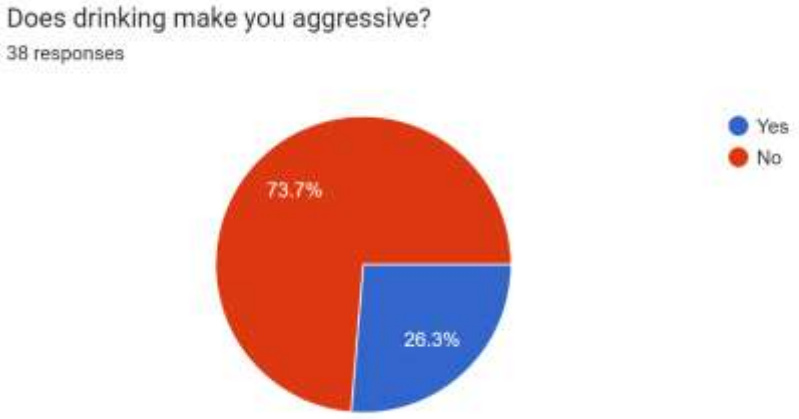
4. 28 out of 38 respondents believed that they feel less shy after drinking. 10 respondents had an opposing answer. People who are reserved and do not speak much tend to become more confident and make rash decisions due the impact alcohol consumption produces on the cerebral cortex. People tend to make poor judgements and do not hold back as they start confessing things to others that lead to more complications when they wake up later into reality.



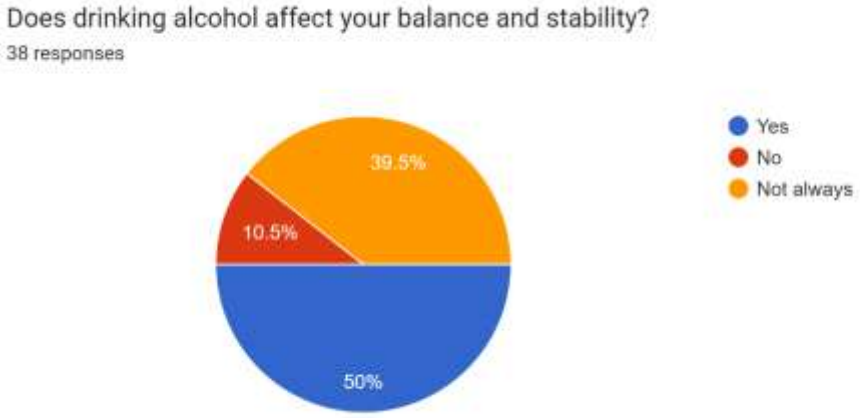
5. 23 respondents said no to the above question. Consumption of alcohol affects one's concentration in two ways- by affecting the thought process which is controlled by the cerebral cortex and by affecting the consciousness which is controlled by the medulla oblongata.



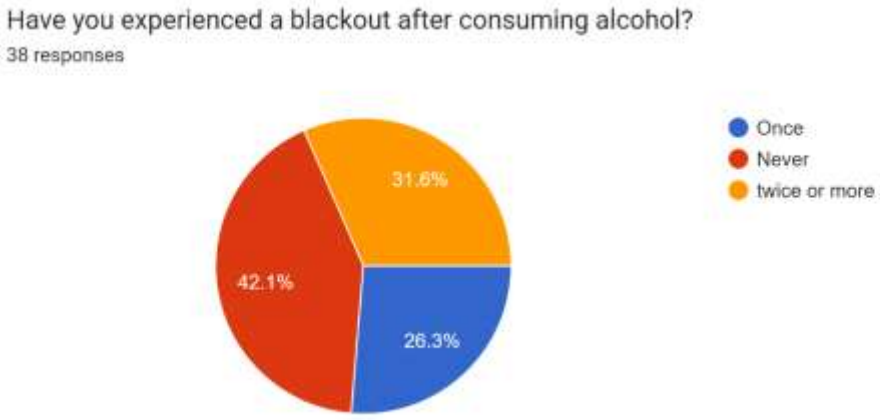
6. 28 out of 38 respondents answered that drinking does not make them aggressive. Consumption of alcohol affects the frontal lobes of people which reduces their self-control and brings about a change in their emotions. A change in personality can occur which will, in turn, change the person's social behaviour.



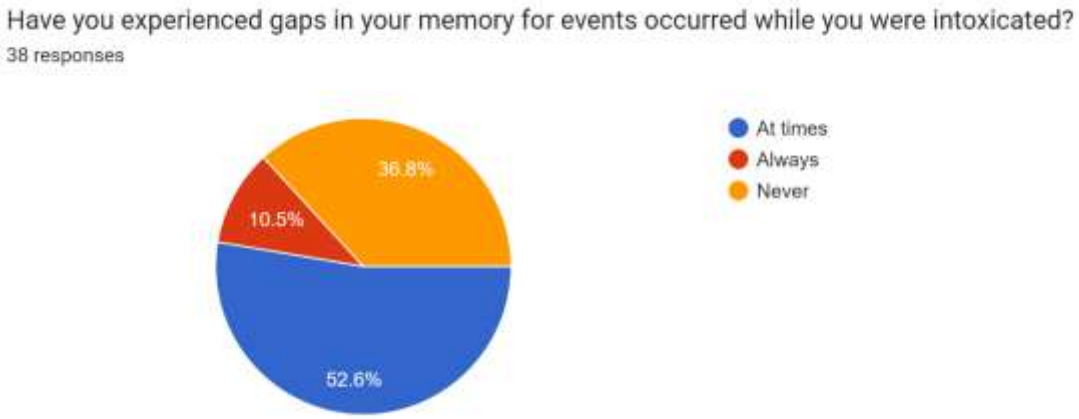
7. 19 respondents were of the opinion that drinking affects their balance and stability. A sizeable proportion of 15 respondents said that drinking does not always adversely affect their balance and stability. Alcohol affects the cerebellum by affecting the posture and balance of a person while standing or walking.



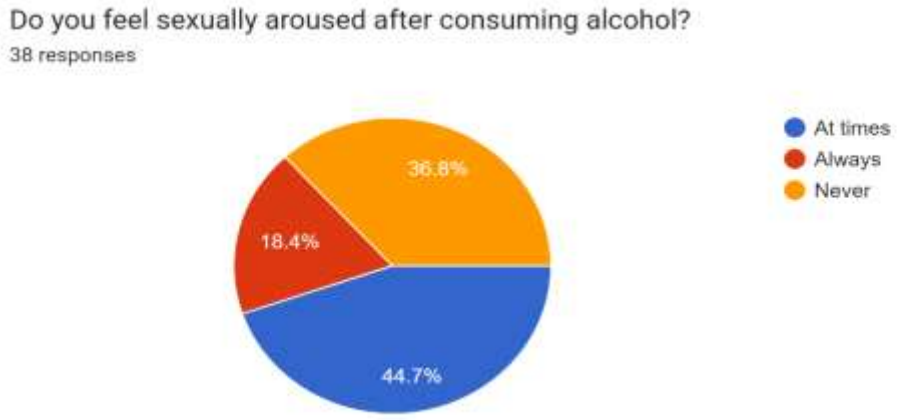
8. 16 respondents said that they have not experienced a blackout after consuming alcohol. 12 of them said that it has happened to them twice or more times and 10 people reported that they have never experienced such a condition. The medulla oblongata performs the function of transmitting messages from the brain to the spinal cord. When an individual consumes alcohol, the line of communication between the brain and spinal cord gets blocked and there is a delay in sending of messages to the spinal cord which may cause the person to lose consciousness and pass out.



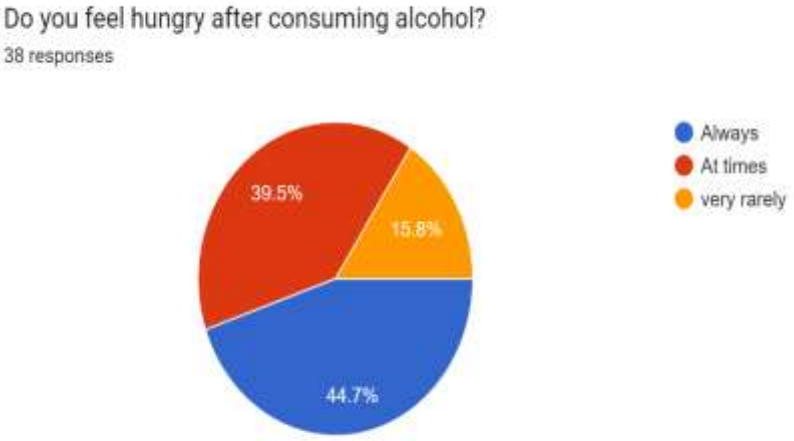
10. 20 respondents claimed that the sometimes experience gaps in their memory for events occurred while they were intoxicated. 14 respondents reported of never having experienced such an episode due to drinking. However, it cannot be ignored that 4 people reported of always experiencing it. When the consumption of alcohol affects one's hippocampus, the part of the brain associated with storage of memory, the individual is subjected to suffer memory loss and they may also find it difficult to remember things that they learnt recently.



11. 17 respondents admitted to feeling sexually aroused, when they are under the influence, at times. 14 respondents said that they have never felt that way after consuming alcohol. 7 people said that they always feel sexually aroused after drinking. Research says that alcohol has the capacity to increase people's sexual desires even though it adversely affects their sexual performance due to hormone irregularity. After the consumption of alcohol, it increases the testosterone level and triggers the release of dopamine which makes a person sexually aroused.



12. 17 respondents admitted that they always feel hungry after consuming alcohol and 15 respondents said that they feel hungry at times after consumption of alcohol. Consumption of alcohol affects the hypothalamus of the brain by increasing the hunger levels of a person.



Chapter 7: Findings and Conclusion

From the research, it was analysed that consumption of alcohol has prolonged effects on the human brain and causes many damages that are not reversible. People know the effects and harms that the consumption of alcohol causes and yet they still drink because of the addictive dopamine pleasure that an individual gets from the consumption of alcohol. Moreover, alcohol has turned out to be a social drink globally and almost 75% of the population consumes. Even though many try to abstain from the consumption, the withdrawal effects cause seizures and other chemical effects in the brain as the brain had adapted to the effect of alcohol and it reacts when there is an absence of consumption

Ethanol impacts the brain by causing shrinkage and deformity of the brain and in severe cases even brain tumour. Alcohol is a nervous depressant and it has severe impacts on the brain. Several studies are going on to find treatments for the irreversible damage done by alcohol to the brain and to the nervous system and it is better to abstain than consume.

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Bibliography

1 Oscar-Berman M, Marinkovic K. Alcoholism and the brain: an overview. Alcohol Res Health. 2003;27(2):125-33. PMID: 15303622; PMCID: PMC6668884.

2. Oscar-Berman, M. (2007, September 15). *Alcohol: Effects on Neurobehavioral Functions and the Brain*. SpringerLink. Retrieved October 24, 2022, from https://link.springer.com/article/10.1007/s11065-007-9038-6?error=cookies_not_supported&code=dd196122-816f-428e-9d4c-c24e00e3147c

3. Addiction Center. (2022, June 15). *Episode 32 – Trauma And Addiction*. Retrieved October 24, 2022, from https://www.addictioncenter.com/alcohol/alcoholism-causes-risk-factors/

4. Edenberg HJ, Foroud T. Genetics and alcoholism. Nat Rev Gastroenterol Hepatol. 2013 Aug;10(8):487-94. doi: 10.1038/nrgastro.2013.86. Epub 2013 May 28. PMID: 23712313; PMCID: PMC4056340.

5. Zahr NM, Pfefferbaum A. Alcohol's Effects on the Brain: Neuroimaging Results in Humans and Animal Models. Alcohol Res. 2017;38(2):183-206. PMID: 28988573; PMCID: PMC5513685.

6. Sullivan EV, Harris RA, Pfefferbaum A. Alcohol's effects on brain and behavior. Alcohol Res Health. 2010;33(1-2):127-43. PMID: 23579943; PMCID: PMC3625995.

7. Abbey A, Smith MJ, Scott RO. The relationship between reasons for drinking alcohol and alcohol consumption: an interactional approach. Addict Behav. 1993 Nov-Dec;18(6):659-70. doi: 10.1016/0306-4603(93)90019-6. PMID: 8178704; PMCID: PMC4493891.

Books

1. Tarter, R. E., & Thiel, D. V. H. (2013, May 31). *Alcohol and the Brain: Chronic Effects* (Softcover reprint of the original 1st ed. 1985). Springer.

2. Hannigan, J. H., Spear, L. P., Spear, N. E., & Goodlett, C. R. (1999, February 1). *Alcohol and Alcoholism: Effects on Brain and Development* (1st ed.). Psychology Press.