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A Quasi-Experimental Study on the Effectiveness of Integrated Electroencephalogram Neurofeedback Training and Group Psychotherapy for Harmful Alcohol Use: Neurocognitive and Clinical Outcomes

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Abstract

Introduction. This study investigates the efficacy of integrating electroencephalogram (EEG) neurofeedback training and group psychotherapy for individuals with harmful alcohol use (AUDIT-10 scores 10–13). **Methods**. Seventy-six participants were purposively sampled and divided into treatment (EEG neurofeedback training and group psychotherapy) and control groups. Baseline assessments measured alcohol consumption (AUDIT-10), stress (perceived stress scale [PSS]), neurocognition (NIMHANS neuropsychological battery), craving (PACS), and visual analog scale. The treatment group underwent 20 sessions of EEG neurofeedback (Peniston-Kulkosky and Scott-Kaiser modification protocols) and four sessions of group psychotherapy (motivational interviewing [MI], psychoeducation). **Result/Discussion**. A repeated measures ANOVA showed significant improvement in postcondition scores for the treatment group compared to controls, who exhibited deterioration over time. The study provides evidence supporting the efficacy of integrated EEG neurofeedback training and group psychotherapy in mitigating harmful alcohol use progression. **Conclusion**. By addressing stress, cognition, and cravings, this intervention offers crucial support to individuals with problematic drinking.

Keywords: craving; executive functions; harmful alcohol use; neurofeedback; psychotherapy; stress

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Introduction

Alcohol is the most common psychoactive substance used by Indians with about 15% (160 million) of the population between 10 and 75 years of age using alcohol of which 5.2% are problem users. That is, more than 50 million individuals are affected by harmful alcohol use (Ambekar et al., 2019). Harmful alcohol users experience harm associated with their alcohol use but do not meet the criteria for alcohol use disorder (Whitlock et al., 2004). Johnson et al. (2013) gave a concrete definition of harmful alcohol users as individuals scoring between 10 and 13, who fall within Zone III of the Alcohol Use Disorder Identification Test 10-Item (AUDIT-10) experiencing negative effects from alcohol use and require brief intervention to reduce or abstain from usage.

Role of Stress and Neurocognition

Stress is one of the several factors contributing to harmful alcohol use. The stress-coping model states that individuals use alcohol as a coping mechanism to deal with stressors and their associated emotional distress (Wittgens et al., 2022). However, this does not clearly explain the association between stressful experiences and harmful alcohol use. Environmental, biological, and psychological factors can explain the relationship between stress and harmful alcohol use. For instance, observational studies show that childhood maltreatment moderates the association between stress and harmful alcohol use and alcohol

use disorder in the later stages of the individual (Kim et al., 2014). The prolonged and excessive activation of the hypothalamic-pituitary-adrenal (HPA) axis causes individual differences in basal cortisol secretion explaining the development of harmful alcohol use behavior (Lijffijt et al., 2014). At the later stages of alcohol use, excessive alcohol consumption causes neuroadaptations in stress and reward pathways promoting increased salience of alcohol-related cues called attentional bias that further increases alcohol craving (Sinha, 2008). This is further accompanied by impaired response inhibition and executive deficits causing a lack of self-regulation in harmful alcohol use consumption (Madhusudhan et al., 2021; Sinha, 2012).

Integrated Intervention: A Biopsychosocial Approach

Harmful alcohol use treatment requires an integrated intervention approach due to the multitude of factors contributing to it. Combining and integrating interventions leads to superior treatment outcomes compared to a single approach alone. Conventional dual models, such as pharmacotherapy and psychotherapy, have demonstrated only modest efficacy among alcohol users, with high relapse rates (Dousset et al., 2020). To address this gap, the present study adopts an integrated approach by combining electroencephalogram (EEG) neurofeedback training and group psychotherapy for the treatment of harmful alcohol users.

The EEG reflects various mental states by recording the brain's electrical activity via electrodes placed on the human scalp (Heinrich et al., 2007). EEG neurofeedback training utilizes this technology to train individuals to self-regulate their brain activity in real time (Masterpasqua & Healey, 2003; Niv, 2013). For instance, a relaxed state is characterized by slow brain wave frequency alpha (8–12 Hz), which is often deficient in individuals with alcohol use behavior (Enriquez-Geppert et al., 2013; Kelly & Daley, 2013; Rangaswamy & Porjesz, 2014; Sokhadze et al., 2008). The Peniston-Kulkosky protocol (also known as alpha-theta neurofeedback) employs feedback of alpha (8–12 Hz) and theta (4–8 Hz) brain waves, teaching participants to increase the amplitude of alpha and theta brain waves and enhance the coherent interaction between the two, inducing a state of profound relaxation and reverie (Phneah & Nisar, 2017; Rangaswamy & Porjesz, 2014). This method was seen as useful in improving stress levels and promoting individual insight.

EEG studies have shown that chronic alcohol consumption can alter brain wave patterns leading to increased beta activity in certain regions of the brain. These changes contribute to cognitive impairments such as impulsivity, attentional bias, and deficits in working memory and executive functions (Rangaswamy & Porjesz, 2014). The Scott-Kaiser Modification protocol, called the beta (12–30 Hz) sensorimotor rhythm (SMR; 12–15 Hz), addresses these cognitive deficits by uptraining the SMR frequency band and regulating beta waves. This intervention aims to improve attention, concentration, response inhibition, and executive functions in individuals affected by harmful alcohol use consumption (Logemann et al., 2010).

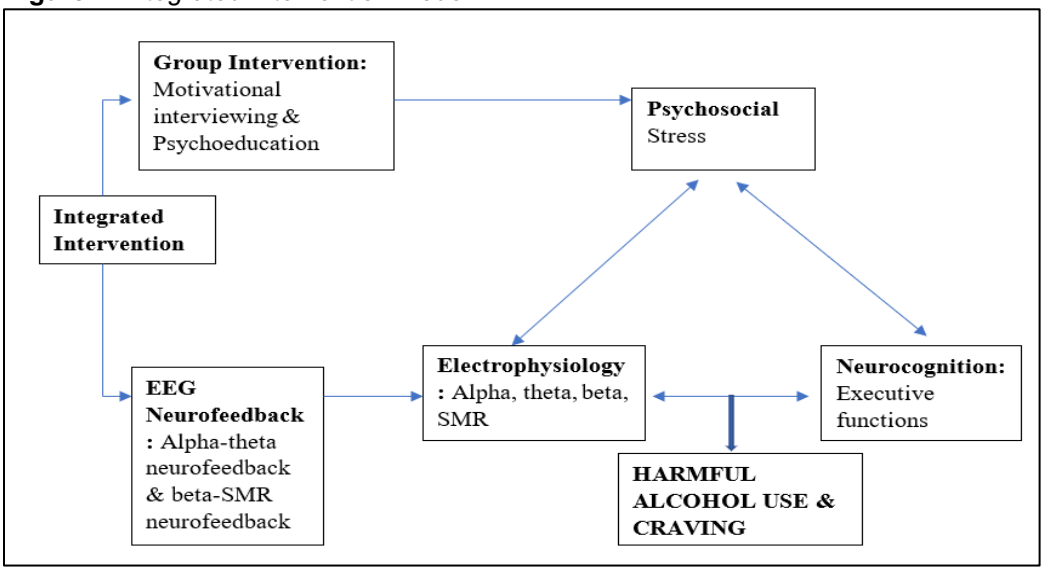
Thus, EEG neurofeedback training helps in addressing biological factors such as altered EEG patterns observed in individuals with harmful alcohol use (Dehghani-Arani et al., 2013; Kadosh & Staunton, 2019; Phneah & Nisar, 2017; Sitaram et al., 2017). However, while EEG neurofeedback training can be considered an efficacious treatment, it alone may not suffice to address the complex psychosocial factors contributing to harmful alcohol use. For instance, stress, which fluctuates over time, can significantly impact motivation, treatment retention, and overall recovery of individuals undergoing EEG neurofeedback training (Kadosh & Staunton, 2019).

This study integrated group psychotherapy incorporating motivational interviewing (MI) and psychoeducation, with EEG neurofeedback training to create a supportive environment for individuals to explore psychosocial factors such as stress and associated emotional distress contributing to their harmful alcohol use (Feldstein Ewing et al., 2011). Within the group setting, participants have the opportunity to share experiences, gain insight, and receive feedback and encouragement from one another (Pombo et al., 2016; Santa Ana et al., 2021; Valeri et al., 2018). Group psychotherapy addresses the psychosocial dimension of harmful alcohol use behavior, complementing and reinforcing the positive changes induced by EEG neurofeedback training (Kadosh & Staunton, 2019; Morgenstern et al., 2017). Integrating the supportive environment, shared learning, and emotional regulation provided by group psychotherapy with the neurobiological intervention of EEG neurofeedback training, individuals are afforded enhanced treatment outcomes and an increased likelihood of sustained recovery from a biopsychosocial perspective of harmful alcohol use behavior.

The Proposed Model of the Study

The intervention comprises a structured program consisting of 20 sessions, including 10 sessions of the Peniston-Kulkosky protocol and 10 sessions of the Scott-Kaiser modification protocol for EEG neurofeedback training. The group psychotherapy incorporates MI and psychoeducation. The proposed model of the integrated intervention is provided in Figure 1.

Figure 1. *Integrated Intervention Model*.



The objective of the study is to understand whether the integration of EEG neurofeedback training and group psychotherapy leads to improved stress levels, neurocognitive functioning, and reduced craving among harmful alcohol users. Therefore, this study comes with three hypotheses:

- **Hypothesis 1**: The integration of EEG neurofeedback and group psychotherapy will lead to decreased stress levels among individuals with harmful alcohol use.
- **Hypothesis 2**: The integration of EEG neurofeedback and group psychotherapy will lead to improvement in neurocognition among individuals with harmful alcohol use.
- **Hypothesis 3**: The integration of EEG neurofeedback and group psychotherapy will lead to a reduction in alcohol cravings among individuals with harmful alcohol use.

Methods

Participants

The inclusion criteria were participants with a history of alcohol use who meet the criteria of the AUDIT-10 with scores of 10 to 13 indicating harmful alcohol use consumption between the age range of 18 to 50 from Bangalore, India. A general health questionnaire (GHQ-12) was used to evaluate and understand the mental health status of the individuals. The participants were to be literate to perform the screening tests and participate in the intervention. The exclusion criteria consisted of people who are already seeking treatment for alcohol use and people with a history of significant psychiatric, neurological, and neurosurgical conditions. The study assessed the eligibility of 90 participants in total. A total of 76 participants met the inclusion criteria of the study. All of the recruited participants went abstinent for 14 days before the commencement of the intervention and were abstinent during the intervention.

The 14-day abstinence period aligns with clinical guidelines and research findings indicating that withdrawal symptoms typically peak within the first few days of alcohol cessation and gradually subside over the following week or two (Kattimani & Bharadwaj, 2013). By ensuring that participants are abstinent for 14 days before the intervention, researchers can minimize the potential confounding effects of acute withdrawal symptoms on the outcomes of the study.

Recruitment

The study was conducted in the Clinical Assessment and Training Lab in CHRIST (Deemed to be University), Bangalore. The participants were recruited with the assistance of the Centre for Counselling (CHRIST, Bangalore). Recruitment efforts included the distribution of brochures on the university campus and through social media channels, accompanied by clear communication of the study's purpose and procedures.

Informed Consent

The informed consent form had three parts: the information sheet (to share information about the research with participants), information on the integrated intervention, and a certificate of consent (for signatures if the participant is willing to take part in the study). The individuals self-recruited themselves into treatment and control groups. The intervention took place between September 2022 and June 2023 in the university lab after obtaining approval from the Research Conduct and Ethics Committee of Centre for Research, CHRIST, Bangalore with referral number RCEC/00394/01/22.

Sampling

The study used a purposive sampling technique. The G power software version 3.1 suggested a sample size of 28 each in the treatment and control groups to attain the effect size of .7. The treatment group consisted of 37 participants, and the control group consisted of 39 participants.

Research Design

This is a quasi-experimental study that includes a treatment group and a control group of harmful alcohol use individuals. A flowchart showing the sequence of recruitment, assessment, and intervention is shown in Figure 2.

Experimental Procedure

The intervention consisted of 20 sessions of neurofeedback training, incorporating 10 sessions of the Peniston-Kulkosky protocol and 10 sessions of the Scott-Kaiser modification protocol, and four sessions of group psychotherapy consisting of MI and psychoeducation. Every five sessions of EEG neurofeedback training was followed by group psychotherapy. This design facilitates ongoing monitoring of psychosocial factors throughout the treatment process. By initiating the Peniston-Kulkosky protocol, the intervention prioritizes addressing stress due to its significant influence on individuals' overall performance during treatment. The participants in the treatment group underwent all 20 sessions of neurofeedback and four sessions of group psychotherapy (see Table 1).

Materials

General Health Questionnaire. The 12-item GHQ is used for detecting psychological distress (Hystad & Johnsen, 2020). The items on GHQ-12 are rated on a 4-point Likert scoring method (0-1-2-3) which is commonly used in research (Anjara et al., 2020). The test–retest reliability ranges from 0.70 to 0.95 and the concurrent validity is 0.80 (Kirmani & Suman, 2010).

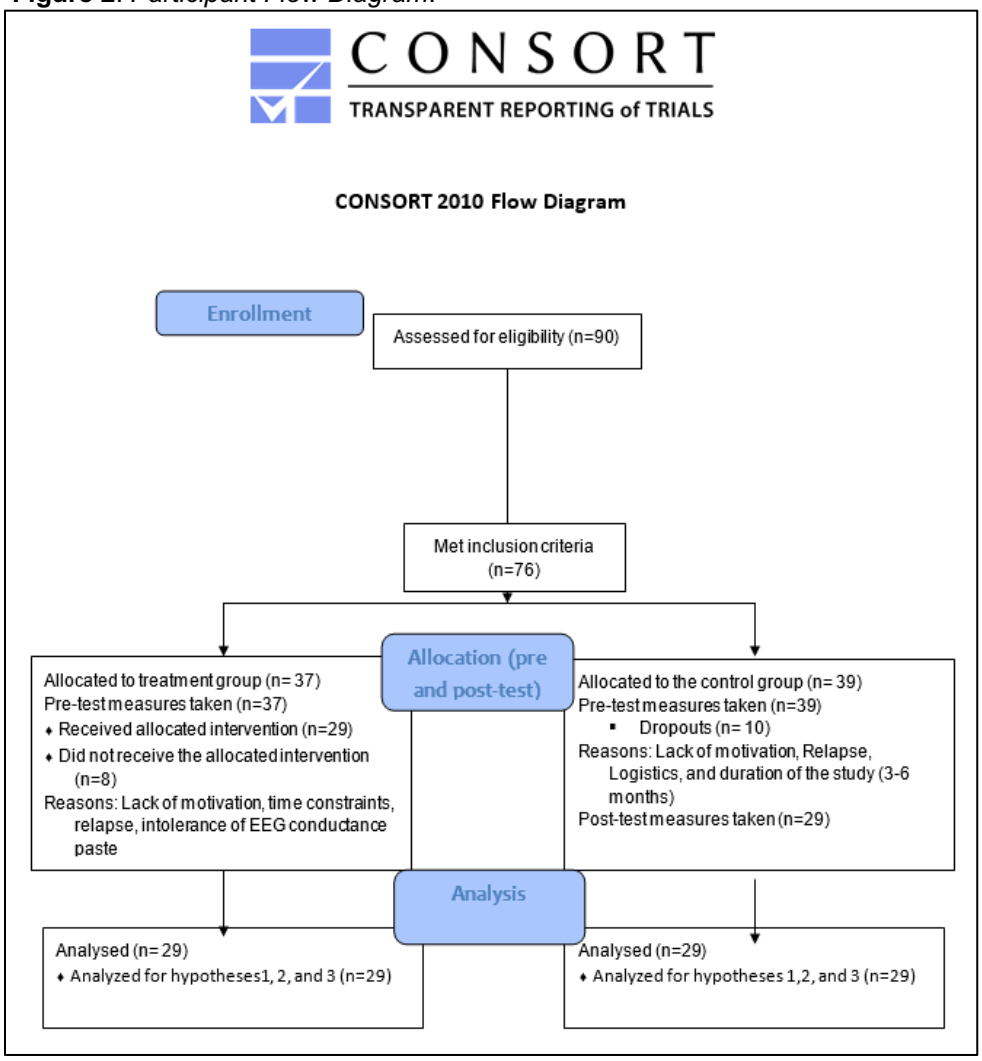
Alcohol Use Disorder Identification Test 10-Item (AUDIT-10). The AUDIT-10 questionnaire is a screening instrument developed by the World Health Organization (WHO) to screen for a range of drinking problems. The scale has a reliability of .84 (Endsley et al., 2017).

Perceived Stress Scale (PSS). The PSS, developed by Sheldon Cohen, is used as a self-appraisal measure for individuals to assess the extent of the perceived stressfulness of their various life situations (Pangtey et al., 2020). Six items of the scale measure stress and four items measure coping strategies for stress (Manzar et al., 2019). The scale has an internal reliability of .84 (Lee, 2012).

Penn's Alcohol Craving Scale (PACS). The PACS is a five-item questionnaire that measures the frequency, intensity, and duration of craving, the ability to resist drinking, and asks for an overall rating of alcohol craving in the past week (Flannery et al., 1999). The 0.92 Cronbach's alpha coefficient obtained from the prerandomization PACS scores shows that the PACS possesses a high degree of internal consistency (Flannery et al., 1999).

The National Institute of Mental Health and Neuroscience (NIMHANS) Neuropsychological Battery. The NIMHANS neuropsychological battery is used to study and understand cognitive impairments associated with substance use disorders. It is a lobe-based test focusing on lateralization and localization of higher mental functions (Porrselvi & Shankar, 2017). The tests used in the study are of mental speed (Digit Symbol Substitution Test [DSST]), of sustained attention (Digit Vigilance Test [DVT]), of executive functions (Animal Naming Test [ANT]), of working memory (*N*-back tasks), of planning (Tower of London [ToL]), of set-shifting (Wisconsin Card Sorting Test [WCST]), of response inhibition (Stroop test), of verbal learning and memory (Rey Auditory Verbal Learning

Figure 2. *Participant Flow Diagram*.



Test [RAVLT]), and of visuospatial working memory (Rey Complex Figure Test [RCFT]).

Visual Analog Scale (VAS). This study uses 0 to 10 cm VAS, which considers the scores to be at an ordinal level of measurement, where a lower numerical value of VAS reflects less severity of symptoms and a higher numerical value reflects more severity of symptoms for the following factors urge to drink, quality of sleep, and anxiety.

EEG Neurofeedback Training. The EEG neurofeedback was administered to the patients using the Brain Avatar 4.0 software acquired on the Brain Master Discovery 24E. The EEG and other signals are sampled at higher rates and high resolution and are processed and reconstructed for transmission of the same to the personal computer. The signals sent to the personal computer are already processed to remove any interference and provide wide bandwidth signals. For EEG acquisition and processing, the Brain Avatar modules are supported by the Brain Master Discovery 24E software. The Notch filler will be set at 50 Hz, and the EEG sampling rate at 256 sps.

The alpha-theta protocol focuses on the augmentation of alpha and theta activity simultaneously at Occipital (O_1 and O_2) locations and the beta-SMR neurofeedback protocol helps the augmentation of beta and SMR activity simultaneously at C_3 and C_4 locations. The ground electrodes were placed at A_1 and A_2 (Mastoids) locations, and the reference electrode was placed at Nasion.

Table 1
Experimental Procedure

Intervention	Description	Objectives	Duration	Measures
Peniston/Kulkosky (Alpha/Theta Protocol)	Learning to uptrain alpha and theta O_1-O_2 location of the brain	To voluntarily regulate brain waves associated with stress	Sessions 1–5, lasting 30 min each	Nil
Group psychotherapy	Group members narrate their experiences of harmful alcohol use	Facilitate decisional balance	Session 1, 1 hr 30 min	VAS
Peniston/Kulkosky (Alpha/Theta Protocol)	Learning to self-regulate alpha and theta at the occipital region of the brain	To voluntarily regulate brain waves associated with stress	Sessions 6–10, lasting 30 min each	Nil
Group psychotherapy	Educate on stress and neurocognitive risk factors associated with alcohol use behavior	Decrease the erroneous rationalization	Session 2, 1 hr	VAS
Scott-Kaiser Modification (beta-SMR Protocol)	Learning to uptrain SMR and regulate beta at C_3-C_4 location of the brain.	To voluntarily regulate brain waves associated with cognition	Sessions 1–5, 37 min each	Nil
Group psychotherapy	Activity: Change Plan Worksheet	To enhance autonomy, competence, and self-efficacy by setting realistic goals.	Session 3, 1 hr	VAS
Scott-Kaiser Modification (beta-SMR Protocol)	Learning to uptrain SMR and regulate beta at C_3-C_4 location of the brain.	To voluntarily regulate brain waves associated with cognition	Sessions 6–10, 37 min each	Nil
Group psychotherapy	Increase the conviction and confidence to sustain a behavior change.	Review progress, Renewing the motivation, Redoing commitment	Session 4, 1 hr	VAS

Note. VAS: visual analog scale.

Psychosocial Intervention. The psychosocial intervention consisted of MI and psychoeducation conducted in groups as explained (see Table 1). The treatment group was divided into four separate groups comprising eight in two groups and six and seven members in the other two groups. The groups formed were closed as no new members were added once the groups were formed.

Results

Descriptive Analysis, Categorical Comparison of Variables, and Test of Normality

Table 2 shows the demographic characteristics of the participants in the treatment and control groups. Table 3 shows the categorical comparison of demographic variables using the Chi-square test between the treatment and control groups. Based on demographic factors, there is no significant difference between the two groups. Table 4 represents Shapiro-Wilk's Normality test of the variables under study. The normally distributed variables have a significance level higher than .05, whereas those with a significance level lower than .05 are not normally distributed.

Analyses of Hypothesis

Hypothesis 1. Hypothesis 1 states that the integration of EEG neurofeedback and group psychotherapy will lead to decreased stress levels among harmful alcohol users in the treatment group. A repeated measures analysis of variance (ANOVA) was conducted to examine the effect of conditions (pre vs. post) on perceived stress levels within the treatment group (Table 5). The results revealed a significant effect of conditions on perceived stress, $F(1, 27) = 437$, $p < .001$, $\eta^2 = .88$. This indicates that there was a substantial difference in perceived

stress levels between the pre- and postconditions within the treatment group.

A post hoc analysis using Tukey's honestly significant difference (HSD) test further demonstrated significant differences between the pre- and postconditions, in which participants exhibited significantly lower perceived stress levels in the posttreatment condition showing the effectiveness of the intervention ($p < .001$).

Table 2
Participant Demographic Variables

	Group	Mean	Median	*SD*	Minimum	Maximum
Age	Treatment	23.6	22	5.20	19	46
	Control	24.8	24	4.28	20	34
General Health	Treatment	16.2	16	1.44	14	19
	Control	15.9	16	1.51	12	19

Demographics	Treatment group		Control group	
	n	%	*n*	%
Gender				
Male	10	17.2	14	24.1
Female	19	32.8	15	25.9
Occupation				
Employed	12	20.7	16	27.6
Unemployed	17	29.3	13	22.4
Marital status				
Married	5	8.6	6	10.3
Single	24	41.4	23	39.7
Parental alcohol use				
Yes (Disorder)	8	13.8	10	17.2
Moderate use (Social drinking)	12	20.7	9	15.5
No	9	15.5	10	17.2
Previous treatment failures (if any)				
Yes	1	1.7	3	5.2
No	28	48.3	26	44.8
Age of first alcohol use				
13–16	3	5.2	3	5.2
17–20	23	39.7	26	44.8
20+	3	5.2	0	0

Table 3
Chi-Square Test of Categorical Variables Between Treatment and Control Groups

Characteristics	Categories	Treatment (29)	Control (29)	χ^2	*p*
		M ± *SD* or *n* (%)	*M* ± *SD* or *n* (%)		
Age (years)		23.6 ± 5.20	24.8 ± 4.28		.3
Age of first alcohol use					
	13–16	(5.2)	(5.2)	3.18	.2
	17–20	(39.7)	(44.8)		
	20+	(5.2)	(0)		
Gender					
	Male	(17.2)	(24.1)	1.14	.2
	Female	(32.8)	(25.9)		
Occupation					
	Employed	(20.7)	(27.6)	1.10	.2
	Unemployed	(29.3)	(22.4)		
Marital Status					
	Married	(8.6)	(10.3)	.11	.7
	Single	(41.4)	(39.7)		
Parental alcohol use					
	Yes (Disorder)	(13.8)	(17.2)	.70	.7
	Moderate use (Social drinking)	(20.7)	(15.5)		
	No	(15.5)	(17.2)		
Previous treatment failures					
	Yes	(1.7)	(5.2)	1.0	.3
	No	(48.3)	(44.8)		

Table 4
Shapiro Wilk Test of Normality

Variables	Treatment group						Control group					
	Pre			Post			Pre			Post		
	M	*SD*	*w*	*M*	*SD*	*w*	*M*	*SD*	*w*	*M*	*SD*	*w*
Harmful alcohol use	11	1.16	.79	4.55	2.27	.88	10.48	.94	.55	11.7	1.16	.82
Perceived stress	27.8	3.18	.95*	14.24	1.64	.94*	25.4	2.42	.93*	28.7	2.40	.91
Alcohol craving	7.2	1.67	.75	3.24	1.05	.48	6.3	1.23	.70	8.8	2.17	.87
Cognitive flexibility (PE)	11.4	7.85	.84	10	3.13	.96*	18	5.02	.97*	19.1	4.97	.97*
Concept formation (TCF)	13.7	4.93	.71	12.1	1.67	.91	19.6	5.40	.95*	21.3	7.20	.89
Ability to maintain set (FMS)	.8	2.08	.48	.03	.18	.18	.06	.25	.28	.03	.18	.18
Stroop effect (Response inhibition)	315.6	88.8	.96*	177.13	73.6	.94*	324.2	71.33	.96*	352.2	66.25	.96*
Learning (IR)	12.6	2.61	.84	14.8	.40	.28	14.6	.77	.56	14.6	.80	.43
Learning (DR)	12.1	2.55	.88	14.5	.68	.69	13.9	1.03	.84	13.6	1.13	.85
Long-term memory retention	88.5	14.72	.89	97	4.43	.67	93.2	6.34	.85	91.6	6.53	.86

Table 4
Shapiro Wilk Test of Normality

Variables	Treatment group						Control group					
	Pre			Post			Pre			Post		
	M	*SD*	*w*	*M*	*SD*	*w*	*M*	*SD*	*w*	*M*	*SD*	*w*
Visuospatial working memory (IR)	17.7	6.29	.96*	22.5	3.12	.94*	15.9	2.67	.95*	14.5	2.45	.94*
Visuospatial working memory (DR)	16.5	5.95	.95*	22.9	3.94	.96*	13.8	2.18	.95*	13.4	1.84	.90
Mental speed	173.4	41.93	.91	123.9	39.52	.92	149.2	42.70	.97*	153.2	27.37	.97*
Sustained attention (time taken)	441.5	134.4	.94*	374	158.8	.87	441.4	91.9	.91	474.4	55.10	.97*
Category fluency	15	3.25	.87	16.8	2.39	.82	13.7	1.66	.94*	13.2	1.25	.92
Verbal working memory (hits)	6.8	1.98	.83	8.9	.18	.18	8.7	.43	.53	8.8	.40	.28
Planning	9.0	1.03	.92	12.1	.91	.89	9.4	1.37	.89	9.3	1.77	.84

Table 5
Repeated Measures ANOVA Within the Treatment Group for Perceived Stress

Variables		Treatment group Mean/Median ± *SD*	*F*/χ^2	*df*	*p*	Effect size (η^2)	$p^{\text{Tukey/Durbin Conover}}$
Perceived stress	Pre	27 ± 3	437	1,27	< .001*	.88	< .001*
	Post	14 ± 1.6					

*$p < .05$

Hypothesis 2. Hypothesis 2 states that the integration of EEG neurofeedback and group psychotherapy will lead to improved neurocognition among harmful alcohol users in the treatment group. The repeated measures ANOVA showed a significant effect on Stroop effect scores, $F(1, 27) = 47.6$, $p < .001$, $\eta^2 = .42$ indicating a notable difference in Stroop effect scores between the two conditions. A post hoc analysis using Tukey's HSD demonstrated significant differences between the pre- and postconditions ($p < .001$) wherein, the posttest scores were reduced compared to the of pretest scores suggesting that the intervention had a significant impact on reducing Stroop effect scores. This shows that the intervention has been effective in improving response inhibition among the treatment group (Table 6).

For visuospatial working memory, the repeated measures ANOVA showed a significant effect on immediate recall (IR) scores, $F(1, 27) = 22.7$, $p < .001$, $\eta^2 = .19$, and on delayed recall (DR) scores, $F(1, 27) = 34.9$, $p < .001$, $\eta^2 = .29$, indicating that there is a significant effect on visuospatial working memory scores between the pre- and posttest conditions. The post hoc analysis using Tukey's HSD shows significant improvements in posttest conditions compared to pretest conditions ($p < .001$) for both the immediate and delayed recall scores within the treatment group indicating improved visuospatial working memory (Table 6).

For the tests of mental speed and sustained attention, a significant effect was observed with $F(1, 27) = 31.9$, $p < .001$, $\eta^2 = .27$ and $F(1, 27) = 6.25$, $p < .01$, $\eta^2 = .05$, showing a significant difference on mental speed and sustained attention scores between pre- and posttest conditions within the treatment group. A post hoc analysis using Tukey's HSD further showed that the postcondition scores improved compared to preconditions with $p < .001$ and $p = .01$ respectively showing mental processing capacity and sustained attention (Table 6).

A Friedman test was conducted for those variables that violated normality, to examine the effect of conditions (pre vs. post) on cognitive flexibility, concept formation, and ability to maintain set scores within the treatment group. The analysis revealed a nonsignificant effect on cognitive flexibility scores, $\chi^2(1) = .14$, $p = .7$, and concept formation scores, $\chi^2(1) = 1.50$, $p = .2$. The post hoc analysis using the Durbin-Conover test did not show any significant pairwise differences between the pre- and postconditions for cognitive flexibility ($p = .7$) and

concept formation (p = .2). The ability to maintain set scores showed a significant difference between the pre- and postconditions, $\chi^2(1) = .7$, p = .008. The post hoc analysis also showed that the posttest conditions significantly improved compared to the pretest conditions (p = .006; Table 6).

The Friedman test for learning (IR, DR, long-term memory retention) showed a significant difference between the pre- and postconditions, $\chi^2(1) = .20$, p = .001; $\chi^2(1) = .14.7$, p = .001; and $\chi^2(1) = 8.05$, p = .005, respectively. The postanalysis showed a significant improvement in postconditions compared to the preconditions for IR, DR, and long-term memory retention (p < .001, p < .001, and p = .003, respectively). Likewise, the Friedman test for category fluency, verbal working memory (B2 hits), and planning also showed a significant difference between pre- and postconditions within the treatment group, $\chi^2(1) = 14.1$, p = .001; $\chi^2(1) = 25$, p = .001; and $\chi^2(1) = 29$, p = .001, respectively. The post hoc analysis showed that the postcondition scores improved significantly for category fluency, verbal working memory (B2 hits), and planning (p < .001, p = .001, and p = .001, respectively; Table 6).

Table 6

Repeated Measures ANOVA Within the Treatment Group for Neurocognition

Variables		Treatment group Mean/Median ± *SD*	*F*/χ^2	*df*	*p*	Effect size (η^2)	$p^{\text{Tukey/Durbin Conover}}$
Cognitive flexibility[a]	Pre	10 ± 7	.14	1	.7	-	.7
	Post	9 ± 3					
Concept formation[a]	Pre	12 ± 4	1.50	1	.2	-	.2
	Post	12 ± 1					
Ability to maintain set[a]	Pre	0 ± 2	7	1	.008*	-	.006*
	Post	0 ± 1					
Stroop effect (Response Inhibition)	Pre	316 ± 88	47.6	1, 27	<.001*	.42	<.001*
	Post	177 ± 73					
Learning (IR)[a]	Pre	13 ± 2	20	1	<.001*	-	<.001*
	Post	15 ± .4					
Learning (DR)[a]	Pre	12 ± 2	14.7	1	<.001*	-	<.001*
	Post	15 ± .6					
Long-term memory retention[a]	Pre	92 ± 14	8.05	1	.005*	-	.003*
	Post	100 ± 4					
Visuospatial working memory (IR)	Pre	17 ± 6	22.7	1, 27	<.001*	.19	<.001*
	Post	22 ± 3					
Visuospatial working memory (DR)	Pre	16 ± 5	34.9	1, 27	<.001*	.29	<.001*
	Post	22 ± 3					
Mental speed (Time taken)	Pre	173 ± 41	31.9	1, 27	<.001*	.27	<.001*
	Post	123 ± 39					
Sustained attention (Time taken)	Pre	442 ± 134	6.25	1, 27	.01*	.05	.01*
	Post	374 ± 159					

Table 6
Repeated Measures ANOVA Within the Treatment Group for Neurocognition

Variables		Treatment group Mean/Median ± *SD*	*F*/χ^2	*df*	*p*	Effect size (η^2)	$p^{\text{Tukey/Durbin Conover}}$
Category fluency[a]	Pre	14 ± 3	14.1	1	<.001*	-	<.001*
	Post	17 ± 2					
Verbal working memory (B2-hit)[a]	Pre	8 ± 1	25	1	<.001*	-	<.001*
	Post	9 ± .18					
Planning	Pre	9 ± 1	29	1	<.001*	-	<.001*
	Post	12 ± .9					

[a] Violation of normality; * $p < .05$

Hypothesis 3. Hypothesis (3) states that the integration of EEG neurofeedback and group psychotherapy will lead to decreased clinical outcomes among harmful alcohol users in the treatment group. A repeated measures ANOVA on harmful alcohol use and alcohol craving scores also showed a significant difference between pre- and postconditions, $\chi^2(1) = 29$, $p = .001$ and $\chi^2(1) = 29$, $p = .001$, respectively. The post hoc analysis of paired comparison showed that the postcondition scores for harmful alcohol use and alcohol craving significantly improved ($p = .001$ and $p = .001$, respectively) within the treatment condition (Table 7).

Table 7
Repeated Measures ANOVA Within the Treatment Group for Clinical Outcomes

Variables		Treatment group Mean/Median ± *SD*	*F*/χ^2	*df*	*p*	Effect size (η^2)	$p^{\text{Tukey/Durbin Conover}}$
Harmful alcohol use[a]	Pre	11 ± 1	29	1	<.001*	-	<.001*
	Post	5 ± 2.2					
Alcohol craving[a]	Pre	6 ± 1	29	1	<.001*	-	<.001*
	Post	3 ± 1					

[a] Violation of normality; * $p < .05$

Repeated measures ANOVA and its nonparametric alternative have been done for the control group to understand the overall effect between the two conditions (pre vs. post) on the variables and pairwise comparison to see any notable difference between the conditions (Table 8). The results show that there is a significant difference between the two conditions (pre and post) on perceived stress, neurocognition, and clinical outcomes within the control group. The post hoc analysis show that the posttest conditions have deteriorated over time compared to that of the pretest conditions in stress, neurocognition, and clinical outcomes.

Table 8
Repeated Measures ANOVA Within the Control Group

Variables		Control group Mean/Median ± SD	*F*/χ^2	*df*	*p*	Effect size (η^2)	$p^{\text{Tukey/Durbin Conover}}$
Perceived stress	Pre	25 ± 2	52	1, 27	<.001*	.33	<.001*
	Post	28 ± 2					
Cognitive flexibility	Pre	18 ± 5	2.95	1, 27	.09	.01	.09
	Post	19 ± 4					

Table 8
Repeated Measures ANOVA Within the Control Group

Variables		Control group Mean/Median ± SD	F/χ^2	*df*	*p*	Effect size (η^2)	$p^{Tukey/Durbin\ Conover}$
Concept formation	Pre	19.7 ± 5	5.76	1, 27	.02*	.01	.02*
	Post	21 ± 7					
Ability to maintain set[a]	Pre	0 ± .25	.33	1	.5	-	.57
	Post	0 ± .18					
Stroop effect (Response Inhibition)	Pre	324 ± 71	4.03	1, 27	.05	.04	.05
	Post	352 ± 66					
Learning (IR)[a]	Pre	15 ± .7	.66	1	.4	-	.42
	Post	15 ± .8					
Learning (DR)[a]	Pre	14 ± 1.03	4.45	1	.03*	-	.03*
	Post	14 ± 1.13					
Long-term memory retention[a]	Pre	93 ± 6.3	6.23	1	.01*	-	.01*
	Post	93 ± 6.5					
Visuospatial working memory (IR)	Pre	15 ± 2	7.40	1, 27	.01*	.06	.01*
	Post	14.6 ± 2					
Visuospatial working memory (DR)	Pre	13.9 ± 2	1.17	1, 27	.2	.01	.28
	Post	13.4 ± 1.8					
Mental speed (Time taken)	Pre	149 ± 42	1.05	1, 27	.3	.003	.31
	Post	153 ± 27					
Sustained attention (Time taken)	Pre	441 ± 92	6.88	1, 27	.01*	.04	.01*
	Post	483 ± 55					
Category fluency	Pre	13 ± 1	2.66	1, 27	.1	.02	.11
	Post	13 ± 1.2					
Verbal working memory (B2-hit)[a]	Pre	9 ± .4	2.91	1	.08	-	.08
	Post	9 ± .4					
Planning[a]	Pre	9 ± 1	2	1	.15	-	.16
	Post	9 ± 1					
Harmful alcohol use[a]	Pre	10.5 ± .9	13.8	1	<.001*	-	<.001*
	Post	12 ± 1.16					
Alcohol craving[a]	Pre	6 ± 1	21	1	<.001*	-	<.001*
	Post	9 ± 2					

[a] Violation of normality; *$p < .05$

A visual analog scale assessment for the urge to drink, quality of sleep, and anxiety was taken from the treatment group postpsychotherapy. Friedman's test for the urge to drink, quality of sleep, and anxiety was measured considering the complex relationship of stress with the urge to drink, quality of sleep, and anxiety among harmful alcohol users. The results show that there is a significant difference in the urge to drink, quality of sleep, and anxiety scores between the two conditions within the treatment group collected at four time points, $\chi^2(3) = 77$, $p < .001$; $\chi^2(3) = 81$, $p < .001$; and $\chi^2(3) = 80$, $p < .001$, respectively. The post hoc analysis using the Durbin Conover test showed that the urge to drink, quality of sleep, and anxiety levels improved significantly across different conditions ($p < .001$, $p < .001$, and $p = <.001$, respectively; Table 9).

Table 9
Friedman Test for VAS Within the Treatment Group

Variables	Conditions	Median ± *SD*	χ^2	*df*	*p*	$p^{\text{Durbin-Conover}}$
Urge to drink	UD1	7 ± .9	77.7	3	<.001*	<.001*
	UD2	5 ± 1				
	UD3	4 ± 1.47				
	UD4	2 ± 1.1				
Quality of sleep	QS1	4 ± .8	81.4	3	<.001*	<.001*
	QS2	5 ± .7				
	QS3	7 ± .7				
	QS4	8 ± .7				
Anxiety	Anxiety1	8 ± .9	80.3	3	<.001*	<.001*
	Anxiety2	6 ± .9				
	Anxiety3	4 ± .8				
	Anxiety4	3 ± .9				

*$p < .05$

A visual analog scale for the assessment of the urge to drink, quality of sleep, and anxiety was taken from the control group on the same day as that of the treatment group. Friedman's test for the urge to drink, quality of sleep, and anxiety shows that there is a significant difference across the conditions, $\chi^2(3) = 28.6$, $p < .001$; $\chi^2(3) = 25.2$, $p < .001$; and $\chi^2(3) = 28.8$, $p < .001$, respectively. The post hoc analysis shows that the urge to drink varied significantly across the different conditions with the most notable difference observed in first and third ($p < .001$) and first and fourth ($p < .001$) time points. The quality of sleep showed notable difference in first and third ($p < .001$) and first and fourth ($p < .001$) time points. Anxiety showed significant differences across first and fourth ($p < .001$) and second and fourth ($p < .001$) time points (Table 10).

Table 10
Friedman Test for VAS Within the Control Group

Variables	Conditions	Median ± SD	χ^2	*df*	*p*	$p^{\text{Durbin-Conover}}$
Urge to drink	UD1	7 ± 1	28.6	3	<.001*	UD1–UD3 (<.001*)
	UD2	7 ± 8				
	UD3	8 ± 8				UD1–UD4 (<.001*)
	UD4	8 ± 8				
Quality of sleep	QS1	4 ± 0.9	25.2	3	<.001*	QS1–QS3 (<.001*)
	QS2	4 ± 0.9				
	QS3	4 ± 0.9				QS1–QS4 (<.001*)
	QS4	3 ± 1.1				
Anxiety	Anxiety1	7 ± 1.1	28.8	3	<.001*	Anxiety1–Anxiety4 (<.001*)
	Anxiety2	7 ± 1.30				
	Anxiety3	8 ± 1.15				Anxiety2–Anxiety 4 (<.001*)
	Anxiety4	8 ± 0.88				

*$p < .05$

Discussion

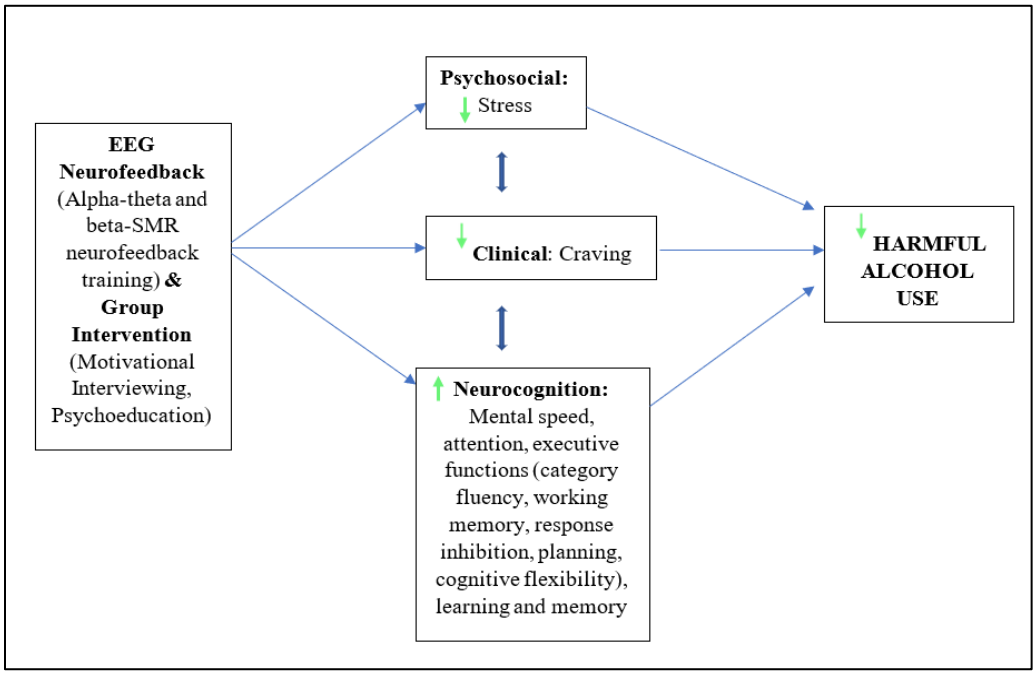
This study aimed to investigate the effectiveness of EEG neurofeedback training and group psychotherapy on harmful alcohol users. Although researchers have previously combined and integrated EEG neurofeedback with psychotherapy, this study has been integral in explaining how the integration mechanism works. Significant improvements were observed in stress, neurocognition, and clinical outcomes of harmful alcohol users in the treatment group following the intervention compared to the control group (see Figure 3).

Effect on Stress

The literature is replete with compelling evidence on the role of stress in the initiation and maintenance of alcohol use behavior (Becker, 2017; Blaine & Sinha, 2017; Keyes et al., 2011; Koob & Colrain, 2020; Mohan et al., 2015; Sinha et al., 2009). The treatment group was first subjected to alpha-theta neurofeedback training due to heightened stress levels and high levels of stress impact the overall performance of the individual in neurofeedback training and treatment retention in general. The group showed improvement in stress levels following the neurofeedback training as the alpha-theta neurofeedback is reported to have beneficial effects on stress, anxiety, and fear of relapse (Dalkner et al., 2017). The intervention facilitated individuals to think of strategies that help them to self-regulate their brain waves imparting a sense of self-efficacy. Such voluntary regulation allowed subjects to better tolerate stress and anxiety, which are prominent during the initial stages of recovery. Additionally, the enhanced alpha and theta during the training support individuals to be calm, tolerate stress, and impart a sense of inner empowerment (Dave & Tripathi, 2023). Gaining control over physiological processes helps in increased self-confidence, and reduces emotional stress and anxiety, feelings of inadequacy, insecurity, and fear (Lackner et al., 2016). Neurofeedback as a procedure helps reduce subjective stress and anxiety that could interfere with the HPA axis by impacting the stress-related systems of the brain directly (Mohan et al., 2015; Moss, 2022; White & Richards, 2023).

Improvements in stress may have caused improvements in neurocognition and clinical outcomes considering the bidirectional relationship between the variables. However, stress and related anxiety, are psychological variables that vary over time and hence need monitoring throughout the treatment conditions (Kadosh & Staunton, 2019). Group psychotherapy amplifies the effect of neurofeedback training by keeping a check on the psychosocial factors that could affect the overall performance of the individuals.

Figure 3. *A Diagram Showing the Effectiveness of Integrated Intervention in Reducing Harmful Alcohol Use*.



The group psychotherapy helped participants manage emotions in a social setting, overcoming the shame and fear of relapse associated with alcohol use which can act as potential stressors. Group support in times of pain and trouble can help people grow in ways that are healthy and creative (Valeri et al., 2018). This was true for our female participants to overcome the stigma associated with gender while seeking treatment for alcohol use. Once the individual learns emotional regulation and adaptive coping it engages the prefrontal cortex quieting the hyperactivation of the limbic system that governs the emotional response of the individual (Baxter et al., 1992; Rostami & Dehghani-Arani, 2015)

The collaborative approach of the group considers resistance to change or ambivalence as a normal aspect of human nature taking the blame away from clients that in turn aggravates stress-related relapse among individuals who are in the initial stages of their recovery (Ehret et al., 2015). Psychoeducation facilitated risk perception of alcohol use behavior that further increased the discrepancy between individual's behavior and resulting consequences motivating individuals to take accountability for their harmful alcohol use behavior (Magill et al., 2021). It was also helpful in addressing the repercussions of self-treating stress, anxiety, and poor sleep using alcohol. The improved levels of sleep can be attributed to better management of stress and anxiety through the intervention.

Effect on Neurocognition

The treatment group showed improvements in executive functions such as response inhibition, cognitive flexibility, learning and memory, working memory (visuospatial and verbal), mental processing capacity, sustained attention, and executive functions following the intervention. The beta-SMR facilitated uptraining of SMR brain wave activity that is associated with increased perceptual sensitivity, sustained attention, and decreased impulsivity (Logemann et al., 2010).

During the neurofeedback training, participants were encouraged to think of a mental strategy that would help them in improving their attention and other cognitive domains. The autonomy of identifying and controlling their brain waves (to self-decisively choose to start, maintain, or stop an action) and competence (to act efficiently) by gradually regulating the impulsive responses have been instrumental in improving participant compliance and acquisition of positive results (Ko & Park, 2018). The participants reported the ability to visualize the cons of alcohol use behavior far more than the pros which facilitated a neurocognitive shift. Study reports clinical improvements in patients' postneurofeedback training and the effects can last up to 12 months depending on the ability of the brain to learn (neuroplasticity; Loriette et al., 2021). Studies have reported electrophysiological, structural, and functional changes that result in reinforcement learning and brain plasticity on neurofeedback training (Hinterberger et al., 2005; Sherlin et al., 2011). Literature shows that EEG neurofeedback can be used as an add-on tool to enhance cognitive abilities that are pertinent to maintaining abstinence among individuals with alcohol use behavior (Dousset et al., 2020).

The group psychotherapy utilized improved cognition to facilitate neurocognitive shifts by tapping the decisional balance, which was inclined towards alcohol use and the urge to drink before the intervention. Verbalizing change talk further gave clarity to the cost-benefit analysis by maximizing the cognitive dissonance of harmful alcohol use behavior. Brain imaging studies show that change talk impacts the inferior frontal gyrus which is a key regulator in the brain's inhibitory control circuit (Ma et al., 2022; Zhuang et al., 2023). Understanding the consequences of alcohol use through psychoeducation and experiences shared by fellow participants motivated individuals to come for subsequent sessions of the intervention. The need to complete the intervention systematically became the priority of the clients. Literature shows that when patients are provided information on the nature of their alcohol use behavior, it enhances their treatment compliance with better retention and improvements in treatment outcomes (Ekhtiari et al., 2017). The therapy sessions enhance psychological integration that is, cognitive functions of the executive brain to have increasing access to information across networks of sensation, behavior, and emotion that in turn impacts cognition in psychotherapy (Malhotra & Sahoo, 2017).

Effect on Clinical Outcomes

The preoccupation/anticipation (third stage of the addiction cycle) stage is commonly linked to craving and the urge to drink and the prefrontal activation of craving reported executive deficits that interfere with decision-making, self-regulation, inhibitory control, and working memory (Koob & Volkow, 2016). The treatment group showed a marked reduction in the urge to drink following the intervention. The alpha-theta neurofeedback training helped in reducing the stress and anxiety levels and the group psychotherapy increased awareness of stress and related cravings that could trigger the individual to

alcohol use. The integrated intervention facilitated the identification of triggers which helped them to be aware of the same and take appropriate actions that work best for them. The beta-SMR sessions followed by group psychotherapy enhanced the cognitive flexibility through a neurocognitive shift that directed the attention to reducing alcohol use rather than craving the substance in general. Neurofeedback reduces drug seeking symptoms, improves psychological and neurophysiological variables, and results in longer periods of abstinence (Dehghani-Arani et al., 2013). The integrated intervention had a positive effect on decreased craving (Dave & Tripathi, 2023; Fahrion et al., 1992; Hashemian, 2015)

The affective component of craving involves the activation of motivational systems associated with specific subjective, behavioral, physiological, and cognitive correlates (Pombo et al., 2016). Fox et al. (2007) report that exposure to stress and alcohol cues can significantly increase craving, anxiety, and negative emotions. The group psychotherapy provided the role of a social setting to understand and manage emotion regulation healthily. The administration of alpha-theta neurofeedback and group psychotherapy significantly reduced the levels of craving by improving the stress, anxiety, and fear of relapse among individuals in the treatment group. It also facilitated the adoption of healthy strategies that can be used in times of stress-related craving rather than resorting to alcohol use as a coping mechanism.

Scope and Future Implications

This study was able to address one of the major gaps associated with gender in the diagnosis and treatment of harmful alcohol use. It ensures equitable access to care and tailored support for individuals of all genders affected by harmful alcohol use. To an extent, the nonclinical setting offered a promising avenue for reducing the stigma attached to treatment seeking and enhancing treatment accessibility. Future efforts should explore innovative approaches to destigmatizing harmful alcohol use and promoting help-seeking behaviors within community-based settings, fostering a supportive and inclusive environment for individuals seeking treatment recovery. The group sessions presented a unique opportunity to reach out to a greater number of people within a short period without compromising the effectiveness of the same. Furthermore, individuals felt less burdened to change in a group setting.

Limitations

This study did not specifically look into the impact of group dynamics and group cohesion on the psychosocial variables of the study. It has been found that some of the dropouts' demotivation was due to their inability to self-regulate their brain waves. Nonresponders and nonregulators should be further studied to understand the factors that could explain the inability to self-regulate and further improve the efficacy and administration of EEG neurofeedback among alcohol and other drug use behavior.

Conclusion

The integration of EEG neurofeedback training with group psychotherapy represents a promising approach to addressing harmful alcohol use. Our study demonstrates that this integrated intervention leads to significant reductions in stress levels, improvements in neurocognition, and reductions in craving among individuals with harmful alcohol use compared to those who did not receive the intervention. These findings underscore the potential of combining neurobiological interventions with psychosocial support to effectively address the multifaceted challenges associated with harmful alcohol use. Moving forward, further research is warranted to explore the long-term effects and mechanisms underlying this integrated approach, with the ultimate goal of optimizing treatment strategies and improving outcomes for individuals struggling with alcohol-related problems.

Author Disclosure

The authors declare no conflict of interest concerning the research, authorship, and publication of this article. There is no financial interest or benefit that has arisen from this research.

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