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Original Article

The Effectiveness of Cognitive Rehabilitation on Cognitive Flexibility, Working Memory, Response Inhibition, and Drug Craving in Abstinent Addicts

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Abstract

Introduction: Drug addiction leads to significant impairments in executive functions. This study aimed to assess the effectiveness of cognitive rehabilitation (NEAT) in addiction treatment, focusing on cognitive flexibility, working memory, response inhibition, and drug craving.

Method: A quasi-experimental pretest-posttest design with a control group was employed. Thirty participants undergoing treatment at a mandatory addiction center in Semnan were randomly assigned to experimental ($n=15$) and control ($n=15$) groups. The experimental group received 14 sessions of NEAT. Assessments included the Desires for Drug Questionnaire, N-back task, Wisconsin Card Sorting Test, and Go/No-Go task. Data were analyzed using MANCOVA.

Results: NEAT significantly improved all target outcomes. Compared to the control group, the experimental group showed statistically significant improvement in working memory ($F=24.53$, $P<0.001$, $\eta^2=0.47$), response inhibition ($F=17.33$, $P<0.001$, $\eta^2=0.39$), and cognitive flexibility ($F=6.98$, $P=0.01$, $\eta^2=0.20$), as well as a marked reduction in drug craving ($F=10.11$, $P=0.004$, $\eta^2=0.27$).

Conclusion: The findings showed that the Neurocognitive Empowerment for Addiction Treatment (NEAT) protocol was effective in enhancing executive function and reducing drug craving in abstinent individuals. Implementing this protocol in addiction treatment centers can serve as a valuable therapeutic supplement alongside drug therapy. It is also recommended that future studies be conducted on more diverse populations.

Trial Registeration: IRCT20230808059086N1.

Keywords: Cognitive flexibility, Working memory, Response inhibition, Drug craving, Cognitive rehabilitation

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Introduction

Substance use disorder (SUD) is a chronic, relapsing condition that severely impairs individuals' neurocognitive functioning, particularly in executive domains such as cognitive flexibility, working memory, and response inhibition.[1,2] These deficits not only contribute to the onset and maintenance of addiction but also play a central role in poor treatment outcomes and high relapse rates.[3] Studies estimate that over 80% of individuals relapse within the first month post-treatment.[4,5] Among the various psychological constructs influencing relapse, craving has been repeatedly identified as a core mechanism driving substance-seeking behaviors.[6] Craving is often involuntarily triggered by internal or external cues and has been shown to intensify when executive control is compromised.[7] Executive functions refer to a set of top-down cognitive processes that enable self-regulation, goal-directed behavior, and adaptive decision-making.[8] Chronic drug use disrupts these functions by altering prefrontal cortex circuitry, leading to diminished inhibitory control, impaired attentional regulation, and reduced cognitive flexibility.[9-11] These impairments persist even after detoxification and abstinence, suggesting that mere cessation of substance use may not suffice to restore cognitive integrity.[12,13] Importantly, individuals with more intact executive functions at baseline demonstrate better adherence to treatment and greater success in long-term recovery.[14] Despite the centrality of cognitive dysfunction, standard treatment approaches, including pharmacotherapy and psychotherapy, often overlook these deficits or assume they will resolve with abstinence. However, evidence indicates that executive dysfunctions are highly stable and require targeted intervention to improve.[15,16] In response to this need, cognitive rehabilitation programs have been developed to remediate these neuropsychological impairments and enhance treatment outcomes.[17,18] These interventions include computerized cognitive training, metacognitive strategies, and task-based exercises aimed at improving attention, memory, planning, and inhibition.[19-21] One emerging approach in this domain is the Neurocognitive Empowerment for Addiction Treatment (NEAT) program. NEAT is a structured, manualized, and neuroscience-informed intervention designed specifically for individuals with substance use disorders. It incorporates psychoeducation, cognitive training, and metacognitive development, targeting ten core cognitive domains including executive control, decision-making, and attentional shifting. What differentiates NEAT from other programs is its integration of motivational engagement through cartoon-based modules, adaptive difficulty, and emphasis on real-world cognitive challenges. Recent studies have shown that NEAT significantly improves cognitive performance, reduces craving, and enhances treatment adherence in opioid and stimulant users.[22] Although several studies have investigated the general effectiveness of cognitive training in populations suffering from substance use disorder, there remains a lack of focused research assessing the impact of NEAT on specific executive functions such as cognitive flexibility, working memory, and response inhibition in abstinent individuals[21]. Furthermore, most existing interventions do not sufficiently address craving as a cognitive-emotional construct intertwined with executive dysfunction.[23] Thus, there is a critical need to evaluate interventions like NEAT that simultaneously target executive processes and craving regulation. The present study seeks to fill this gap by examining the effectiveness of NEAT-based cognitive rehabilitation in improving executive functions and reducing craving among individuals in recovery from substance use disorder. By focusing on abstinent patients receiving structured cognitive intervention, this study aims to contribute to the growing body of evidence supporting integrated neurocognitive treatments in addiction care.

Methods

Sampling Method, Population, Sample

The research method employed was a quasi-experimental pretest-posttest design with a control group. The statistical population consisted of all patients receiving addiction treatment at mandatory drug treatment centers in Semnan. The substance used by these people was heroin. From this population, 30 individuals were randomly selected and assigned to either the experimental or the control group. Randomization was conducted using simple random allocation (1:1 ratio) generated via Random.org. An independent researcher not involved in the study generated the allocation sequence. Participants were enrolled by a clinical psychologist, and group assignment was performed by a research coordinator. Inclusion criteria included informed consent, at least elementary education, an age range of 25 to 40 years, a history of substance use for a minimum of one year, and having spent over one week in the addiction treatment center. The exclusion criterion was the participants' unwillingness to continue cooperation. Ethical principles of the research, including confidentiality, security, and privacy of individuals, were strictly observed. Data analysis was conducted using MANCOVA in SPSS software.

Wisconsin Card Sorting Test

The initial version of the Wisconsin Card Sorting Test was developed by Berg (1948), and it has since been widely used to assess executive function.[24] This test has been utilized to examine cognitive flexibility, abstract reasoning, and the capacity to analyze concepts. It is linked to the frontal lobe of the brain and can assess functional deficits in the dorsolateral prefrontal cortex. The test comprises two sets of 64 cards, differentiated by colors (green, blue, red, yellow) and shapes (triangle, star, cross, circle). There are four response cards and four stimulus cards included in the test. Scoring for the test encompasses several factors: duration, number of correct responses, number of incorrect responses, number of perseverative errors, number of trials completed, and number of non-perseverative errors. At the start of the test, when a participant insists on an incorrect response and continues to respond based on that, they are likely to make perseverative errors. Furthermore, if they persist in responding according to a previously successful principle, they may also commit perseverative errors. The total number of trials completed by the participant is derived from the sum of all correct and incorrect responses. The number of errors, excluding perseverative errors, is calculated by subtracting the number of perseverative errors from the total number of incorrect responses. Given the participant's responses across six categories, it is clear that the maximum score in this section is 6. The inter-rater reliability of this test has been reported to be 0.83.[25]

Go/No-Go Task

This test measures response inhibition, a key component of executive functions. The initial version was developed by Hoffman in 1984. It consists of two sets of stimuli: congruent (Go) and incongruent (No-Go). Participants must respond only to the congruent stimuli. A commission error occurs when a motor response is made during the presentation of a non-target stimulus. In the Go/No-Go test, the number of congruent (Go) stimuli exceeds that of incongruent (No-Go) stimuli. In the computerized version of the Go/No-Go task, three separate scores are obtained: percentage of commission errors, percentage of inappropriate inhibition, and reaction time. A high score in these three areas indicates the participant's difficulty and weakness in response inhibition. For each correct response to a congruent stimulus, one positive point is recorded, while each incorrect response to an incongruent stimulus results in one negative point. The reaction time is also measured by the computer in milliseconds. The reported reliability coefficients for this test are 0.72 for commission errors, 0.71 for inappropriate inhibition, and 0.87 for reaction time.[26]

N-Back Test

The n-back test is one of the most widely used tools for evaluating working memory. This test was first introduced by Kirchner in 1958 as a measure of working memory capacity.[27,28] The n-back test comprises a series of 100 linear images (visual stimuli) that appear sequentially and rapidly at 300-millisecond intervals on a computer screen. If the stimulus matches the one presented previously, the participant presses the "1" key. If it does not, they press the "2" key on the keyboard. In this task, the individual is required to retain information about only one stimulus in memory. Participants must respond to all stages of the test, necessitating continuous monitoring and updating of information in working memory. The output of this test includes the number of correct and incorrect responses provided. To evaluate working memory, both the number of correct responses and reaction time are considered. The n-back test possesses strong face validity and is now widely utilized as a measure of working memory in both clinical and experimental studies. Its validity has been established through comparisons with several other working memory tests.

Desire of Drug Questionnaire (DDQ)

This questionnaire was initially designed and implemented by Franken et al. 2002. It comprises 14 items, originally modeled after the Alcohol Craving Questionnaire, and was utilized for individuals dependent on heroin. However, due to its effectiveness in assessing craving, this questionnaire has also been employed to measure craving for other substances. A general reliability coefficient of 0.85 for this scale has been reported using the Cronbach's alpha method. For the subscales of craving, negative reinforcement, and perceived control over substance use, the coefficients of 0.77, 0.80, and 0.75, respectively, have been reported. Franken et al also confirmed the reliability of this test for each of the three above-mentioned components.[29]

I*ntervention and Procedures*

After completing the implementation steps, coordinating with addiction treatment centers in Semnan, and obtaining the ethical code **(IR.IAU.SEMNAN.REC.1402.O34)** from the Ethics Committee of Islamic Azad University, a random sample of 30 participants was selected from the community. Following the consideration of entry and exit criteria, these 30 participants were randomly divided into two groups of 15: experimental and control. To establish initial familiarity with the patients, build therapeutic relationships, and conduct a preliminary assessment, a pre-test was administered. The assessment of variables in the first stage (pre-test) was conducted individually on the 30 participants using the Wisconsin Card Sorting Test, the n-back test, the Go/No-Go task, and the craving questionnaire. In the next stage, participants were assigned to the control and experimental groups, adhering to the exit criteria and necessary coordination. Subsequently, the NEAT cognitive rehabilitation intervention was implemented through cognitive tasks and exercises. The NEAT rehabilitation sessions followed a progressive structure, beginning with foundational skills like attention and working memory, and gradually advancing to complex functions like inhibition and planning. The NEAT (Neurocognitive Empowerment for Addiction Treatment) protocol includes psychoeducation, metacognitive strategies, and cognitive training in ten domains, including attention, memory, and executive function. The NEAT cognitive exercises were conducted over 14 sessions, two sessions per week, each lasting 90 minutes, for the experimental group. The tasks presented in the sessions included finding differences, locating lost objects, proverbs, synonyms, and antonyms, drawing paths, mazes, and puzzles, spatial visualization and orientation, mathematical calculations, story creation, and more. All these tasks were derived from the Brain Club series books, authored by Hamed Ekhtiari and Tara Rezapour. The NEAT training sessions included time for learning and time practicing with a planner. Exercises were provided to each participant in paper format during every session. The NEAT rehabilitation sessions followed an incremental structure, introducing basic cognitive functions (attention and working memory) before progressing to higher-order cognitive functions (response inhibition, planning, prospective memory). New concepts and skills were gradually incorporated throughout the sessions. The rehabilitation intervention lasted for two months. Upon completion of the sessions, the second stage (post-test), which involved re-assessment using the relevant tests, was conducted individually for both the control and experimental groups. The collected data were analyzed using SPSS software.

The NEAT session structure included (Figure 1):

Session 1 and 2: Introduction to cognitive functions and attention training

Session 3 and 4: Working memory exercises (e.g., updating and serial recall)

Session 5 and 6: Inhibitory control and cognitive flexibility (e.g., Stroop and go/no-go)

Session 7 and 8: Planning and problem-solving tasks (mazes and logical sequences)

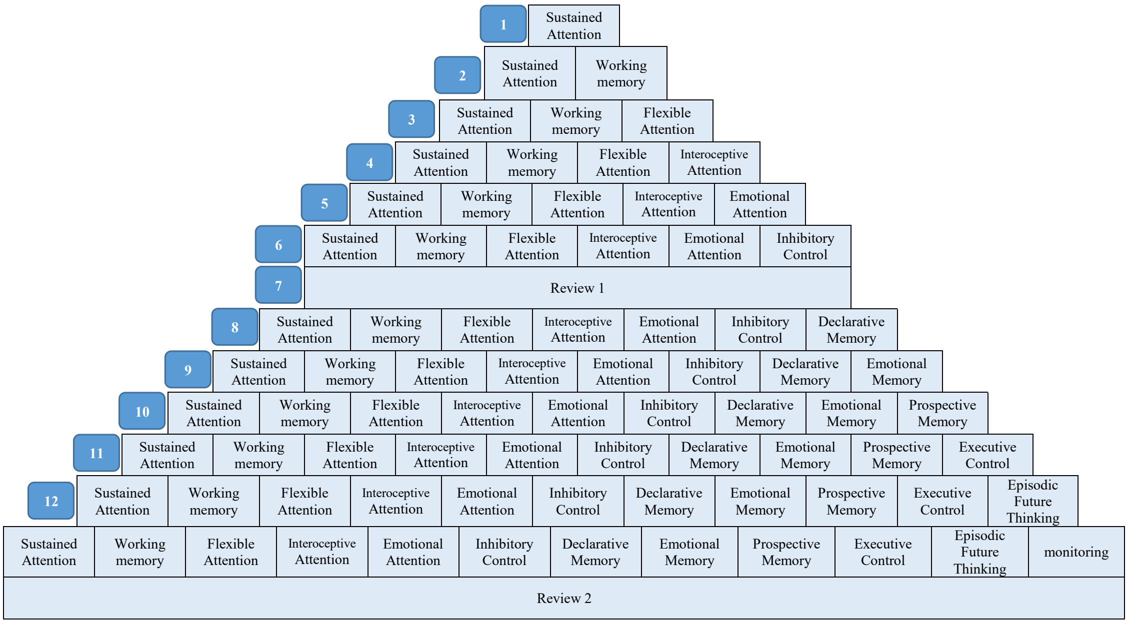

Figure 1. Architecture of Neur ocognitive Empowerment for Addiction Treatment (NEAT) for 14 sessions (adapted from Tara Rezapour et al)[30]

Session 9 and 10: Metacognitive strategies and self-monitoring

Session 11 and 12: Visual-spatial reasoning and story-based tasks

Session 13 and 14: Review, consolidation, and application to real-life challenges

Results

In the current study, among 30 participants from substance abuse treatment centers in Semnan, there was one bachelor's degree holder, one associate degree holder, 11 high school diploma holders, and 17 individuals with less than a high school education. Of these, 13 individuals were married, while 17 were single. Table 1 presents the mean and standard deviation of the study variables in the pre-test and post-test, categorized by experimental and control groups. Box's M test was utilized, and the results were significant ($P<0.05$), indicating that the assumption of equality of covariance matrices was violated. Therefore, Pillai's Trace, which is more robust to such violations, was used for interpreting MANCOVA results.

The results in Table 2 indicate a significant difference between the pre-test and post-test scores of executive functions in the experimental and control groups. According to the findings from the multivariate covariance analysis and the achieved significance level, there is a notable difference between the experimental and control groups in at least one of the subscales of cognitive flexibility, response inhibition, working memory, and craving.

According to the values in Table 3, the cognitive rehabilitation sessions resulted in a significant difference between the experimental and control groups in the subscales of the number of categories and commission errors. Therefore, it can be concluded that cognitive rehabilitation had a positive and significant impact on cognitive flexibility. These sessions also produced a notable difference between the experimental and control groups in the subscales of commission errors, inhibition, and response time for correct responses. Additionally, there was a significant difference between the experimental and control groups in the subscales of the number of correct responses and response time from the working memory test. Effect sizes were interpreted using Cohen's guidelines: $\eta^2=0.01$ (small), 0.06 (medium), and 0.14 (large). The observed values (e.g., $\eta^2=0.47$ for working memory) reflect significant effects, indicating the substantial impact of NEAT on executive functions.

Table 1. Mean and standard deviation of participants' scores in pre-test and post-test by group

Variable	Group	Pre-test mean (SD)	Post-test mean (SD)
WCST (errors)	Experimental	4.35 (0.81)	1.85 (0.25)
WCST (errors)	Control	2.56 (0.69)	4.12 (0.61)
Go/No-Go RT	Experimental	391.07 (15.12)	295.92 (10.84)
Go/No-Go RT	Control	413.43 (23.24)	395.25 (22.18)
N-Back Correct	Experimental	92.28 (6.66)	97.28 (4.17)
N-Back Correct	Control	95.31 (4.98)	67.06 (4.30)
Craving	Experimental	35.14 (4.31)	19.28 (4.07)
Craving	Control	33.00 (3.11)	36.87 (3.58)

Descriptive statistics (mean and standard deviation) of cognitive flexibility, response inhibition, working memory, and craving in experimental ($n=15$) and control ($n=15$) groups before and after the intervention. Table 1 indicates a statistically significant difference between groups in post-test scores ($P<0.05$).

Discussion

The findings of this study provide evidence that cognitive rehabilitation using the NEAT protocol can

Table 2. Results of the MANCOVA Test

Variable	Test	Value	*F*	*df1*	*df2*	*P*	*η²*
Cognitive flexibility	Pillai's Trace	0.40	5.61	3	25	0.004	0.40
Response inhibition	Pillai's Trace	0.73	16.83	4	24	0.001	0.73
Working memory	Pillai's Trace	0.60	19.81	2	26	0.001	0.60
Craving	ANCOVA	-	10.11	1	27	0.004	0.27

Multivariate analysis of covariance (MANCOVA) results comparing post-test scores of executive functions and craving between experimental and control groups while controlling for pre-test scores. $P<0.05$ indicates significant group differences.

Table 3. Results of the ANCOVA test for comparing cognitive flexibility between the two groups

Domain	Subcomponent	*SS*	*df*	*MS*	*F*	*P*	*η²*
Cognitive flexibility	Number of categories	10.22	1	10.22	6.98	0.01	0.20
Cognitive flexibility	Commission error	34.14	1	34.14	9.09	0.001	0.25
Response inhibition	Presentation error	19.53	1	19.53	10.98	0.003	0.28
Response inhibition	Inhibition	174.617	1	1747.61	17.33	0.001	0.39
Response inhibition	Correct RT	711.88	1	71167.88	13.83	0.001	0.33
Working memory	Correct responses	683.13	1	6839.12	24.53	0.001	0.47
Working memory	Response time	517.94	1	517053.94	22.13	0.001	0.45

ANCOVA results for components of cognitive flexibility, response inhibition, and working memory indicate significant differences between groups ($P<0.05$) in favor of the experimental group.

effectively enhance executive functions and reduce craving among individuals with substance use disorder. The participants in the experimental group showed significant improvement in cognitive flexibility, working memory, and response inhibition, and reported lower craving levels post-intervention compared to the control group. These results are consistent with previous research emphasizing the importance of executive functions in addiction treatment.[7,8,31,32] Improvements in cognitive flexibility may be attributed to NEAT's structured tasks, which involve adaptive thinking and planning strategies that strengthen prefrontal cortex functions.[33] Likewise, the enhanced working memory and response inhibition are likely related to NEAT's progressive cognitive exercises targeting attentional control and impulse regulation.[32,34] The observed reduction in craving aligns with prior studies demonstrating that improving executive control can mitigate the impact of internal and external cues that typically trigger relapse.[34,35] Inconsistencies with a few past studies that reported minimal effects of cognitive rehabilitation on executive functions may stem from differences in program structure, treatment duration, or the cognitive status of participants. The NEAT program distinguishes itself through its integrative use of metacognitive education, engaging activities, and its focus on real-life functional improvement, which may explain its superior outcomes.[36] Theoretically, NEAT may influence executive functions by promoting neuroplasticity in brain regions associated with self-regulation and decision-making. Repeated cognitive challenges in NEAT activate and reinforce neural circuits implicated in attention, memory, and inhibition—domains often compromised in addiction.[22] By engaging these circuits through targeted and incremental practice, participants may regain lost executive control, thus reducing compulsive drug-seeking behaviors. From a clinical perspective, the inclusion of cognitive rehabilitation in addiction treatment protocols appears essential, particularly for individuals who present with significant neurocognitive deficits. As NEAT is manualized, low-cost, and adaptable to various settings, it holds promise for scalable implementation in rehabilitation centers and outpatient programs. Furthermore, its utility extends to enhancing treatment adherence and improving long-term functional outcomes in recovery. This study, however, is not without limitations: the small sample size and restriction to male participants receiving mandatory treatment limit the generalizability of the findings.

Additionally, the lack of long-term follow-up precludes conclusions about the sustainability of observed improvements. Future studies should include larger and more diverse populations and explore whether combining NEAT with pharmacotherapy or psychosocial interventions produces synergistic effects. Moreover, neuroimaging or electrophysiological assessments could provide deeper insights into the neural mechanisms underlying the intervention's effects. In summary, the NEAT-based cognitive rehabilitation program demonstrates promising outcomes in enhancing executive functions and reducing craving in abstinent individuals with substance use disorders. These findings support the incorporation of structured cognitive training into standard addiction treatment frameworks.

Following the NEAT cognitive rehabilitation intervention, the experimental group showed a significant reduction in the average number of errors on the Wisconsin Card Sorting Test (WCST). This improvement highlights an enhanced ability to shift strategies and adapt to new stimuli, which is indicative of increased cognitive flexibility (Figure 2).

The test results (Go/No-Go) showed that the experimental group experienced a decrease in reaction time and fewer inhibition errors compared to the control group. This indicates that the ability to suppress incorrect responses improved after the NEAT intervention (Figure 3).

The findings from the n-Back test indicate that participants in the intervention group demonstrated a notable increase in the number of correct responses, alongside a reduction in reaction time. This suggests that NEAT cognitive rehabilitation has effectively enhanced both working memory performance and sustained attention (Figure 4).

The results of the craving questionnaire revealed a decrease in average scores within the experimental group following the intervention. This suggests that NEAT cognitive rehabilitation is effective in reducing cravings and enhancing inhibitory control (Figure 5).

Conclusion

Cognitive rehabilitation interventions can effectively target cognitive processes linked to addiction, significantly reducing cravings. These interventions generally include a variety of evidence-based techniques such as cognitive restructuring, attention training, problem-solving skill enhancement, and mindfulness practices. By concentrating on these cognitive elements, it is believed that individuals can cultivate healthier coping strategies and diminish the intensity and frequency of their cravings. Including cognitive rehabilitation in addiction treatment programs can be highly beneficial for patients who struggle with temptations and urges. The significant positive impact of cognitive rehabilitation on cravings suggests that this therapeutic approach has the potential to enhance the overall effectiveness of addiction treatment interventions. In conclusion, this study had limitations, including its focus on male participants undergoing mandatory addiction treatment. Therefore, its findings cannot be generalized to women or other groups undergoing voluntary treatment. Due to the full-time mandatory presence of patients at the treatment center, there is a possibility that other intervening factors and mediators could influence the research outcomes. It is recommended to conduct research aimed at elucidating the fundamental mechanisms through which cognitive rehabilitation affects executive functions and cravings. Additionally, exploring the potential synergistic effects of combining cognitive rehabilitation with evidence-based approaches such as pharmacotherapy, psychotherapy, and social-psychological interventions would be valuable. The benefits of integrating or synergizing these treatments to further enhance executive functions and reduce cravings could be assessed.

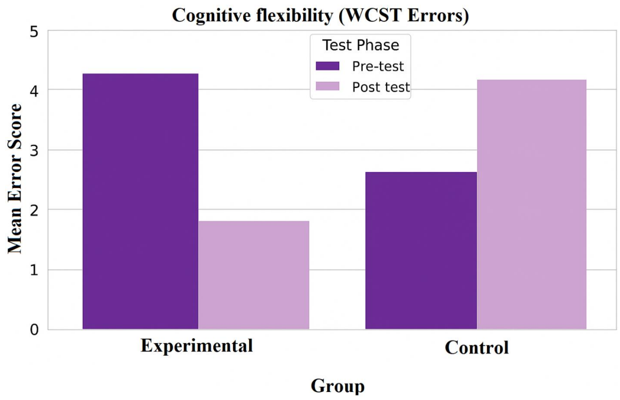

Figure 2. comparison of pre- and post-test results by group

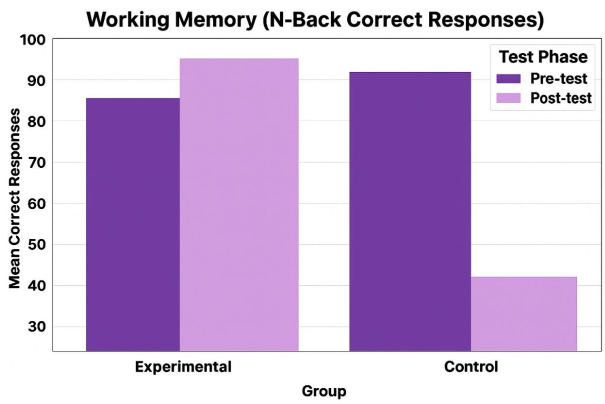

Figure 4. Working memory

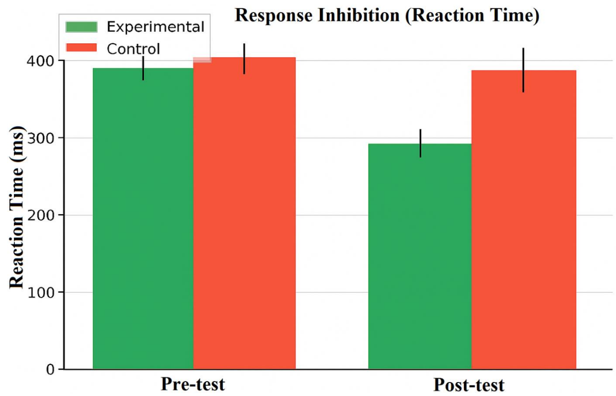

Figure 3. Response inhibition

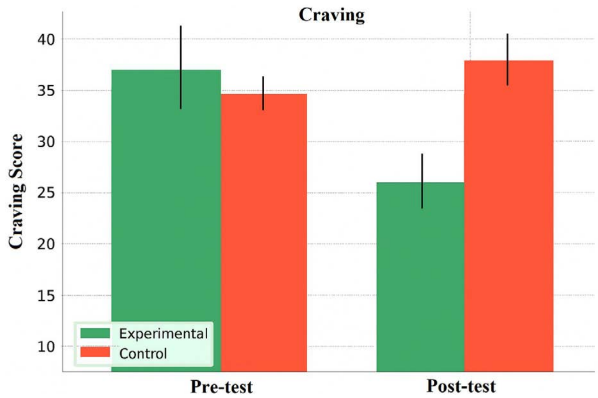

Figure 5. Craving questionnaire

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Authors' Contribution
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Project administration: Mojtaba Rajabpour.
Resources: Mahnaz Zargarani.
Software: Mahnaz Zargarani, Mojtaba Rajabpour.
Supervision: Ali Rashidy-Pour.
Validation: Mojtaba Rajabpour.
Visualization: Mahnaz Zargarani.
Writing–original draft: Mahnaz Zargarani, Mojtaba Rajabpour.
Writing–review & editing: Mojtaba Rajabpour, Ali Rashidy-Pour.

Competing Interests
The authors have no conflict of interest.

Ethical Approval
This study was approved by the Ethics Committee of Islamic Azad University, Semnan Branch, Semnan, Iran. Ethics code: IR.IAU.SEMNAN.REC.1402.O34.
Ethical considerations included informed consent from individuals to participate in the research and protection of participants' rights, including anonymity and confidentiality of information.

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