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Comparing the Effect of Transcranial Direct Current Stimulation (TDCS) and Cognitive-Behavioral Therapy on Substance Craving Control and Rumination in Methamphetamine-Dependent Patients

Masoud. Rezaee Kochaksaraei[1], Abdollah. Mafakheri[2*], Mahmoud. Jajarmi[3]

[1] Ph.D Student of General Psychology, Bojnord Branch, Islamic Azad University, Bojnord, Iran
[2] Assistant Professor, Department of Psychology, Payam Noor University, Bojnord, Iran
[3] Assistant Professor, Department of Psychology, Bojnord Branch, Islamic Azad University, Bojnord, Iran

*** Corresponding author email address**: a.mafakheri@pnu.ac.ir

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A B S T R A C T

Objective: The aim of the current study was to compare the effect of Transcranial Direct Current Stimulation (TDCS) and Cognitive-Behavioral Therapy on substance craving control and rumination in methamphetamine-dependent patients.
Methods and Materials: The present study, in terms of its objective, was applied research, utilizing a pre-test post-test design within a quasi-experimental research framework. The statistical population included all male patients dependent on methamphetamine who visited the Gam Addiction Treatment Clinic in Ghaemshahr city in the year 2020, from whom 45 individuals were selected through convenience sampling and randomly divided into three groups of 15 (two experimental and one control group). Participants in all three groups responded to the Drug Desire Questionnaire (DDQ) (2002) and the Hocksmann-Nolen Marw Rumination Questionnaire (1991) in three stages: pre-test, post-test, and follow-up. For the first experimental group, Transcranial Direct Current Stimulation (TDCS) was applied with a maximum current intensity of 2 milliamperes, and for the second experimental group, twelve sessions of Cognitive-Behavioral Therapy were conducted based on the Cognitive-Behavioral Therapy protocol (Bayling, McCabe, Antony, 2011), while the control group received no treatment. Data were analyzed using SPSS statistical software.
Findings: The results showed that both treatments were effective. However, the effectiveness of Transcranial Direct Current Stimulation (TDCS) on craving control and the effectiveness of Cognitive-Behavioral Therapy on rumination were greater.
Conclusion: Both treatments can be used to reduce psychological problems in methamphetamine-dependent patients.

Keywords: *Transcranial Direct Current Stimulation (TDCS), Cognitive-Behavioral Therapy, Substance Craving Control, Rumination, Methamphetamine*

1. Introduction

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ubstance use is categorized into various types based on the kind and effects it has on the consumer. Methamphetamine

is a potent form of amphetamine that abusers consume through inhalation, smoking, or intravenous injection. Its psychoactive effects last for hours and are very strong. Unlike cocaine, which must be imported from abroad, methamphetamine is a synthetic drug that can be produced in local illegal laboratories (Pirzadeh & Parsakia, 2023; Sopheab et al., 2020). The high prevalence of methamphetamine use and the very high mortality rate of its users in recent years have attracted the attention of various researchers and have been the subject of many studies (Rajabpour & Nejat, 2019; Ruisoto & Contador, 2019). From 2006 to 2015, there was an approximate 23% increase in the number of drug users worldwide. The global prevalence rate of substance use was about 4.9% in 2006 and reached 5.39% in 2015. According to statistics, in 2017, 2,880 people were officially reported as regular drug users in Iran. Drug-related mortality in 2016 increased by approximately 6.8% compared to 2015, meaning more than 3,200 addicts died due to substance abuse (Degenhardt et al., 2018; Kendler et al., 2017). All narcotics, including psychoactive substances like methamphetamine, not only have direct consequences and side effects on users but also entail secondary social costs such as disturbances in family, work life, and the emergence of various types of violence (Mirza Nia & Firoozi, 2020). The greatest threat to a recovering patient and the primary cause of relapse is the craving for substance use, which can be very confusing and distressing if not accurately identified and controlled, potentially leading to resumed consumption (Ehteshami et al., 2018; Hamednia et al., 2017; Ruisoto & Contador, 2019). In clinical studies, craving has been reported as an important predictor of drug use and relapse. Craving is an uncontrollable desire to consume drugs; a desire that, if unmet, can lead to psychological and physical suffering in drug-dependent individuals, including aggression, anxiety, depression, and weakness (Di Nicola et al., 2015; Ehteshami et al., 2018; Ameneh Oji et al., 2020; Rosenberg, 2009; Sadeghi & Karimi, 2019). One issue that significantly contributes to the continuation of substance use in addicts is rumination about substance use. Rumination is an abnormal emotional cognitive regulation strategy that individuals exhibit in response to experiencing a negative mood. Rumination involves thoughts and behaviors that repeatedly direct a person's attention to negative feelings and the nature and implicit meanings of these feelings, including their reasons, meanings, and consequences (Carlucci et al., 2018; Raines et al., 2017). These thoughts involuntarily enter consciousness, causing a diversion of attention from intended subjects and goals. Researchers have proposed various methods to improve craving and rumination, affecting the brain through different pathways. One such method is direct stimulation of the skull using electrical current (tDCS). In this therapeutic approach, a constant and mild electrical current passes through the head using large electrodes placed on the person's head. The passing electrical current determines the effectiveness of tDCS (Aghaziarati et al., 2023; Ferrucci & Priori, 2014; Jacobson et al., 2012; Keshvari et al., 2017; Moslemi et al., 2019; Nitsche et al., 2012). Cathodal stimulation decreases brain activity and excitability, whereas anodal stimulation does the opposite, increasing brain activity (Aghaziarati et al., 2023). Various studies have highlighted the effectiveness of tDCS treatment in improving craving and rumination. For example, many studies confirmed the effectiveness of Transcranial Direct Current Stimulation (TDCS) on depression, anxiety, and rumination in patients with stress disorder (Ferrucci & Priori, 2014; Fregni et al., 2008; Moslemi et al., 2019).

Another effective therapeutic method for controlling craving and rumination is Cognitive-Behavioral Therapy. One of the most promising psychotherapies for addicts is Cognitive-Behavioral Therapy, particularly effective in preventing relapse and returning to drug use. Cognitive-Behavioral Therapy is an active, directive, time-limited, and structured approach based on an underlying theoretical rationale, where an individual's emotions and behavior are primarily determined by their worldview (Kalmbach et al., 2020). Cognitive-Behavioral Therapy is a therapeutic method where patients freely and without fear express their inefficient thoughts and cognitive distortions, then proceed to examine and correct thoughts, underlying beliefs, and cognitive distortions, aiming to help individuals understand how their behavior affects their thoughts and feelings (Cheng et al., 2020; Cook et al., 2019). Its effectiveness is confirmed by various researchers in diverse clinical and non-clinical (Afshari et al., 2022; Asghari et al., 2020; Atwood & Friedman, 2020; Caletti et al., 2022; Fitzsimmons-Craft et al., 2023; Kazem Zadeh Atoofi et al., 2023; Khosravani Shayan et al., 2020; Matsumoto et al., 2022; Salza et al., 2020; Shareh & Robati, 2021; Wickberg et al., 2022)settings. Given the prevalence of methamphetamine abuse in society and the resulting social and individual problems, it is essential to take measures for prevention and improvement of these individuals. Treating methamphetamine abuse and proper prevention of this harmful phenomenon will reduce treatment costs and prevent the waste of social resources. Considering that

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variables related to relapse, such as craving and rumination, can play an important role in predicting the extent of return and reuse in methamphetamine-dependent individuals; the current research was conducted with the aim of comparing the effect of Transcranial Direct Current Stimulation and Cognitive-Behavioral Therapy on controlling substance craving, rumination in methamphetamine-dependent patients.

2. Methods and Materials

2.1. Study Design and Participants

This research is a quasi-experimental study conducted in 2021. The statistical population includes all female high school students in the city of Sabzevar, from which samples were purposefully and completely randomly selected into three groups of 15 individuals.

2.2. Measures

2.2.1. Desire for Substance Abuse

A 14-item questionnaire developed by Franken et al. (2003) that assesses current craving and includes three subscales: desire and intention to use substances, negative reinforcement, and perceived control over substance use. Responses are scored on a Likert scale from one to seven. Franken et al. (2003) reported the overall reliability of this scale using Cronbach's alpha as 0.85, and for the subscales of desire and intention to use substances, negative reinforcement, and perceived control over substance use, respectively, as 0.77, 0.80, and 0.75. In Iran, the overall Cronbach's alpha was 0.82, and for the subscales, respectively, 0.70, 0.82, and 0.70 (Mohammadkhani et al., 2011).

2.2.2. Rumination

This 22-item questionnaire measures the tendency to respond to negative mood and life events with a ruminative coping style (Turn & Jorman, 2013). Scoring for each item is on a Likert scale from 5 (almost never) to 1 (almost always), with the score range for each participant varying from 22 to 88. A study showed Cronbach's alpha ranges from 0.88 to 0.92 and interclass correlation of 0.75 for this scale (Ramezani et al., 2023).

2.3. Interventions

2.3.1. tDCS & CBT

The implementation of the current study was conducted by the researcher working at the Gam Addiction Treatment Clinic in Ghaemshahr city, who selected 45 individuals based on the research entry and exit criteria. These individuals were placed in three groups (two experimental groups of 15 each) and one control group (15 individuals). The relevant questionnaires were administered to the participants. Accordingly, a pre-test was initially conducted for each group, followed by sessions of Transcranial Direct Current Stimulation (TDCS) and Cognitive-Behavioral Therapy, dividing the experimental group members into three groups of five for the sessions. The sessions were conducted while fully observing health protocols (using masks and gloves and disinfecting patients at the site). After the treatment sessions, patients were asked to respond to these questionnaires again (post-test). The device used in the research was the ActivaTek, made in the USA, with a maximum current intensity of 2 milliamperes. Carbon electrodes with a size of 35 square centimeters and a sponge pad for covering the electrodes were used in this study (Aghaziarati et al., 2023; Jacobson et al., 2012; Moslemi et al., 2019). The Cognitive-Behavioral Therapy was a 12-session course based on the Cognitive-Behavioral Therapy protocol (Lindenberg et al., 2022; Amne Oji et al., 2020), conducted once a week with each session lasting 90 minutes.

Table 1

Cognitive-Behavioral Therapy (CBT) Protocol

Session	Content
1	Motivational feedback, decision-making table for continuing or discontinuing substance use, harms of continuing use and not changing, benefits of change, benefits of continuing use without change
2	Identifying high-risk situations (interpersonal and intrapersonal, emotional triggers, people, places, and objects), practical plans for dealing with high-risk situations
3	Identifying predisposing factors for substance misuse, planning methods to deal with cravings and desires (thought stopping, balance decision-making exercise, delaying)

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4	Dealing with negative thinking, the relationship between thought and emotion, identifying negative thinking patterns, combating negative thoughts and cognitive restructuring
5	Seemingly irrelevant decisions, awareness of high-risk situations, functional analysis of thinking at risk
6	Planning and anticipating emergency situations, unexpected triggers or high-risk situations, "If... then..." action plans, hierarchy of coping strategies
7	Refusal skills and dealing with direct offers to use substances, the "No, thank you" principle, designing personal refusal test cards, role-playing assertive responses
8	Giving and receiving criticism, assertive response to criticism, presenting critical descriptions with assertiveness
9	Anger management and substance use, identifying signs and symptoms of anger, relaxation skills, cognitive restructuring regarding anger-inducing thoughts, problem-solving in anger-related stories, role-playing
10	Pleasurable and rewarding activities and substance use, examining withdrawal from pleasurable activities as a result of substance use, identifying pleasurable activities as appropriate and healthy solutions, planning for their implementation
11	Labeling and problems related to substance use, problem-solving skills, defining the problem, presenting possible solutions, selecting a solution, implementing the chosen solution, evaluating the implemented solution, presenting practical examples in session
12	Developing friendships not focused on substance use, cutting ties with harmful friends and acquaintances, disconnecting from dealers and users, finding a supportive group, forming self-help groups

2.4. Data analysis

In the inferential statistics section, one-way analysis of variance, multidimensional chi-square for checking the homogeneity of groups, Shapiro-Wilk test for examining data normality, and repeated measures analysis of variance considering within-group (test) and between-group (group membership) factors were used. Tukey's test was also used for comparing experimental groups with each other and with the control group.

3. Findings and Results

As observed in Table 2, the mean scores of pre-test for craving control and rumination were nearly equal across both experimental groups (TDCS and CBT) and the control group. However, in the post-test, the mean scores for craving and rumination in the experimental groups (TDCS and CBT) were significantly lower than those of the control group. This pattern was also visible in the follow-up values for both experimental groups (TDCS and CBT) and the control group. The Shapiro-Wilk normality test was used to examine the hypothesis of normality. Shapiro-Wilk values in pre-test, post-test, and follow-up scores for craving control and rumination in methamphetamine-dependent patients, for both experimental groups (TDCS and CBT) and the control group, were significant in most variables, indicating the normal distribution of variables. The Levene's test also confirmed the assumption of homogeneity of variances.

Table 2

Mean and Standard Deviation of Pre-test, Post-test, and Follow-up Scores for Substance Craving Control and Rumination

Dependent Variable	Group	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	Follow-up Mean	Follow-up SD
Pleasure and Lack of Control	TDCS	9.51	1.57	8.14	1.23	8.07	1.14
	CBT	9.79	1.31	8.69	1.31	8.57	1.22
	Control	10.07	1.26	10.64	1.55	10.71	1.49
Desire to Use	TDCS	8.50	1.69	7.06	1.20	7.03	1.24
	CBT	8.29	1.68	7.64	1.39	7.54	1.29
	Control	8.43	1.82	8.36	1.86	8.27	1.86
Intention and Inclination to Use	TDCS	7.91	1.23	7.14	1.29	7.11	1.08
	CBT	8.97	1.63	7.86	1.16	7.67	1.26
	Control	9.01	1.61	8.87	1.38	8.75	1.38
Substance Craving	TDCS	29.91	3.30	25.09	4.03	25.02	4.37
	CBT	30.21	3.37	27.29	3.45	27.23	3.13
	Control	30.29	3.40	30.36	3.36	30.43	3.50
Rumination Contemplation	TDCS	10.64	1.08	9.36	1.15	9.29	2.67
	CBT	10.90	1.41	8.27	0.91	8.21	0.99
	Control	10.87	1.26	10.93	1.49	10.70	1.54
Rumination Immersion	TDCS	11.71	0.82	10.29	1.13	10.50	0.94
	CBT	11.60	0.82	9.21	1.36	9.09	0.97
	Control	11.79	0.80	12.07	0.82	12.01	0.82
Rumination	TDCS	51	3.25	43.79	4.35	43.21	4.35
	CBT	50.57	4.66	39.71	4.12	39.26	4.84
	Control	50.37	3.11	50.86	3.32	50.57	3.20

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The results in Table 3 indicate that, regarding the within-group and between-group factors in craving and rumination variables, the calculated F value for the effect of stages (pre-test, post-test, and follow-up) was significant at the 0.01 level. Specifically, for the between-group factor for pleasure and severity of control loss (F=28.052, P<0.01, Eta^2=0.791), desire to use and negative reinforcement (F=24.437, P<0.01, Eta^2=0.743), intention and inclination towards use (F=39.967, P<0.01, Eta^2=0.810), and craving (F=49.575, P<0.01, Eta^2=0.885), ruminative contemplation (F=39.245, P<0.01, Eta^2=0.843), ruminative immersion (F=46.864, P<0.01, Eta^2=0.881), and rumination (F=60.747, P<0.01, Eta^2=0.916) were obtained. Therefore, there is a significant difference between the mean scores of pre-test, post-test, and follow-up scores of rumination in methamphetamine-dependent patients across the three stages of pre-test, post-test, and therapeutic follow-up.

Table 3

Summary of Mixed Repeated Measures ANOVA Results with Within-Group and Between-Group Factors

Factor	Source	SS	Df	MS	F	p	Effect Size	Power
Within-Group								
Pleasure and Lack of Control	Therapy Stages × Group	152.788	1	152.788	62.052	0.000	0.858	1
Desire to Use and Negative Reinforcement	Therapy Stages × Group	121.039	1	121.039	52.437	0.000	0.824	1
Intention and Inclination to Use	Therapy Stages × Group	177.693	1	177.693	87.967	0.000	0.883	1
Substance Craving	Therapy Stages × Group	529.762	1	529.762	106.125	0.000	0.961	1
Between-Group								
Pleasure and Lack of Control	Group	139.377	2	69.688	28.052	0.000	0.791	1
Desire to Use and Negative Reinforcement	Group	110.431	2	55.215	24.437	0.000	0.743	1
Intention and Inclination to Use	Group	164.055	2	82.027	39.967	0.000	0.810	1
Substance Craving	Group	234.738	2	117.369	49.575	0.000	0.885	1
Within-Group (Rumination Factors)								
Rumination Contemplation	Therapy Stages × Group	412.622	1	412.622	78.638	0.000	0.921	1
Rumination Immersion	Therapy Stages × Group	539.134	1	539.134	89.754	0.000	0.943	1
Rumination	Therapy Stages × Group	829.714	1	829.714	129.110	0.000	0.987	1
Between-Group (Rumination Factors)								
Rumination Contemplation	Group	388.691	2	194.345	39.245	0.000	0.843	1
Rumination Immersion	Group	411.003	2	205.501	46.864	0.000	0.881	1
Rumination	Group	619.714	2	309.857	60.747	0.000	0.916	1

The results in Table 4 show that there is a significant difference between the scores of craving control and rumination in methamphetamine-dependent patients in the TDCS experimental group compared to the CBT experimental group.

Table 4

Summary of Tukey's Post Hoc Test Results for Two Experimental Groups

Variable	Groups Comparison	Mean Difference	Standard Error	Significance (Sig.)
Pleasure and Lack of Control	TDCS Group - CBT Group	0.690	0.121	0.001
Desire to Use and Negative Reinforcement	TDCS Group - CBT Group	0.391	0.052	0.001
Intention and Inclination to Use	TDCS Group - CBT Group	0.581	0.104	0.001
Substance Craving Control	TDCS Group - CBT Group	1.81	0.153	0.001
Rumination Contemplation	TDCS Group - CBT Group	1.011	0.131	0.001
Rumination Immersion	TDCS Group - CBT Group	0.986	0.105	0.001
Rumination	TDCS Group - CBT Group	3.64	0.327	0.001

4. Discussion and Conclusion

The aim of the present study was to evaluate the effectiveness of Transcranial Direct Current Stimulation (TDCS) and Cognitive-Behavioral Therapy on controlling craving and rumination in patients dependent on methamphetamine. The findings indicated a significant difference between the craving control scores in methamphetamine-dependent patients in the TDCS experimental group compared to the CBT experimental

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group, suggesting a greater effectiveness of Transcranial Direct Current Stimulation (TDCS). This part of the research supports past studies (Aghaziarati et al., 2023; Chitsazha et al., 2019; Ferrucci & Priori, 2014; Fregni et al., 2008; Hellberg et al., 2019; Jacobson et al., 2012; Keshvari et al., 2017; Maddineshat et al., 2016; Mohyadini et al., 2021; Moslemi et al., 2019; Nitsche et al., 2012; Ameneh Oji et al., 2020; Quartarone et al., 2004; Rajabpour & Nejat, 2019; Saeidi et al., 2021). To explain the difference in effectiveness of Transcranial Direct Current Stimulation (TDCS) and Cognitive-Behavioral Therapy on controlling substance craving, it is hypothesized that TDCS, by affecting the dorsolateral prefrontal cortex, may have corrected dysfunction in this area, leading to reduced craving, desire to use, planning and intention for use, reduced expectation of positive outcomes from substance use, and relief from withdrawal symptoms. TDCS was also applied in the left dorsolateral prefrontal cortex, and results showed no change in craving. This study did not use a control group. Contradictory findings exist in this area. Two studies using FMRI showed that substance craving is related to activity in the left dorsolateral prefrontal cortex (Jacobson et al., 2012; Moslemi et al., 2019). Reviews indicate that stimulation in the left dorsolateral prefrontal cortex reduced food craving in participants. Another experiment reported increased activity in the left dorsolateral prefrontal cortex when alcohol-dependent individuals were exposed to alcohol cues. Another possible explanation for these findings relates to the considerations of induced craving tests. Given this issue, induced craving syndromes only create cravings in some individuals (Jacobson et al., 2012; Moslemi et al., 2019; Silvanto & Pascual-Leone, 2008).

Other results showed a significant difference between the rumination scores in methamphetamine-dependent patients in the TDCS experimental group compared to the CBT experimental group, indicating greater effectiveness of Cognitive-Behavioral Therapy. This part of the research also supports past studies (Aghaziarati et al., 2023; Cheng et al., 2020; Cook et al., 2019; Ferrucci & Priori, 2014; Fregni et al., 2008; Jacobson et al., 2012; Kalmbach et al., 2020; Keshvari et al., 2017; Moslemi et al., 2019; Nitsche et al., 2012; Quartarone et al., 2004). To explain the greater impact of Cognitive-Behavioral Therapy on rumination, it should be noted that the primary goal of Cognitive-Behavioral Therapy is to change and correct thinking and behavior patterns, thereby altering negative emotions and empowering individuals to deal with life events. In fact, by changing cognitions, the entire emotional and behavioral system of the person will change. This type of therapy, by enhancing cognitive-behavioral skills such as problem-solving, discovering and identifying semi-conscious and distorted thoughts, interpreting events from newer perspectives, creates a stronger sense of control and places individuals in a position where they feel they can manage uncontrollable affairs. Furthermore, clients learn to focus not only on negative events or aspects of an event but also on its positive aspects, avoid making predictions without sufficient evidence, and strengthen a forward-looking, positive, realistic perspective in themselves, overcoming rumination by de-catastrophizing situations. Patients, due to repeated exposure to unpredictable and uncontrollable events, gradually become more passive and often fear social environments and worry about others' misinterpretations, which prevents them from experiencing many positive experiences. Isolation and passivity also affect the patients' self-perception, causing them to experience significant rumination and effectively miss many opportunities for effective functioning. Using cognitive therapy, which included correcting negative automatic thoughts and underlying beliefs of the patients, challenged patients' attitudes about their illness and its disabling effects. From a behavioral perspective, the use of activity scheduling techniques was very helpful. Since their self-perception was negatively reinforced, activity scheduling helped patients minimize the likelihood of failure in achieving daily plans. Patients were encouraged to value any increase in daily activity level and reinforce it with positive thinking.

5. Limitations & Suggestions

The study faced limitations such as a limited sample size, restricting generalizability. It primarily focused on methamphetamine users, potentially overlooking the effects on individuals with other substance dependencies. The research design was quasi-experimental, lacking randomization, which might have introduced bias. Furthermore, the study relied on self-reported measures, possibly leading to response biases.

Future research should consider expanding the sample size and diversity to enhance generalizability. Implementing a randomized controlled trial design could mitigate potential biases and improve the robustness of findings. Additionally, exploring the effects of interventions on various substances could offer a broader understanding of effective treatments. Incorporating objective measures alongside self-reports would also strengthen the validity of the results.

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The findings suggest that combining psychological interventions with medical treatments could offer a comprehensive approach to substance dependency. Implementing these interventions in rehabilitation programs could enhance recovery outcomes. Healthcare providers should receive training on these techniques to apply them effectively. Moreover, policy makers should consider these findings when designing public health strategies to combat substance abuse, emphasizing the importance of accessible and varied treatment options.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. This research was conducted with the ethical code IR.IAU.BOJNOURD.REC1399.040 from the Islamic Azad University, Bojnourd Branch.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors contributed equally.

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