Binaural Beats Effect on Addicted People Based on EEG

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Abstract

Objective: This study was aimed to investigate binaural beats effect on addicts to evaluate use of this technology as an aid in the stable treatment of addiction. **Method:** The population of this study included 15 addicted people who admitted to rehab clinic with an average age of 30.5 that were chosen under medical supervision and by using the Eysenck Personality Questionnaire and urine test. Then, 10 addicted people received the controlled binaural beats in three sessions and 5 addicted people who were as control received just the normal treatment. Urine dopamine test, Electroencephalography (EEG) and Brunel Mood Scale (BRUMS) are administered to the participants. **Results:** Controlled binaural beats can reduce anger, tension, confusion and increased vigor and the desire to continue the treatment for get full recovery in addicted people. **Conclusion:** By using controlled binaural beats in conjunction with other activities in the treatment process can accelerate and consolidation the people treatments without side effects.

Keywords: Binaural Beats, Addiction, Dopamine, Electroencephalography

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Introduction

Addiction is a psychological, social and economic illness that results from unnecessary and unlawful use of certain substances such as alcohol, opium, hashish, etc., and causes the psychological or physiological dependence of the addicted person to substance (Naseri, Palangerd, Mohammadi, Doleh, & Nasseri, 2013). This dependence has undesirable effects on the physical, psychological and social function of the addicted person and, in severe cases, even threatens his personal and social life (Noel, Brevers, & Bechara, 2013, quoted by Soleimani, Senobar, 2015). Addiction and complications from substance abuse are one of the major problems in the world. Difficulties with addiction impair all aspects of the life of the individual, the family, and even the community, and spoil the huge social resources in the material and spiritual realm (Lee, Herrenkohl, & Kosterman 2013, quoted by Soleimani, Senobar, 2015). In fact, drug addiction and drug abuse as a social issue is a phenomenon that ruins the society's ability to organize and maintain the existing order, disrupts the normal functioning of social life and causes structural transformations in the economic, social, political and cultural systems of a community (Miri Ashtiani, 2006). In a brief estimation, eight people die every day and, on the other hand, at least 100 new drug users are being added every year, and the country incurs more than 10 trillion Tomans annually (Mozaffar, Zakeriyayi & Sabeti, 2009). According to the American Society of Addiction Medicine, addiction is a chronic and primary disease of brain rewards, motivation, memory and related brain circuits. Disturbance in each of these circuits leads to biological, psychological, social and spiritual manifestations. Following rewards or opiate relief is a behavioral reflection to such disorders. Addiction is described as a disorder in behavioral control, desire to consume, declining recognition of the underlying issues, and personal relationships and ineffective emotional reactions, and like other chronic diseases, often include the relapse and recovery cycle. Addiction without treatment or employment in recovery activities is progressive and can lead to disability or early death (American Society of Addiction Medicine, 2011).

For the fuller expression of "addiction", it can be said that the addiction of Neurotransmitters and interactions factors affect the structure of the brain reward, including the nucleus accumbens, the anterior cerebral cortex, the brain base and the amygdala. These effects change the incentive hierarchy, create addictive behaviors and ultimately replace them with healthy behaviors. Also, addiction affects neurotransmitters and interactions between the cerebral cortex and the hippocampal circuits of the brain reward structure (Hyman, Malenka, & Nestler, 2006). The nucleus accumbens is the most significant center of brain pleasure (brain reward system), and the neurotransmitter dopamine plays an essential role of the reward system of the brain (Mavridis, 2015). Dopamine increases in the brain when it comes to sexual pleasure, food, etc. Drugs that are

being misused also have this attribute that their consumption is associated with pleasure and euphoria, which actually act as a behavioral reinforcement (Hyman, Malenka, & Nestler, 2006).

Substance in addicts can also enhance their previous behaviors by eliminating distressing or unpleasant conditions such as pain, anxiety, or depression (Jamssadok, quoted by Rezaei, 2008). In fact, side effects of drugs can be mentioned as the behavioral problems, restlessness, impatience, paranoid thoughts, depression and increased aggression, social behavior change, and social isolation of consumers (Gorman et al., 2004; quoted by Nejati, Shiri, & Noori , 2012). Therefore, addiction is not only a matter of drug, but there is a two-way relationship between the substance and the personality of the consumer (Oraki & Hosseini Nasab Bazkiani, 2012). There has been a lot of research about the behavioral problems of people involved with addiction. Soleimani, Najafi, Elahi, and Sharghi (2013) evaluated the frequency of anxiety and depression in addicts under drug treatment. Their results showed that 49.3% of 51 patients had anxiety symptoms and 51% had symptoms of depression. The results of a study conducted by Ketabi, Maher, and Barjali (2011) also showed that addicts receive high scores in Eysenck psychosis and psychosis, and in another study, Nasetizai (2007) showed that 95% of drug addicts also during the first 6 months of quit due to mood and anxiety problems return to recurrence. Finally, Terracciano, Crum, Bienvenu, and Costa (2008); Pourkord, Abolghasemi, Narimani, and Rezaei Jamalouyi (2013); Karimi, Hemmatisabet, Ahmadpanah and Mohammad beigi (2013); Rostami, Ahadi, and Cheraghali Gol (2012); Ghasemi Hamed, Rabiei, Haghayegh, and Palahang (2011) concluded that being in stressful situations and using inefficient and exciting solving methods leads to a defective cycle and increased stress and decreased compatibility in them. And ultimately it increases the incidence of relapse in these individuals. Drugs used to treat anxiety have many side effects, although they have a rapid effect, and should be taken for 8 to 12 months, and in most cases, anxiety relapses again. One of the major drawbacks of these drugs is the development of tolerance and dependence in the long term (Pour Afkari, 2010). Behavioral therapy methods, non-pharmacological anxiety-reducing therapies including therapeutic touch, use of heat and cold, various methods of relaxation (hypnosis, guided imagination, thinking deviance, biofeedback, meditation, yoga, progressive muscle relaxation and muscle relaxation of Benson) and music therapy that can reduce the amount of anxiety. These methods are non-invasive, in addition to being safe and inexpensive (Zolfaghari, 2003; quoted by Hashemi & Zakeri-Moqaddam, 2012). Sokhadze, Cannon, and Trudeau (2008) concluded that the eclectic method of neuropsychological methods, conventional psychological treatments and neurofeedback had a significant effect on cognitive (such as executive control) and emotional performance improvement (such as temptation, high sensitivity to drugs, symptomatic treatment and executive control). Zolfagharzadeh, Khalilzadeh, Ghashhoni, and Hashemian (2016) also showed that patients with

methamphetamine-dependent substances can improve the severity of their craving under the influence of neuro-feedback.

In the present study, the effect of binaural beats on the brain signals of addicted people is investigated. According to the research, the ability to follow brain activity is considered the application of binary beats technology (Carlo Calaberse, 2007). If two audio signals are broadcasted at different frequencies of the two ears, the internal sound frequency that the brain perceives will equal to the difference between the two signals, which is the binaural beats phenomenon. The binaural beats provide a suitable basis for simulating the auditory system at low frequencies below the auditory frequency (Lane et al., 1988). Previous research has suggested that binaural beats technology in the beta frequency band in the EEG signal can enhance memory and attention activities (Kennerly, 1994) or the use of binaural beats in the alpha frequency band range can enhances people's calmness (Foster, 1996). Electroencephalography, on the other hand, is one of the non-invasive methods for measuring the activity of brain waves from sensors placed on the scalp skin. The human brain has millions of neurons, due to the electrical activity of these neurons, a small voltage signal is created on the skull surface. This is called electroencephalography (Jailani, Norhazman, & Zaini, 2013). The brain has four alpha, beta, delta and theta frequencies. Beta waves are fast-moving brain waves that interact with thinking, focusing and analyzing information. Alpha waves are associated with calm and silence. Waves of theta are related to memory, deep relaxation and fantasy. Delta waves are the slowest brain waves associated with deep sleep (jailani, Norhazman, & Zaini, 2013).

Given the significance of addiction and its treatment and the results of the past research, since the frequencies associated with different genes of human brain activity produce different, but certainly predictable, effects on the brain (Jailani et al., 2013), in this research attempts were made to investigate the effect of binaural beats at a given frequency on patients hospitalized in the addiction treatment center, so that this technology can be used as a treatment aid for them. But since this technology is new and its use as a stimulant of emotion is under investigation, the published articles in this area are very limited and its investigation on addicted people is not yet done with the aim of accelerating their treatment.

Method

Population, sample and sampling method

This research is a quasi-experimental study using pre-test and post-test with the control group. Participants in this study conducted an Eysenck Personality Test, under the supervision of a psychiatrist and social worker close to the patients, among male addicts admitted to Khorasan Razavi Therapeutic Community Clinic, the Pioneer Health Institute of the Sun Land in Mashhad. After giving the necessary explanations to the psychologist, the social worker and the clinic

officials, 20 men in the age range of 30.5 were considered to participate in this research. Then, using the Eysenck Personality Test, the participants were selected and the subjects that were most similar in terms of personality and basic conditions were selected (Ketabi, Maher, & Barjali, 2011). Subsequently, the participants were informed about the test and they filled in the consent form for the test. Also, the Brums mood questionnaire was used to examine the status of individuals as a result of applying the stimulus. Using these results, the two groups were screened for the magnitude and type of affectedness.

Regarding the care provided by the Center for Addiction Treatment and the medical records of the subjects, participants were prohibited from taking active drugs during the project, or they were among people who did not generally receive drug treatment. However, for more precision in the work, all subjects who participated at the beginning and the end of the study had dopamine test from their urine sample. According to this test and urine test, the data of 5 people were inappropriate for analysis and only the results of 15 people were reviewed. Among them, the effect of binaural beats was considered on 10 people in the first group and the remaining 5 subjects were studied as control group and during the usual treatment in the clinic.

Instruments

1. Recording Brain Signal: The EEG signal was recorded by using a 10-channel FlexComp Infiniti encoder device. In this study, eight channels of Tables (1) and a standard placement of 10-20 was used. Also, electrodes are fixed on the head using a conductive adhesive of the electrodes. To record signals on a computer, the device software was used, and finally for output analysis, data is called in MATLAB software.

Table 1. Channels used to Record EEG Signal

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
C_z	T_3	T_4	P_z	F_7	F_z	F_{pz}	F_8

The i-Dozer software was used to broadcast the binaural beats. This software is used to combine and play binaural beat frequencies with different frequencies. According to the purpose of this research, 7 Hz frequency was used to create relaxation for addicted people (Pejman, Rahati, & Fathi, 2013). Playback of songs and binaural beats is also done using the ASUS N53S laptop, and played with a Philips handset.

2. Brums Mood Questionnaire: Another tool for collecting data in this research is a questionnaire derived from the personal statements of the participants. For better information on the mental status of the people at the end of each session, the participants were asked to fill in the Brums mood questionnaire (Lane et al., 1988). Modulo et al. (2011) also used this questionnaire to assess and compare the quality of life and the mental states of male and female athletes. The questionnaire has 24 questions about expressing

the person's emotions. By examining and analyzing using the test key and consulting with the psychologist, 6 states of anger and aggression, depression, tension, confusion, fatigue, and vigor are measured. At the end, each of these mental states was assigned with scores ranging from 0 to 16, where increase in the score indicates the intensity of the state.

Procedure

The protocol for recording this research is based on previous studies. The test was administered in 3 consecutive days at identical hours in a room controlled by light and temperature (about 24 °C), as well as calm and without any possible contamination in the clinic. For adapting people with the testing process, 10 minutes were considered. Also, people were asked to avoid taking relaxing and caffeinated drinks 12 hours before the start of the test. In each session, the participant (Fig. 1) was placed on a comfortable chair with closed eyes, without any sudden movement or speaking, and the electrode cap and headphones were placed on his head.

Figure 1. A View of the Testing Process

The experiment is designed so that each participant in each 11-minute session is influenced by the neutral music as the foreground and binaural beats at the same time. In order to observe the changes, the evaluation of the operation mode and the result of applying the waves, 2 minutes before and 2 minutes after applying binaural beats, the brain signaling test was also administered to the subjects in the same conditions (Pejman, Rahati, & Fathi, 2013). At the end of each session, the Brums mood questionnaire was provided to the participants. In the control group, the procedure was performed without music playback and binaural beats.

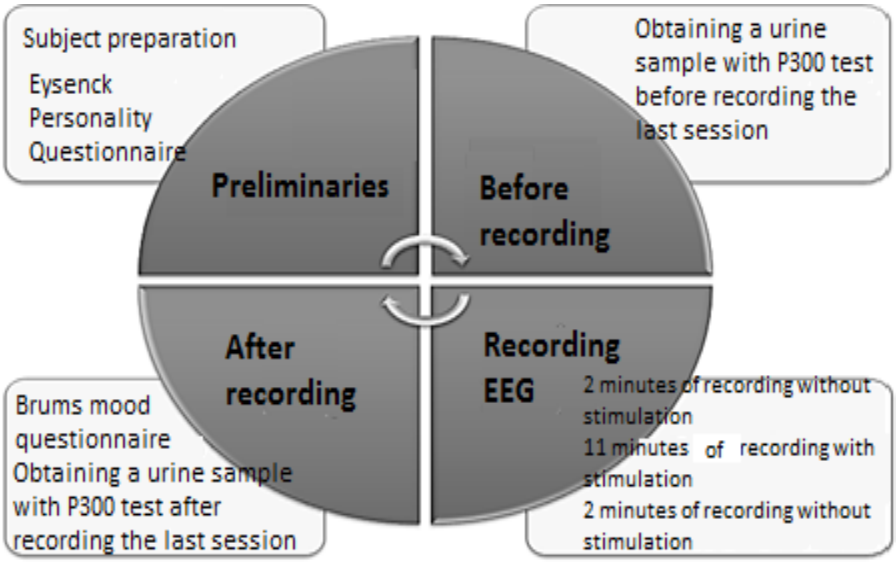

Figure 1. Signal Recording Protocol

Data were processed using MATLAB software. First, for eliminating the noise and the existing artifacts, using the downstream and the upstream filters tailored to the pre-processing of signals. Then, in order to understand and compare the variations of the Binaural distribution, 14 characteristics including time characteristics (moderate, diffraction, skewness and sharpness), frequency characteristics (Delta band relative power (0 to 4 Hz), theta band relative power (4 to 8 Hz), the slow alpha band relative power (8 to 10 Hz), the relative power of the fast alpha band (10 to 13 Hz), the relative power of the beta band (13 to 30 Hz), the signal energy, the relative power of the band 6.5 to 7.5 Hz and maximum band power 6.5 to 7.5 Hz), and nonlinear characteristics (Lyapanov exponent and fractal dimension) were extracted from the first 3 minutes and the final 3 minutes of each signal (Pejman, Rahati, & Fathi, 2013). Due to the broadness of the characteristics, the extracted characteristics of the elementary and end segments were measured in MATLAB software by t test. Frequency domain characteristics are among the characteristics that show relatively good performance in different brain signal processes. Various methods have been developed for estimating the power of spectrum from data, which usually provide a good estimate of the specific type of signals. Due to the significance of spectral changes in the EEG signal in frequency bands of delta, theta, slow alpha, fast alpha, beta, and gamma for various mental and mental states, several articles were reviewed and, given these, the frequency characteristics were considered. After calculating the power of each band, the relative power of each band is considered as a characteristic, which is obtained by dividing the power of that frequency band in the total power of the signal spectrum frequencies.

Another approach used to derive the characteristic of the EEG signal is the use of nonlinear characteristics. Nonlinear techniques can describe processes produced in biological systems in more effective ways. Parameters expressing chaotic behavior fall into two categories. The first group is the ones that emphasize the dynamics of chaotic behaviors, such as Lyapanov exponent. These sets of parameters describe the behavior of the system over time. The second group emphasizes the geometric nature of the motion paths in the space state, such as the fractal dimension. The Lyapunov exponent value expresses how fast the predictability is lost in the system. This feature is intended to measure the rate of trajectory absorption or desorption of a system's state of equilibrium points. To calculate the largest Lyapunov exponent (MLE) from a time series, we need to examine the widening gap between successive samples. An MLE signal is calculated using the equation (1), where d_n is the consecutive time interval at time n-th, and d_0 is the consecutive interval in the initial time.

Equation (1):

$$\lambda = \frac{1}{n} \ln \frac{d_n}{d_0}$$

The fractal dimension also indicates the geometric characteristics of the absorption substrate. The speed of computing is high. The Higuchi Algorithm method is used to calculate fractal dimension. In this method, using the series of input data $x_1, x_2, \ldots, x_n$ a new series is made as equation (2).

Equation (2):

$$x_m^k = \left\{ x(m), x(m+k), x(m+2k), \ldots, x\left(m + \left[\frac{N-m}{k}\right] k\right) \right\}$$

Where m denotes the initial point of each series and $\lfloor \rfloor$ represents the integer of the number. For each x_m^k, the length $L_m(k)$ is equal to equation (3):

Equation (3):

$$L_m(k)J = \frac{\sum_{i=1} |x(m+ik) - x(m+(i-1)k| \, (N-1)}{\left[\frac{N-m}{k}\right] k}$$

Where N represents the number of samples and $\frac{N-1}{\left[\frac{N-m}{k}\right] k}$ is the normalization coefficient. For each value k, the length of k length is obtained, and then their mean is calculated as the mean length. This action is repeated up to k max. The Higuchi Algorithm is the best approximated line with the least squares of error for the $\ln(L(k))$ in terms of $\ln(\frac{1}{k})$.

Result

Using the results of the t test, the characteristics with the highest change from the first and the last part of the recorded signal were investigated. The descriptive statistics of the various characteristics are presented in Table 2.

Table 2. Descriptive Statistics and Significance Values for Different Characteristics

The statistics	*Mean*	*Standard deviation*	*significance*
Moderate	-0.2050	1.68	0.54
Diffraction	0.00098	0.003	0.003
Skewness	0.165	0.01	0.47
broadness	3.125	0.01	0.37
Delta band relative power (0 to 4)	92.707	0.002	0.001
Theta band Relative power (4 to 8)	0.0014	0.00	0.24
Slow alpha band relative power (8 to 10)	20.0052	3.05	0.03
Fast alpha band relative power (10 to 13)	932.10	0.00	0.04
gamma-band relative power (13 to 30)	966.79	0.01	0.29
Signal energy	0.0001	0.00	0.02
The maximum relative power of band 6.5 to 7.5	0.1365	0.02	0.52
relative power of band 6.5 to 7.5	0.1183	0.015	0.53
Lyapunov exponent	7.5087	0.01	0.001
Fractal dimension	1.2779	0.01	0.005

As shown in Table 2, the characteristics of 1-power of the Delta band, 2-Lyapunov exponent, 3-signal energy, 4-variance, 5-power of the alpha band (8-10 Hz) and 6-fractal dimension, have the values $P < 0.05$ and in fact, the differences are significant. Also, the intuitive results indicated that frequency characteristics such as delta frequency band power and nonlinear characteristics had the most decreasing differences during the sessions. Therefore, according to the Delta brain wave characteristic, it can be stated that the consciousness of addicted people after reduction of binaural beat and relaxation level in these individuals has increased. Finally, it has been shown that the results of the EEG signal corresponded to the personal statements of the People in the Brums Questionnaire. Reduction in the amount of nonlinear and frequency characteristics extracted from signals such as the results of the completed questionnaires by the participants, indicate that inducing relaxation in people is done by binaural beat. Figure (2) shows the changes in the states of the end of the first session and the third session of the participants. In these horizontal axis diagrams, the horizontal axis represents the states and vertical axis the level of each of these states.

Analysis of the Brums questionnaires of the first and final of the participants through the test key under the psychiatrist's supervision showed that most people after the binaural beats faced a reduction of anger, tension and confusion and increased vigor and the desire to continue the treatment and were fully recovered. To better illustrate the results of the questionnaires, the mean scores for each of the six states of anger, depression, tension, confusion, fatigue, and vigor that have scores between 0 and 16 are presented in Table 3. Also, changes in each of the states are expressed as percentages, indicating that the state of anger, depression, and tension were greatly reduced after applying binaural beats. The

state of confusion acts depending on the person and their vigor and their fatigue was mutually increased, which ultimately reflects the improvement of the negative spiritual states and increase in calmness in them.

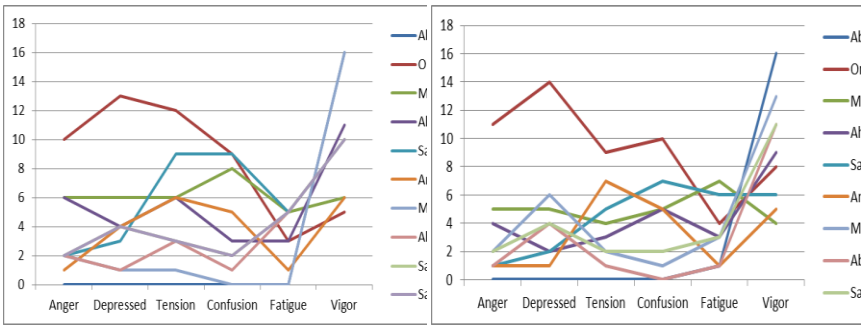

Figure 2. The Result of the Addiction Participant Registration Questionnaire A) End of the First Session B) End of the Second Session

The descriptive statistics of the changes and the mean scores of the 6 states expressed in the Brums questionnaire are presented below in Table 3.

Table 3. Descriptive Statistics of Changes and Mean Scores in 6 States Expressed in the Brums Questionnaire

Index	*Test type*	*Anger*	*Depression*	*Tension*	*Confusion*	*Fatigue*	*Vigor*
Percentage of changes	Post- Test	-88%	-66%	77%	-45%	78%	77%
Mean scores (0 to 16)	First session	-3.40%	-4.64%	-5.10%	-4.10%	3.22%	2.90%
	Last session	-3%	-4.22%	-3.60%	-3.40%	3.80%	10%

Finally, in order to confirm the results of questionnaires and analyze brain signals, Figure (2) shows the brain mapping of one of the participants as a result of listening to the desired binaural beat. As shown in this figure, the most effect of people in the frequency bands are related to relaxation, such as delta and alpha.

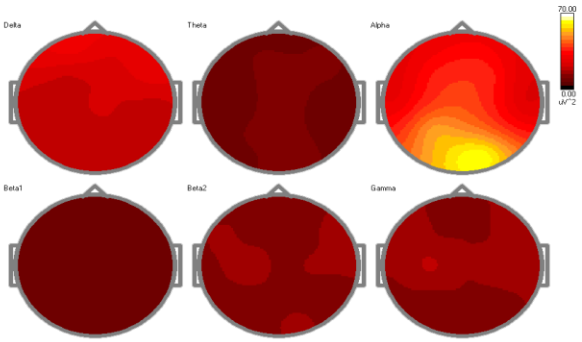

Figure 2. Brain Map

Discussion and Conclusion

The purpose of this study was to investigate the effect of binaural beats on addicted individuals, with the assumption that they have a fast effect and more manifestation than non-addicted people. Since the new binaural beat technology and its use as a stimulant of emotion are newly emerging, the published articles in this area are very limited and this study is considered to be new due to the discussion of the effects of binaural beats on a specific group of individuals who sample the long-term effect of the stimulus. According to the results done in the experimental group treated with binaural beats and control group, it was found that these waves have a positive effect on the treatment of addicted people and in addition to the reduced anger, tension and confusion and increased vigor, it has helped them as a supplemental therapy.

Different methods were presented to improve the mental states of addicted people. More conventional methods mentioned in this article, which are consistent with the present research topic, can be used, namely, the use of music or neurofeedback to improve addicts. In fact, art therapy is one of the oldest and most commonly used methods. Due to the incomplete efficacy of drug therapy and the increasing attention to non-pharmaceutical methods, art therapy, especially music therapy, has been considered as one of the most commonly used treatments (Guetin, 2009; Wakim, 2010; Mc Caffrey, 2011; Stanczyk, 2001).

Khorramabadi et al. (2012) showed that musical therapy sessions in addicted people who are quitting and recovering can increase positive emotion and decrease anxiety. In addition, Punkanen (2007) in his study showed that using active and passive music therapy programs in the drug recovery phase can relieve mood and anxiety disorders of addicts, and Salmani, and Senobar (2015) also stated that music therapy alone or along with other psychological interventions can be an effective way to reduce the anxiety of addicts in the non-drug rehab. In a study by Khorramabadi and Asadi (2016), it was shown that music therapy as a complementary therapy helps people to improve their general attitude toward mental and social performance. In explaining the results, it can

be said that listening to relaxing music by stimulating alpha waves in the brain can provide a relaxing condition through the release of endorphins, dopamine, and decreasing the secretion of catecholamine, thereby reducing depression, anxiety and anger. (Salmani & Senobar, 2015). In regard to the neurofeedback effect, Zolfagharzadeh et al. (2016) showed that patients with methamphetamine-dependent substances can improve their craving under the effect of neurofeedback. The Studies of Sokhadze et al. (2008) also suggested the effectivity of neurofeedback on the reduction of tempting idea of morphine consumption. On the other hand, past studies in the use of binaural beat rate have shown that binaural beats affects psychological and mental performance (Lane et al., 1988), or in the alpha band range, it can create relaxation (Foster, 1996). In addition, binaural beats have a positive effect on physiological parameters such as anxiety (Carlo Calaberse, 2007), and after applying them, they appear to be cooler (jailani, Norhazman, & Zaini, 2013).

Finally, in a general conclusion, by comparing the results of this study with previous papers, in addition to verifying the general effects of these waves on individuals, it can be stated that these results are consistent with the effect of binaural beats on the addicted people and this technology with decreasing negative mental states and improvements in the individual can be helpful as a treatment aid. As a result, it is suggested that in addiction treatment centers, prisons, or any other organization engaged in addiction recovery, the use of binaural beats apart from complementary therapies be developed, and by increasing the number of sessions and using different binaural beats frequencies, the effect of this technology be studied along with other current treatments in the overall treatment process. In addition, in subsequent studies one can observe the similarity of the effects of these stimuli with the addictive substance used and plan for its prediction and control. It should be noted that due to the intensity of changes in frequency characteristics and nonlinear characteristics, regarding the focus on the control of mental states, later works focus more on this group of characteristics. Because of some limitations, the present research was conducted only on men. In future research, both groups of women and men can be evaluated for further understanding of changes.

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