Comparison of Learning Ability and Memory between Opiate- and Methamphetamine-Dependent Patients and Healthy People

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Abstract

Objective: The present study aimed at comparing the learning and memory ability between methamphetamine- ant opiate-dependent patients and healthy people. **Method:** A causal-comparative research method was employed in this study. The statistical population of the study included the men with methamphetamine and opioid dependence and healthy men in Tehran. The sample consisted of 20 men with methamphetamine, 17 opioid dependent men, and 20 healthy men who were selected via convenience sampling method. In this research, Rey Auditory Verbal Learning Test and Depression Anxiety Stress Scales (DASS) were used for data collection. **Results:** The results of this study showed that drug dependent persons had lower scores in learning ability and memory than the healthy group. The opioid group was weaker in the recall ability and recognition of information. The methamphetamine group showed more repetition in the recall and interference in the recognition of the words. **Conclusion:** The drug-dependent group undergone a higher degree of harm to learning and memory ability. Further study of the vulnerability of these groups provides constructive tips for the arrangement of appropriate interventions in the realm of rehabilitation.

Keywords: cognitive ability, learning, memory, opioid dependence, methamphetamine dependence

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Introduction

Drug disorder has a high prevalence in the world population (UNODC, 2014). Iran has a long history of opioid consumption and these substances are still the most common abusive substances in Iran (Shari'ati-Rad, Mo'arefvand, & Ekhtiari, 2013). Although opioid dependence is highly prevalent, drug use has seen a significant and increasing trend (World Health Organization, 2004). Stimulants primarily affect the young population (American Psychiatric Association, 2013). The population of Iran is mostly composed of young people aged between 20 and 40 years. Young people's less awareness about the signs and symptoms of prolonged use of stimulants, especially methamphetamine, has prevailed the use of these substances in Iran in such a way that the abuse of stimulants today has become one of the most serious social concerns (Shari'ati-Rad et al., 2013).

Findings show that the chronic use of psychoactive substances is associated with many defects in the nervous system (Verdejo-Garcia, Lopez-Torrecillas, Gimenez, & Perez-Garcia, 2004). Addiction to substances affects various cortical and subcortical systems of the brain and causes long-term structural changes in the brain (Meilandt, Barea-Rodriguez, Harvey, & Martinez, 2004). One of the functions that is affected by brain changes is individuals' decision-making ability and executive functions (Rapeli et al., 2006), working memory (Lundqvist, 2005), and spatial memory and learning (Ersche, Clark, London, Robbins, & Sahakian, 2006).

Learning refers to changes pertaining to the experiences that are caused by changes in brain connections. If we regard learning as some changes resulting from experience, memory will be the continuation of these changes (Byrne, Eichenbaum, Menzel, Roediger, & Sweatt, 2008). Learning is a mechanism that makes the organism adaptable, and memory contributes to the continuity of behavior change, but both of them are aspects of the same system for gathering information about experiences (Lieberman, 2011). Several findings have shown that different brain regions, especially hippocampus and prefrontal cortex contribute to learning ability and memory function (Byrne et al., 2008). Also, many transmitters, such as glutamate, norepinephrine, endogenous opioids, GABA, and dopamine play a role in the process of data encoding and retrieval from memory (Hyman, 2014; Johansen, Cain, Ostroff, & LeDoux, 2011). Since the above-mentioned structures and transmitters are also involved in the process of drug use dependence, memory and learning in drug users undergo changes with the change of these substances and structures (Koob & Moal, 1977).

Previous research has also focused on exploring simple learning mechanisms, such as learning based on responses like conditioning, sensitivity, and silence in animal studies in laboratory designs (Recinto et al., 2012; Parsegian & See, 2014). Human research has also mainly focused on conditioning and the impact of reinforcement on attention to drug-related stimuli (Hyman, 2014; Robbins &

Everitt, 2002) and has shown that substance users have weaker performance in cognitive abilities, especially learning and memory, whereas no mention of the memory capability to learn complex issues has been made. A number of studies have investigated memory and learning in substance dependent individuals according to their performance in cognitive tasks. These tasks have mainly compared spatial memory (Ersche et al., 2006) or work memory (Landkvist, 2005) between drug-dependent and normal groups but have not compared verbal memory between drug-dependent people and normal people. Despite these findings, it can be expected that the memory and ability to learn verbal information will be influenced by substance use and will be different from those in the normal group. On the other hand, narcotics and stimulants have a different effect on the central nervous system in such a way that they weaken and stimulate it, respectively. These substances influence different types of neurotransmitters in various brain structures (Meilandt et al., 2004). It is expected that memory changes vary in these two groups. Considering the importance of memory and learning in doing routine actions and adapting to the environment, this study compares methamphetamine-dependent men, opioid men, and normal people together in terms of memory and learning.

Method

Population, sample, and sampling method

The statistical population of the study consisted of methamphetamine-dependent men, opioid-dependent men, and ordinary people in Tehran. The sample consisted of 20 men with methamphetamine, 17 opioid-dependent men, and 20 healthy men who were selected via convenience sampling method. The three groups were matched with each other in terms of the intervention characteristics in such a way that the results of analysis of variance and chi-square test did not show any significant difference between the three groups in terms of the level of education ($P> 0.05$, $\chi^2 = 1.72$), age ($F = 1.48$, $P>0.05$), anxiety ($F=1.06$, $P> 0.05$), depression ($F = 1.01$, $P > 0.05$), and stress ($F = 0.99$, $P>0.05$). Similarly, there was no difference between the two groups of methamphetamine-dependent and opioid-dependent men in terms of the duration of drug use ($t = 0.93$, $p> 0.05$) and the duration of withdrawal ($t = 1.41$, $p> 0.05$). Consumption in the clinical groups was in the smoking format and these groups were placed in the middle socioeconomic class.

These individuals were under treatment according to the 60th Congress of the Human Revival Program, which was based on the use of opioid tincture for both methamphetamine and opioid users. In the protocol of the 60th Congress, the gradual reduction of opioid tincture is used where the decrease is accomplished by the coefficient of 0.8, and the treatment duration according to this protocol is 10 months, which is taken during twenty-one-day steps. To investigate the drug use withdrawal, some tests and experiments are performed that lasts up to one year after the withdrawal where morphine, amphetamine, hashish, benzodiazepine, and methadone tests are performed at each run (Dejakam, 2009). Due to the matching problems, three candidates were excluded from the sample because of their non-compliance with the entry criteria of the research. The sampling method was convenience one. The entry criteria of the research were: 1. The age range of 18 to 50 years; 2. Having a minimum of secondary education degree; 3. Individuals' willingness to participate in the test; and 4. The history of methamphetamine and opioid use in the two drug-dependent groups (without simultaneous consumption of other substances) for at least 12 months. The exit criterion was physical and psychological inability to participate in the test. The participants were introduced to the researcher by the authorities of the 60th Congress. At first, the research process was explained to them, informed consent was obtained from them, then, participants were evaluated based on the entry and exit criteria, and their characteristics were compared for homogeneity with members of other groups. Thereafter, Rey Auditory Verbal Learning Test was conducted under standard conditions.

Instruments

1. Rey Auditory Verbal Learning Test: This test is one of the most valid ones for the measurement of learning ability, immediate memory, and false memory. It consists of three lists, namely a 15-word list (the first list), another 15-word list in the name of the intervention list (the second list) whose terms are phonetically and semantically very similar to the first one, and a recognition list that includes 50 words composed from those of the first and second lists, along with thirty new words that are phonetically and semantically similar to the presented lists and are used to examine incorrect recognition (Lezak, 2004). In this test, the lists have been prepared according to the common words available in the Persian language. Studies have shown that the Persian version of this test enjoys the desired reliability in such a way that the reliability of this test has been reported at a moderate level, i.e. 0.55 during a one-year interval. The re-test reliability of this test has been reported to equal 0.65 during a one-month interval (Jafari, Moritz, Zandi, Akbari, & Malayeri, 2009). In this research, the first list was performed for participants 5 times according to standards and, after each run, the participants reminded the words and wrote them on a sheet. Then, the second list was distributed and the words were reminded and recorded. The participants were then asked to recall the first list of words without replaying and, finally, the recognition sheet was given to the participants. The test scores were as follows:

The number of words mentioned in each of the 5 first list attempts, the words recalled from the second list, the number of words recalled from the first list with delay and without replay (also titled recall of the first list with delay 1) (immediately after the second playlist) and recall of the first list with delay 2 (fifteen minutes after the second playlist), the number of duplicate recalled words, the number of incorrect recalled words, the number of false recognition, and the learning ability (improved recall of words) were obtained in the first five attempts.

2. Depression Anxiety Stress Scales (DASS): This questionnaire contains 42 items that measure each of the constructs of stress, anxiety, and depression (14 different questions for each construct). Early evidence suggests that this questionnaire has appropriate divergent and convergent validity (Lovibond & Lovibond, 1995). In Iran, Afzali, Delavar, Borajali, & Mirzamani (2007) administered it to a sample of 400 students and obtained the Cronbach's Alpha coefficients of 0.94, 0.85, and 0.87 for depression scale, anxiety scale, and stress scale, respectively. Cronbach's alpha coefficients of these scales in this study were obtained higher than 0.7.

Results

The descriptive statistics of the variables related to recalls in the 5 attempts of the first list, the second list, as well as the delayed recalls, incorrect recalls, repetition in the recall of words, and incorrect recognition have been presented in Table 1 for each group.

Table 1: Descriptive Statistics of Recall, Recognition, and Learning Variables

Group	*Variable*	*Mean*	*SD*	*Variable*	*Mean*	*SD*
Stimulants	First recall	6.40	1.79	Delayed recall	10.50	1.91
Opiate		5.71	1.69		10.17	1.74
Control		7.32	2.00		11.84	1.96
Stimulants	Second recall	8.90	1.97	Delayed recall 2	8.75	2.01
Opiate		8.65	2.45		8.71	2.33
Control		10.42	2.31		11.32	2.11
Stimulants	Third recall	10.60	1.60	Incorrect recall	1.65	1.49
Opiate		9.41	3.22		0.88	1.97
Control		11.89	2.08		0.63	0.86
Stimulants	Fourth recall	10.95	2.19	Repetition of recalled words	1.15	1.59
Opiate		10.18	3.97		0.88	1.11
Control		12.63	1.38		0.21	0.43
Stimulants	Fifth recall	11.65	1.84	Incorrect recognition	3.85	2.43
Opiate		11.76	2.56		2.35	1.97
Control		13.47	1.84		1.95	2.30
Stimulants	Recall of second list	4.80	1.96			
Opiate		5.00	1.12			
Control		7.53	2.89			

For data analysis, repeated measures analysis of variance was used. Box's test was used to assess the equality covariance matrix, which was not significant ($F = 0.51$, $P > 0.05$). Mauchly's Test of Sphericity ($P \leq 0.089$, $P < 0.001$) was significant, which indicates the non-homogeneity of the covariance matrix of the dependent variable. In this way, the modified F value of Greenhouse-Geisser statistic was used. The investigation of the main effect of the within-group variable, i.e. learning during 5 attempts and the interaction effects of learning and group were calculated using the F-Greenhouse-Geisser test. The results show a significant change in learning over time ($F = 106.03$, $p<0.001$, $\eta^2 = 0.667$). As ETA shows, nearly 67% of the within-group variance is explained by the effect of time. Also, the findings do not indicate any interactive effect of time in the three groups ($F = 0.939$, $P> 0.05$). Thus, the learning process does not interact with membership in the drug-dependent groups and does not vary in different groups.

Considering that the main effect of the within-group variable of learning is significant over time, it is possible to compare the mean values of within-group variables at this stage (Table 2).

Table 2: Means of Within-group Variables

Attempt	*Mean*	*SD*	*Attempt*	*Mean*	*SD*
First	6.47	0.25	Fifth	12.29	0.28
Second	9.32	0.30	List 2	5.77	0.29
Third	10.64	0.31	Recall 1	10.84	0.36
Fourth	11.25	0.36	Recall 2	9.59	0.43

The comparison of the mean of the groups showed that the participants have had the maximum recalls in the fifth attempt of the first list and the minimum recalls in the second list. The Levene's test was also used to examine the homogeneity assumption of variances for between-group effects. The result showed that Levene's test was not significant ($P\geq0.05$). In this way, the between-group effects were examined.

The findings were indicative of the significant between-group effects ($F=6.68$, $P<0.01$, $\eta^2 = 0.20$). This finding shows that 20 percent of between-group variances is accounted for by the effect of membership in groups. The mean values (standard deviations) of the methamphetamine group, opioid group, and the healthy group were equal to 9.07 (0.42), 8.99 (0.45), and 10.80 (0.43), respectively. The findings of the between-group mean values show that the healthy group has experienced the highest levels of learning, and the methamphetamine group has experienced greater learning than the opioid group. Pairwise comparisons of between-group mean values were made using Bonferroni posthoc test and the methamphetamine group ($P< 0.05$, mean difference = -1.73) and opioid group ($P <0.01$, mean difference= -2.10) were significantly different from the normal group. However, there was no significant difference between the opioid and methamphetamine groups ($P> 0.05$, mean difference = 0.37).

Figure 1 shows learning paths in the three groups of methamphetamine users, opioid users, and healthy people.

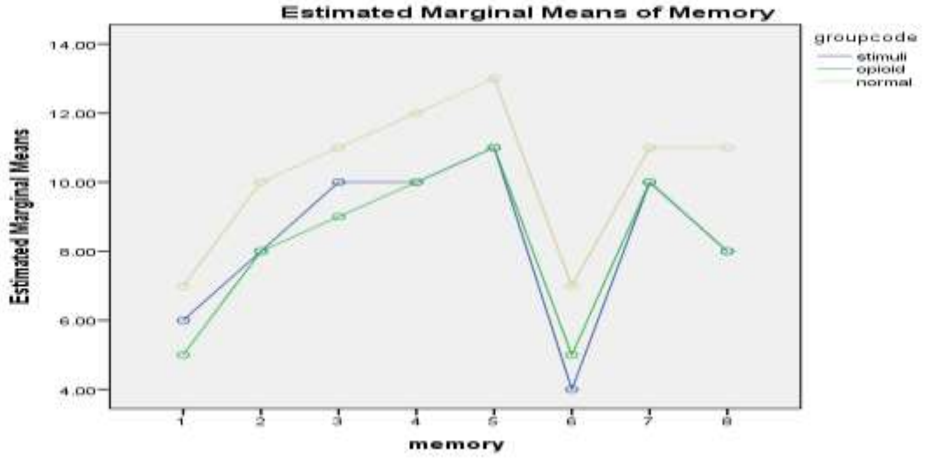

Fig. 1: Learning Path in the Methamphetamine, Opioid, and Healthy Groups in terms of the Number of Recalled Words

Based on what the diagram displays, the mean of word recall has increased in all three groups during 5 attempts. All three groups have acted more weakly in recalling the information of the second list and have reminded fewer words in delayed recalls.

One-way ANOVA was used to compare the groups based on the three variables of repetition of recalls, incorrect recalls, and incorrect recognition of the words. The findings showed a significant difference between the three groups in terms of repetition in recalls ($F = 3.34$, $P < 0.05$) and incorrect recognition ($F = 3.89$, $P < 0.05$); however, no significant difference was observed between the three groups in terms of incorrect recalls ($F = 2.83$, $P > 0.05$). Post-hoc test for the pairwise comparison of the groups based on repetition of recalls ($MD=0.94$, $p < 0.05$) and incorrect recognition ($MD = -1.9$, $P < 0.05$) showed a significant difference between the methamphetamine and healthy groups where the methamphetamine group showed a weaker performance.

Discussion and Conclusion

The aim of this study was to investigate learning and memory differences in opioid-dependent, methamphetamine-dependent, and healthy subjects. The findings were indicative of the weaker performance of substance users than healthy subjects in all memory and learning tasks. These findings are in line with prior research findings where opioid users and methamphetamine users obtained lower scores in brain functions pertaining to learning and memory (Mohammadzadegan et al., 2015).

One of the factors that causes both drug-dependent groups to have a weaker memory and learning performance than the healthy group is that drug use brings about the destruction of neurons. Opioids affect cognitive function through processes, such as planned cell death (apoptosis) and inhibition of new neuronal formation (neurogenesis) (Nyberg, 2012). This effectiveness was also studied by Arguello et al. (2008) and the findings showed that opioid use results in some deficiency in memory by contributing to the reduced reconstruction of nerve tissues in the hippocampal gyrus. On the other hand, recent studies have shown that methamphetamine use influences glutamate transmitter in such a way that this transmitter is reduced after withdrawal from the chronic consumption of methamphetamine (Crocker et al., 2014; Parsegian & See, 2014). Glutamate plays a role in the synaptic deformity arising from learning (Lovinger, 2010). The findings also show that the damage caused by methamphetamine poisoning occurs as a result of glutamate hyperactivity during methamphetamine use. Research carried out on mice has shown that a high dose of methamphetamine can cause the death of cells even months after the withdrawal (Gururajan, Manning, Klug, & Van den Buuse, 2012). Considering the role of glutamate in learning and information maintenance in memory structures (Meilandt et al., 2004), learning and information retrieval are also disturbed when there is a problem in regulating this transmitter. Thus, with regard to the effect of drug use on the increased mortality of cells in the brain structures effective in memory activity, it can be concluded that individuals with opioid and methamphetamine use suffer from similar lesions in memory and learning.

In this study, the comparison between two groups of opioid-dependent and methamphetamine-dependent subjects showed a different performance of these two groups in memory tasks where the opioid-dependent group obtained lower scores in recall and recognition abilities. However, repetition of recalled words and incorrect recognition in the methamphetamine-dependent group have been observed more frequently. These findings are consistent with the studies that have shown that hippocampal structure and forehead play an important role in the coding and stabilization of new information in memory (Schacter & Slotnick, 2004). The dorsal hippocampus is related to the ability to create and retrieve memory (Bannerman et al., 2014). This area covers the mu-opioid receptor. Opioid receptors are among the most recognizable opioid receptors involved in memory creation and retrieval (Meilandt et al., 2004). Opioid sigma receptors, which are frequently found in the hippocampus, amygdala, corpus striatum, and other basal core structures, are involved in learning and memory (Klenowski, Morgan, & Bartlett, 2015). The withdrawal from opioid use is accompanied by impaired opioid production (Sadock, Kaplan, & Sadock, 2007), which is associated with memory disorder. Considering the other effects of opioids on the central nervous system, the long-term use of opioids can affect memory performance, which disrupts the ability to recognize and recall information.

The findings of the study also showed that methamphetamine-dependent subjects had a lower accuracy in recalling and recognizing information. This finding was in line with the research done by Ballard et al. who showed that disruption in the encoding of information among methamphetamine consumers leads to incorrect recognition (Ballard, Gallo, & De Wit, 2012). These findings have shown that avoiding interference of irrelevant information, accuracy in coding, and accuracy in the recognition of information are mainly derived from executive functions (Shimamura, 2014). Executive functions are a set of executions that are responsible for the management and control of other cognitive systems and also direct goal-oriented behaviors. In other words, it is a kind of intelligent control mechanism that enables information processing in a top-down approach (Shimamura, 2000). Prior studies have shown that executive functions undergo impairment in methamphetamine users (Eghtedari, Shari'at, & Farhani, 2010). One of the explanations for the cause of this defect is that methamphetamine mainly affects dopaminergic pathways and leads to the higher release and reduction of dopamine reuptake in the synapses (Mendez & Fras, 2011; Miller, 2011). Dopamine plays a major role in the processes of executive function in the lobes of prefrontal cortex and corpus striatum (Stuss & Knight, 2013).

The results of the current study indicated a significant difference in learning and memory ability between drug-dependent individuals and healthy people where drug-dependent individuals showed a weaker performance. These findings show the vulnerabilities and weaknesses of the two groups of opioid-dependent and methamphetamine-dependent individuals in learning and memory ability. With a better understanding of these patients, it is possible to take effective steps to improve their quality of life and go for their rehabilitation more effectively. Some of the limitations of this study were the lack of objective measures for evaluating drug use, ensuring the treatment of these patients by opioid tincture, and the absence of women in the sample. The replication of this research in two groups of women and men is strongly recommended for future research.

Reference

Afzali, A., Delavar, A., Borjali, A., & MIRZAMANI, M. (2007). Psychometric properties of DASS-42 as assessed in a sample of Kermanshah High School students .

AmericanPsychiatiricAssociation. (2013). *Diagnostic and Statistical Manual of Mental Disorders*. United States.

Arguello, A. A., Harburg, G. C., Schonborn, J. R., Mandyam, C. D., Yamaguchi, M., & Eisch, A. J. (2008). Time course of morphine's effects on adult hippocampal subgranular zone reveals preferential inhibition of cells in S phase of the cell cycle and a subpopulation of immature neurons. *Neuroscience, 157*(1), 70-79 .

Ballard, M. E., Gallo, D. A., & de Wit, H. (2012). Psychoactive drugs and false memory: comparison of dextroamphetamine and delta-9-tetrahydrocannabinol on false recognition. *Psychopharmacology, 219*(1), 15-24 .

Bannerman, D. M., Sprengel, R., Sanderson, D. J., McHugh, S. B., Rawlins, J. N. P., Monyer, H., & Seeburg, P. H. (2014). Hippocampal synaptic plasticity, spatial memory and anxiety. *Nat Rev Neurosci, 15*(3), 181-192. doi: 1/۰,۱۰۳۸nrn3677

Byrne, J. H., Eichenbaum, H., Menzel, R., Roediger, H. L., & Sweatt, J. D. (2008). *Learning and memory: a comprehensive reference*: Elsevier.

Crocker, C. E., Bernier, D. C., Hanstock, C. C., Lakusta, B., Purdon, S. E., Seres, P., & Tibbo, P. G. (2014). Prefrontal glutamate levels differentiate early phase schizophrenia and methamphetamine addiction: A 1 H MRS study at 3Tesla. *Schizophrenia research, 157*(1), 231-237 .

Dezhakam H. (1388). Education , prevention , curbing and free guidance on how to cure addiction.

Eghtedari, A., Shariat, V., & Farahani, H. (2010). The Comparison of Cognitive Functions in Patients with Methamphetamine induced Psychosis and Control Group. *Advances in Cognitive Science, 1*(13), 19-26 .

Ersche, K. D., Clark, L., London, M., Robbins, T. W., & Sahakian, B. J. (2006). Profile of Executive and Memory Function Associated with Amphetamine and Opiate Dependence. *Neuropsychopharmacology : official publication of the American College of Neuropsychopharmacology, 31*(5), 1036-1047. doi: 10.1038/sj.npp.1300889

Gururajan, A., Manning, E. E., Klug, M., & van den Buuse, M. (2012). Drugs of abuse and increased risk of psychosis development. *Australian and New Zealand Journal of Psychiatry, 46*(12), 1120-1135 .

Hyman, S. E. (2014). Addiction: a disease of learning and memory. *American Journal of Psychiatry* .

Jafari, Z., Moritz, P. S., Zandi, T., Akbari, A. A., & Malayeri, S. (2009). Iranian version of the Rey Auditory Verbal Learning Test: a validation study. *Payesh, 9*(3), 307-316 .

Johansen, Joshua P., Cain, Christopher K., Ostroff, Linnaea E., & LeDoux, Joseph E. (2011). Molecular Mechanisms of Fear Learning and Memory. *Cell, 147*(3), 509-524. doi: http://dx.doi.org/١٠,١٠١٦/j.cell.2011.10.009

Kalat, J. (2012). *Biological psychology*: Cengage Learning.

Klenowski, P., Morgan, M., & Bartlett, S. E. (2015). The role of δ-opioid receptors in learning and memory underlying the development of addiction. *British journal of pharmacology, 172*(2), 297-310 .

Koob, G. F., & Moal, M. L. (1997). Drug Abuse: Hedonic Homeostatic Dysregulation. *Science, 278*(5335), 52-58. doi: 10.1126/science.278.5335.52

Lezak, M. D. (2004). *Neuropsychological assessment*: Oxford university press.

Lieberman, D. A. (2011). *Human learning and memory*: Cambridge University Press.

Lovibond, P. F., & Lovibond, S. H. (1995). The structure of negative emotional states: Comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. *Behaviour research and therapy, 33*(3), 335-343 .

Lovinger, D. M. (2010). Neurotransmitter roles in synaptic modulation, plasticity and learning in the dorsal striatum. *Neuropharmacology, 58*(7), 951-961 .

Meilandt, W. J., Barea-Rodriguez, E., Harvey, S. A., & Martinez, J. L. (2004). Role of hippocampal CA3 μ-opioid receptors in spatial learning and memory. *The Journal of neuroscience, 24*(12), 2953-2962 .

Mendez ,M. F., & Fras, I. A. (2011). The false memory syndrome: experimental studies and comparison to confabulations. *Med Hypotheses, 76*(4), 492-496. doi: 10.1016/j.mehy.2010.11.033

Miller, G. M. (2011). The emerging role of trace amine-associated receptor 1 in the functional regulation of monoamine transporters and dopaminergic activity. *Journal of neurochemistry, 116*(2), 164-176 .

Mohammadzadeghan, R., Bayrami, m., Movahedi, Y., Gasem baklo, Y., Mohammadyari, G., & Tahmaseb poor, M. (2015). On the Comparison of Cognitive Function in Substance Abusers and Addicts under Methadone Treatment with Normal Individuals. *Research on Addiction, 9*(34), 23-36 .

Nyberg, F. (2012). *Cognitive impairments in drug addicts*: INTECH Open Access Publisher.

Parsegian, A., & See, R .E. (2014). Dysregulation of dopamine and glutamate release in the prefrontal cortex and nucleus accumbens following methamphetamine self-administration and during reinstatement in rats. *Neuropsychopharmacology, 39*(4), 811-822 .

Recinto, P., Samant, A. R. H., Chavez, G., Kim, A., Yuan, C. J., Soleiman, M., . . . Koob, G. F. (2012). Levels of neural progenitors in the hippocampus predict memory impairment and relapse to drug seeking as a function of excessive methamphetamine self-administration. *Neuropsychopharmacology, 37*(5), 1275-1287 .

Rapeli, P., Kivisaari, R., Autti, T., Kähkönen, S., Puuskari, V., Jokela, O., & Kalska, H. (2006). Cognitive function during early abstinence from opioid dependence: a comparison to age, gender, and verbal intelligence matched controls. *BMC Psychiatry, 6*(1), 9. doi: 10.1186/1471-244x-6-9

Robbins, T. W., & Everitt, B. (2002). Limbic-striatal memory systems and drug addiction. *Neurobiology of learning and memory, 78*(3), 625-636 .

Sadock, B. J., Kaplan, H. I., & Sadock, V. A. (2007). *Kaplan & Sadock's synopsis of psychiatry: behavioral sciences/clinical psychiatry*: Lippincott Williams & Wilkins.

Schacter, D. L., & Slotnick, S. D. (2004). The cognitive neuroscience of memory distortion. *Neuron, 44*(1), 149-160 .

Shariatirad, S., Maarefvand, M., & Ekhtiari, H. (2013). Emergence of a methamphetamine crisis in Iran. *Drug and alcohol review, 32*(2), 223-224 .

Shimamura, A. P. (2000). The role of the prefrontal cortex in dynamic filtering. *Psychobiology, 28*(2), 207-218 .

Shimamura, A. P. (2014). Remembering the Past Neural Substrates Underlying Episodic Encoding and Retrieval. *Current Directions in Psychological Science, 23*(4), 257-263 .

Stuss, D .T., & Knight, R. T. (2013). *Principles of frontal lobe function*: Oxford University Press.

Tomkins, D. M., & Sellers, E. M. (2001). Addiction and the brain: the role of neurotransmitters in the cause and treatment of drug dependence. *Canadian Medical Association Journal, 164*(6), 817-821 .

UNODC. (2014). *world drug report*. New York: Vienna: united nations.

Verdejo-Garciaو A., Lopez-Torrecillas, F., Gimenez, CO., Perez-Garcia, M. (2004). Clinical implications and methodological challenges in the study of the neuropsychological correlates of cannabis, stimulant, and opioid abuse. *Neuropsychology review, 14(1):1-41*.