Title
Effects of neurofeedback on the short-term memory and continuous attention of patients with moderate traumatic brain injury: A preliminary randomized controlled clinical trial.

Permalink
https://escholarship.org/uc/item/0q04s2r8

Journal
Chinese journal of traumatology = Zhonghua chuang shang za zhi, 20(5)

ISSN
1008-1275

Authors
Rostami, Reza
Salamati, Payman
Yarandi, Kourosh Karimi
et al.

Publication Date
2017-10-01

DOI
10.1016/j.cjtee.2016.11.007

Peer reviewed
Effects of neurofeedback on the short-term memory and continuous attention of patients with moderate traumatic brain injury: A preliminary randomized controlled clinical trial

Reza Rostami, Payman Salamati, Kourosh Karimi Yarandi, Alireza Khoshnevisan, Soheil Saadat, Zeynab Sadat Kamali, Somaie Ghiasi, Atefeh Zaryabi, Seyed Shahab Ghazi Mir Saeid, Mehdi Arjipour, Mohammad Saeid Rezaee-Zavareh, Vafa Rahimi-Movaghar

Department of Psychology, Tehran University, Tehran, Islamic Republic of Iran
Department of Neurosurgery, Sina Trauma and Surgery Research Center, Tehran University of Medical Sciences, Tehran, Islamic Republic of Iran
Department of Psychology, Kharazmi University, Tehran, Islamic Republic of Iran
Department of Clinical Psychology, Allame Tabatabaei University, Tehran, Iran
Students’ Research Committee, Baqiyatallah University of Medical Sciences, Tehran, Islamic Republic of Iran

Purpose: There are some studies which showed neurofeedback therapy (NFT) can be effective in clients with traumatic brain injury (TBI) history. However, randomized controlled clinical trials are still needed for evaluation of this treatment as a standard option. This preliminary study was aimed to evaluate the effect of NFT on continuous attention (CA) and short-term memory (STM) of clients with moderate TBI using a randomized controlled clinical trial (RCT).

Methods: In this preliminary RCT, seventeen eligible patients with moderate TBI were randomly allocated in two intervention and control groups. All the patients were evaluated for CA and STM using the visual continuous attention test and Wechsler memory scale-4th edition (WMS-IV) test, respectively, both at the time of inclusion to the project and four weeks later. The intervention group participated in 20 sessions of NFT through the first four weeks. Conversely, the control group participated in the same NF sessions from the fifth week to eighth week of the project.

Results: Eight subjects in the intervention group and five subjects in the control group completed the study. The mean and standard deviation of participants’ age were (26.75 ± 15.16) years and (27.60 ± 8.17) years in experiment and control groups, respectively. No significant improvement was observed in any variables of the visual continuous attention test and WMS-IV test between two groups (p > 0.05).

Conclusion: Based on our literature review, it seems that our study is the only study performed on the effect of NFT on TBI patients with control group. NFT has no effect on CA and STM in patients with moderate TBI. More RCTs with large sample sizes, more sessions of treatment, longer time of follow-up and different protocols are recommended.

© 2017 Daping Hospital and the Research Institute of Surgery of the Third Military Medical University. Production and hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

Traumatic brain injury (TBI) means an injury to the brain that is caused by an external physical force. It is well known that TBI is an important cause of mortality and morbidity and it is reported that each year about 1.7 million people sustain a TBI in USA. Some of them die (about 50,000) and some other experience long-term disability (80,000 to 90,000).1–3 The severity of TBI can be categorized based on the Glasgow coma scale (GCS) at the time of injury as follows: mild (13–15), moderate (9–12) and severe (<9).4 TBI usually affect the brain function such as cognitive status, executive function, memory, data processing, language skills and...
attention. It has heterogeneous aspects and based on the injury location and type. It can have different presentations. Hence it is considered as a difficult one to treat. The brain plasticity could help it in rehabilitation phase to restore its normal function after any trauma or disease. But the amount of this ability is poorly understood. Some studies approved that neurofeedback therapy (NFT) can promote neuroplasticity. In the method of neurofeedback (NF), as a non-pharmacological intervention, the feedback to brain waves which are representative of subconscious neural activity can be observed by the client and then he/she will be able to control and change them. There are some evidences that show NF can be useful in some other diseases like Obsessive-compulsive disorder, attention-deficit/hyperactivity disorder and also refractory epilepsy. There are also some published studies about the effect of NFT on patients with TBI. Surneli in 2007 investigated the effect of NF on 24 patients with mild TBI and reported that NFT can result in significant improvement in test of variables of attention, depression inventory and minnesota multiphasic personality inventory. In a study in 2014, with evaluation of two patients with moderate head injury, it is reported that electroencephalogram biofeedback can lead to increase the cognitive scores and improve the concussion symptoms and finally concluded that NFT can be effective on the changes in the structural and functional connectivity among patients with moderate TBI.

Although these published papers reported a positive effect of NFT on the TBI patients, we have not enough data about the standard treatment protocol with NF, and literature still needs more original studies like randomized controlled clinical trial to suggest NF as a treatment option among patients with TBI regarding the two following functions of cognitive status: short-term memory (STM) and continuous attention (CA).

In this preliminary study, we tried to evaluate the effect of NFT on CA and STM of patients with moderate TBI using a randomized controlled clinical trial.

Materials and methods

Study design and subjects

All the subjects with the history of TBI were included in our RCT if they met following criteria: the patients' GCS should be nine through thirteen at the time of admitting in the emergency department; the patients' age should be between 15 and 60 years and there should be no history of co-morbid disease, psychiatric or mental disorders or substance abuse which shows patients' state of health. 22 patients with moderate TBI who were admitted at the two university hospitals of Sina or Shariati Hospitals (Tehran, IR Iran) were assessed for eligibility by the neurosurgeons participating in this project. Patients with trauma event more than six weeks and patients with Afghan nationality were excluded. Considering current Afghan immigrants' unstable situation in our country so that we were not sure that they could continue their participation in our prospective study, we excluded them. Seventeen patients enrolled randomly to intervention or control group. All patients were injured through traumatic events in Tehran City and had traumatic injury to their head with GCS between nine and thirteen. Due to lost to follow-up, finally eight subjects in intervention group and five in control group were analyzed. The clients paid nothing for NFT and some of the costs related to their transportation were paid.

Intervention

The patients in the intervention group participated in 20 sessions of NFT through the first four weeks, five sessions in each week. Conversely, the patients in the control group participated in the same NF sessions from the fifth week to eighth week of the project. For considering ethical issues, we did not prevent patients from getting routine cares and medicines for traumatic injury and patients in both groups (experiment and control) were getting related medicine based on prescription of their physicians.

The NF was performed at the Atieh Clinical Neuroscience Center in Tehran, Iran. Subjects seated in front of a monitor with open eyes and performed the task determined by neurofeedback biograph software which was produced by Thought Technology Company. Our NF protocols were beta and alpha coherence methods (two-channel). In coherence of beta band, electrodes were positioned on the left hemisphere, pre-frontal and temporal regions (FP1-T3) and the purpose of increasing beta waves was improving the concentration while keeping calm. In coherence of alpha band, electrodes were positioned on the central and occipital regions (Cz-Oz) and the purpose of increasing alpha waves was preparing feeling of relaxation for subjects while performing their alpha task. Each protocol was performed in 25 min and the total time for each session was 50 min. If a participant used any medicine prescribed by his physicians, we would not change them during study.

Measurements

Wechsler memory scale–4th edition

We used the Wechsler memory scale–4th edition (WMS-IV) for evaluation of short-term memory. This scale consists of eight sub-tests including general information, memory quotient, orientation, mind control, learning associations, logical memory, visual memory and repeat numbers.

DAUF

We used the DAUF test, a continuous attention computer based test, for measuring the long-term attention and concentration performance. In this test, the participants watch rows of triangles on the computer screen that are presented under time-critical conditions. The tips of each triangle can point either up or down. The participant should press the reaction button when a previously determined triangles points down. There are three main items in this test that are evaluated: the number of correct and incorrect responses and the mean reaction time.

Outcome assessment

The patients in both intervention and control groups were evaluated for CA using DAUF and short-term memory using WMS, respectively. The DAUF and WMS were administered at the baseline time and then four weeks after the beginning of the study. Accordingly, the subjects in the experiment group were evaluated before and after 20 sessions of NF while the patients in control group were evaluated at the baseline and the fourth week of inclusion without any intervention. A questionnaire was designed to record related data to each participant. We also calculated the mean difference for aforementioned variables at the baseline and the fourth week of inclusion and compared them between control and experiment groups.

Statistical analysis

Quantitative and qualitative variables were presented as mean ± standard deviation (SD) and frequency (percentage), respectively. Independent t-test and paired t-test were used for comparison of each variable between two groups of the study and also before and after the intervention. Categorical variables also
were analyzed by Chi square test. p values less than 0.05 were considered statistically significant.

**Ethics and consent**

The project was approved by the Iranian Registry of Clinical Trials and was assigned as IRT201111085024N2 serial number. After explaining the protocol of study for each participant, all of them or their parent (for patents with age of between 15 and 18) signed their written informed consent for participation to this project.

**Results**

**Demographic data**

The mean and SD of participants’ age in experiment and control groups were (26.75 ± 15.16) years and (27.60 ± 8.17) years, respectively (p = 0.91). All participants were male.

**WMS-IV**

Each variable of WMS-IV was evaluated at the baseline and the fourth week of inclusion based on the each groups of study (Table 1).

Also, the mean differences at the baseline and the fourth week of inclusion for each variable were calculated and then compared between two groups (Table 2). Based on these two tables, none of the mean differences were statistically significant (p < 0.05).

**DAUF**

The mean number of correct answers, incorrect answers and mean reaction time were compared at the baseline and the fourth week of inclusion based on each group of the study (Figs. 1–3). Only mean number of correct answers in control group (p = 0.04) and mean number of incorrect answers in experiment group (p = 0.04) increased significantly at the fourth week. The mean difference (SD) for the number of correct answers for control and experiment groups were 10 (7.74) and –1.14 (9.15), respectively, which showed no significant difference (p = 0.052). Also the mean difference (SD) for number of incorrect answers for control and experiment groups were 36.8 (25.4) and –15.28 (139.15), respectively, which showed no significant difference (p = 0.30). Furthermore, the mean difference (SD) for reaction time in control and experiment groups were 11.2 (12.19) and 1.85 (16.05), respectively (p = 0.43, Table 3).

**Discussion**

Our results showed that 20 sessions of NFT cannot be effective in rehabilitation of brain function among patients with TBI regarding CA and STM. Although reaction time in CA test (DAUF) was reduced after NFT, the number of correct answers was reduced. On the other hand, considering WMS-IV test in both groups, memory quotient, general information, orientation and learning control were increased and logical memory, repeat numbers and visual memory were reduced. Mind control in experiment group was reduced and no change in control group. However, all of these changes in DAUF and WMS-IV tests were nonsignificant. Based on WMS-IV test, only learning association in control group was increased from baseline to fourth week of inclusion (p = 0.01). However, when we compared the improvement between the two groups, it was nonsignificant (p = 0.28, Table 2).

TBI is considered as a silent epidemic and major public health concern. It is an important treat for quality of life, disability and death. The annual incidence rate of TBI in Tehran, Capital of Iran, is 15.3–144/100,000 population. On the other hand head injury in 30% of cases can lead to skull fractures. It is reported that among urban population of Iran, the most common mechanism of skull fracture is related to motor vehicle crash. Head injury also can be associated with decreasing intelligence quotient several months after the injury.

Brain damages due to TBI produces changes in cognitive state, memory and data processing need combination methods of management. Furthermore, there is a report indicating useful effects of electromagnetic energy stimulation of brainwave activity on reducing post-traumatic headache among persons in a military service.

There are some case studies that evaluate the effect of NFT on the brain functions of patients with TBI. In contrast with our results, Reddy et al in 2009 in a single case study evaluated the effect of 20 sessions of NFT on a patient with mild head injury. They compared neuropsychological profile of this patient pre- and post-NFT. Finally they showed that NFT was effective in improvement of both verbal and visual learning memory and suggested NFT as a method for rehabilitation of patients with TBI. Furthermore NFT has been reported as a method for minimal to significant enhancement of learning abilities.

### Table 1

Comparison of the WMS-IV variables at the baseline and the fourth week of inclusion between the two groups.

| Variable           | Group     | Mean (SD) at the baseline | Mean (SD) at the fourth week | p value |
|--------------------|-----------|---------------------------|-------------------------------|---------|
| Memory quotient    | Experiment| 84.83 (23.02)             | 87.66 (16.64)                 | 0.57    |
|                    | Control   | 79.40 (13.42)             | 88.60 (23.07)                 | 0.13    |
| General information| Experiment| 3.75 (1.38)               | 4.50 (1.30)                   | 0.11    |
|                    | Control   | 4.20 (1.78)               | 4.80 (2.16)                   | 0.52    |
| Orientation        | Experiment| 3.75 (1.58)               | 4.25 (0.88)                   | 0.22    |
|                    | Control   | 4.0 (1.22)                | 4.20 (1.78)                   | 0.62    |
| Learning association| Experiment| 12.75 (5.46)             | 15 (4.65)                     | 0.06    |
|                    | Control   | 11.60 (3.59)              | 15.60 (4.56)                  | 0.01    |
| Mind control       | Experiment| 3.87 (3.31)               | 3.75 (2.60)                   | 0.85    |
|                    | Control   | 4.80 (2.28)               | 4.80 (2.04)                   | 1       |
| Logical memory     | Experiment| 6.68 (2.75)               | 2.75 (0.97)                   | 0.48    |
|                    | Control   | 6.0 (2.97)                | 4.18 (1.87)                   | 1       |
| Repeat numbers     | Experiment| 8.62 (1.92)               | 8.50 (1.51)                   | 0.80    |
|                    | Control   | 8.20 (0.44)               | 8.0 (2.00)                    | 0.86    |
| Visual memory      | Experiment| 7.12 (3.04)               | 3.58 (1.26)                   | 0.31    |
|                    | Control   | 9.60 (1.51)               | 2.16 (0.96)                   | 0.46    |

**Table 2**

Comparison of the improvement in the WMS-IV variables at the baseline and the fourth week of inclusion between the two groups.

| Variable           | Group     | Mean difference (SD) at the baseline and the fourth week | p value |
|--------------------|-----------|----------------------------------------------------------|---------|
| Memory quotient    | Experiment| 2.83 (11.30)                                             | 0.38    |
|                    | Control   | 9.20 (11.08)                                             |         |
| General information| Experiment| 0.75 (1.16)                                             | 0.86    |
|                    | Control   | 0.6 (1.94)                                               |         |
| Orientation        | Experiment| 0.50 (1.06)                                             | 0.60    |
|                    | Control   | 0.20 (0.83)                                              |         |
| Learning association| Experiment| 2.25 (2.95)                                             | 0.28    |
|                    | Control   | 4 (2.26)                                                  |         |
| Mind control       | Experiment| –012 (1.88)                                              | 0.90    |
|                    | Control   | 0 (1.87)                                                  |         |
| Logical memory     | Experiment| 0.56 (2.14)                                              | 0.61    |
|                    | Control   | 0 (1.45)                                                  |         |
| Repeat numbers     | Experiment| –012 (1.35)                                              | 0.94    |
|                    | Control   | –020 (2.38)                                               |         |
| Visual memory      | Experiment| 1.37 (3.62)                                              | 0.61    |
|                    | Control   | 0.60 (1.67)                                               |         |
several functional tasks in a brain tumor patient with simultaneous TBI. Authors treated the patient with 40 sessions of NFT. Their study suffered from lack of control group.

NFT has also been used for management of concussion symptoms and improving quality of life in patients with TBI. It is reported that NFT can have significant effects on the functional and structural connectivity in young patients with moderate TBI. In an interventional study in 2014, 60 patients with TBI have been evaluated regarding the effect of NFT on improving their quality of life. Patients in intervention group (n = 30) received 20 sessions of NFT during four weeks while there was 30 patients in wait-list group. This project showed that NFT could have significant effect on improving quality of life in patients with TBI. Therefore authors of this project suggested that NFT can be used in treatment approaches of TBI patients in improving quality of life.

Despite these positive points regarding useful effects of NFT on different aspects of patients with TBI, we could not observe any effect of NFT for improving of continuous attention and short-term memory loss in TBI patients. We think that the whole program including its hardware, software and human resources at the Atieh Clinical Neuroscience Center should be re-evaluated. Also our treatment protocol for neurofeedback and the number of its sessions need to be revisited. 

### Table 3
Comparison of the improvement in the DAUF variables at the baseline and the fourth week of inclusion between the two groups.

| Variable                  | Group       | Mean difference (SD) at the baseline and the fourth week | p value |
|---------------------------|-------------|---------------------------------------------------------|---------|
| Mean number of correct answers | Experiment  | 1.14 (7.74)                                              | 0.052   |
|                           | Control     | 10 (7.74)                                                |         |
| Mean reaction time        | Experiment  | 1.85 (16.05)                                             | 0.430   |
|                           | Control     | 11.2 (12.19)                                             |         |
| Mean number of incorrect answers | Experiment | -15.28 (139.15)                                          | 0.300   |
|                           | Control     | 36.8 (25.4)                                              |         |

**Fig. 1.** Comparing the mean number of correct answers of DAUF test at the baseline and the fourth week of inclusion in the two groups.

**Fig. 2.** Comparing the mean number of incorrect answers of DAUF test at the baseline and the fourth week of inclusion in the two groups.

**Fig. 3.** Comparing the mean reaction time of DAUF test at the baseline and the fourth week of inclusion in the two groups.
sessions which was detailed in the method section may need reconsideration for future studies. Moreover, since the effect of NFT can be observed after a relative long period of time (more follow-up of patients), other researchers had better observe the conditions of their patients for a long time.

Limitations

Our main limitation was about the sample size of this study. Other research with adequate sample sizes may conclude significant relationships among the evaluated variables. Second, we were not able to eliminate or change any medicine prescribed to the patients by their physicians and our results might be affected by co-intervention factors.

Conclusion

We concluded that NFT has no effect on CA and STM of the patients with moderate TBI. However, we believe that for making an exact decision about use of NFT in TBI patients, more research projects with adequate sample sizes, longer time of treatment and follow-up and different protocols should be done.

Conflicts of interest

Dr. Reza Rostami, the head of the Atieh Clinical Neuroscience Center, had conflict of interest in this project.

Acknowledgment

This study was financially supported by the Sina Trauma and Surgery Research Center affiliated to Tehran University of Medical Sciences under contract number 167.

References

1. Thurman DJ, Alverson C, Dunn KA, et al. Traumatic brain injury in the United States: a public health perspective. J Head Trauma Rehabil. 1999;14:602–615.
2. Rehabilitation of persons with traumatic brain injury. NIH Consen Statement. 1998;16:1–41.
3. Cree C. Acquired brain injury: acute management. Nurs Stand. 2003;18:45–54.
4. Shekhvar C, Gupta LN, Premasagar IC, et al. An epidemiological study of traumatic brain injury cases in a trauma centre of New Delhi (India). J Emerg Trauma Shock. 2015;8:131–139. http://dx.doi.org/10.4103/0974-2700.160700.
5. Yan HQ, Osiro ND, Korpion J, et al. Persistent cognitive deficits: implications of altered dopamine in traumatic brain injury. In: Kobetzky FH, ed. Brain Neurotrauma: Molecular, Neuropsychological, and Rehabilitation Aspects. Boca Raton (FL): CRC Press/Taylor & Francis; 2015:33.
6. May G, Benson R, Balon R, et al. Neurofeedback and traumatic brain injury: a literature review. Ann Clin Psychiatry. 2013;25:289–296.
7. Astrand E, Wardak C, Ben Hamed S. Selective visual attention to drive cognitive brain–machine interfaces: from concepts to neurofeedback and rehabilitation applications. Front Syst Neurosci. 2014;8:144. http://dx.doi.org/10.3389/fnsys.2014.00144.
8. Sumec R, Filip P, Sheardova K, et al. Psychological benefits of non-pharmacological methods aimed for improving balance in Parkinson’s disease: a systematic review. Behav Neurol. 2015;2015:620674. http://dx.doi.org/10.1155/2015/620674.
9. Arns M, Heinrich H, Strehl U. Evaluation of neurofeedback in ADHD: the long and winding road. Biol Psychol. 2014;95:108–115. http://dx.doi.org/10.1016/j.biopsycho.2013.11.013.
10. Kopriwova J, Congedo M, Rasza M, et al. Prediction of treatment response and the effect of independent component neurofeedback in obsessive-compulsive disorder: a randomized, sham-controlled, double-blind study. Neuropsychobiology. 2013;67:210–223. http://dx.doi.org/10.1159/000347087.
11. Arns M, de Ridder S, Strehl U, et al. Efficacy of neurofeedback treatment in ADHD: the effects on inattention, impulsivity and hyperactivity: a meta-analysis. Clin EEG Neurosci. 2009;40:180–189.
12. Lantz DL, Serman MB. Neuropsychological assessment of subjects with uncontrolled epilepsy: effects of EEG feedback training. Epilepsia. 1988;29:163–171.
13. Abstracts of scientific papers presented at the 12th anniversary meeting of the biofeedback foundation of Europe in Salzburg/Austria. Appl Psychophysiol Biofeedback. 2008;33:239–250.
14. Munivenkatappa A, Rajeswaran J, Indira Devi B, et al. EEG Neurofeedback therapy: can it attenuate brain changes in TBI? NeuroRehabilitation. 2014;35:481–484. http://dx.doi.org/10.3233/NRE-141140.
15. Reddy RP, Rajeswaran J, Bhagavatula JD, et al. The effects of neurofeedback on quality-of-life. Indian J Psychol Med. 2014;36:40–44. http://dx.doi.org/10.4103/0253-7176.127246.
16. Rahimi-Movaghar V, Saadat S, Rasouli MR, et al. The incidence of traumatic brain injury in Tehran, Iran: a population based study. Am Surg. 2011;77:e112–114.
17. Ghodsi S, Moezzardalan K, Darrowhehedar E. Evaluation of head injury in patients reporting at emergency centers of Sina, Shohada and Fayazbakhsh hospitals. Tehran J Med Counc Islam Repub Iran. 2002;20:193–198.
18. Carson HJ. Brain trauma in head injuries presenting with and without concurrent skull fractures. J Forensic Leg Med. 2009;16:115–120. http://dx.doi.org/10.1016/j.jflm.2008.08.013.
19. Saadat S, Rashidi-Ranjbar N, Rasouli MR, et al. Pattern of skull fracture in Iran: report of the Iran national trauma project. Ulus Trauma Acil Cerrahi Derg, 2011;17:140–151.
20. Shorooee MH, Sharif-Alhoseini M, Saadat S, et al. Effect of mild head injury on intelligence in Zahedan. Iran Chin J Traumatol. 2010;13:345–348.
21. Ferrini R, Constantinoyannis C, Papadakis N. Cross-cultural study of symptom expectation following minor head injury in Canada and Greece. Clin Neurophysiol. 2001;103:254–259.
22. Yousefzadeh-Chabok S, Ramezani S, Reihanian Z, et al. The role of early post-traumatic neuropsychological outcomes in the appearance of latter psychiatric disorders in adults with brain trauma. Asian J Neurosci. 2015;10:173–180. http://dx.doi.org/10.4103/1793-5482.161165.
23. Nelson DV, Esty ML. Neurotherapy for chronic headache following traumatic brain injury. Min Med Res. 2015;2:22. http://dx.doi.org/10.1186/s40779-015-0049-y.
24. Reddy RP, Jamuna N, Devi BI, et al. Neurofeedback training to enhance learning and memory in patient with traumatic brain injury: a single case study. Indian J Neu ātrauma. 2009;6:87–90.
25. Wing K. Effect of neurofeedback on motor recovery of a patient with brain injury: a case study and its implications for stroke rehabilitation. Top Stroke Rehabil. 2001;8:45–53.