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RESEARCH

The Effect of Neurofeedback Training on Variables of Attention in Healthy Adults

Sağlıklı Yetişkinlerde Sinirsel Geribildirim Eğitiminin Dikkat Değişkenleri Üzerindeki Etkisi

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Abstract

The aim of present study is to examine the effect of neurofeedback training on attentional processes in two groups of healthy adult participants. During the experiment, participants in the experimental group were required to complete two puzzles displayed on the computer screen while having neurofeedback training. During this procedure, performance on the puzzles was based on participants' brain activity that was recorded from the Cz area. Moreover, before and after completion of seven neurofeedback sessions, Stroop task was used to measure selective attention performance. Results for the Stroop task showed that although there was a significant reaction time difference before and after the neurofeedback training, there was no significant main effect of group (experimental vs. control group). Furthermore, the reaction time to complete the puzzles across the sessions did not differ significantly between the experimental and the control group. Improving the training program by increasing the number of training sessions and employing a more attention-demanding task in the training sessions might have resulted in an expected effect of neurofeedback.

Keywords*:* Neurofeedback, electroencephalography, attention, Stroop task.

Öz

Bu çalışmanın amacı sinirsel geribildirim (neurofeedback) eğitiminin dikkat süreci üzerindeki etkisi sağlıklı yetişkinlerden oluşan iki katılımcı grubunda incelenmiştir. Deney esnasında, deneysel gruptaki katılımcılar, bir yandan sinirsel geribildirim eğitimi alırken diğer yandan kendilerinden bilgisayar ekranında gösterilen iki adet bulmaca oyununu tamamlamaları istenmiştir. Bu işlem sırasında, katılımcıların bulmaca çözme performansı, elektrotların yerleştirildiği Cz bölgesinden elde edilen beyin dalgalarına göre değişim göstermektedir. Ayrıca, toplam yedi sinirsel geribildirim oturumu öncesi ve oturum sonrasında seçici dikkat performansını ölçmek amacıyla Stroop görevi kullanılmıştır. Stroop görevinin sonuçları, sinirsel geribildirim eğitimi öncesi ve sonrasında kaydedilen tepki süreleri arasında anlamlı fark bulunduğunu gösterse de, grubun (deneysel grup ve kontrol grup) temel etkisi anlamlı bulunmamıştır. Diğer yandan, oturumlar boyunca bulmacaları tamamlamak için gerekli tepki süresi deneysel ve kontrol gruplarında anlamlı olarak değişiklik göstermemiştir. Eğitim oturumlarının sayısını artırarak ve eğitim oturumlarında daha dikkat gerektiren bir görevi kullanarak eğitim programının iyileştirilmesi sonucunda, sinirsel geribildiriminin beklenen etkisi görülebilir.

Anahtar sözcükler: Sinirsel geribildirim, elektroensefalografi, dikkat, Stroop görevi.

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BIOFEEDBACK requires individuals to modify certain psychophysiological processes of which they are not normally aware (Vernon 2005). It simply works as "feeding" the information "back" to individuals who generated the bio-signals in the first place. In this regard, individuals are actively engaged in controlling their own physiology (i.e., heart rate) (Fuller 1984). Here depending on the type of biofeedback technique being used the feedback can be presented either visually or auditory (Thompson and Thompson 2003). Neurofeedback (NF, also called electroencephalographic –EEG– biofeedback) on the other hand, is dependent upon certain electrophysiological features of the brain activity and requires individuals to willingly change their cortical activity (Vernon 2005). In other words, an individual can learn to modify the amplitude and frequency of the relevant electrophysiological components of their own brains. Therefore, the main goal of neurofeedback training (NFT) is to teach individuals to recognize which specific mental/psychological states can lead to changes in cortical activity and how such states can be voluntarily activated. During NFT, the electrophysiological activity is recorded by EEG machine and then the changes in the signal are fed back to participants as visual or auditory stimuli (Vernon 2005).

In the neurofeedback technique, the experimenter measures the frequency and amplitude of different brain waves, which are recorded by electrodes (sensors) placed using a highly conductive electrode paste on the surface of the skull. The electrode records electrical activity produced by the neurons in the brain. The raw EEG then shows the morphology (shape) of the waves, the amplitude (how high the waves are from peak to trough), and the frequency (how many waves there are in one second). Here it is important to mention that different EEG patterns correspond to different mental states. For instance, there are different patterns for sleep and waking, for focused concentration and problem solving, or for day dreaming, and these are categorized as delta, theta, alpha or beta activity (Thompson and Thompson 2003). In the current study, as explained in more detail below, our primary focus was theta and beta activity because previous studies showed they are involved in selective attention (Başar et al. 1999, Başar et al. 2001) and sensorimotor feedback respectively (Egner and Gruzelier 2001, Doppelmayr and Weber 2011).

The activity between the frequency ranges of 3-7 Hz, 4-7 Hz, or 4-8 Hz are called theta activity. The origin of this rhythm appears to be in the thalamus and in the limbic system. These waves are found during drowsiness or arousal in older children and adults (Thompson and Thompson 2003). On the other hand, the source of the beta waves is above 12 Hz (except for sensorimotor rhythm). These waves are found during active, busy, anxious thinking, or active concentration (Vernon 2005). 13-15 Hz is called sensorimotor rhythm (SMR) which is found across the sensor-motor strip. It occurs when there is a decrease in the activity of the sensory and motor pathways, which run through the thalamus (Thompson and Thompson 2003). Similarly, it occurs when less attention is paid to sensory input and when there is decreased motor output. The waves between 16-20 Hz is often referred to as low beta, and the waves between 20-42 Hz are referred to as high beta (Thompson and Thompson 2003).

The underlying rationale of applying NFT to enhance performance is based on the association between the activity in the brain and changes in a mental state for a specific situation. By identifying the relation between the patterns of cortical activity and specific mental states, one can change their behavior (Enriquez-Geppert et al. 2017). The training process results in changes in the EEG signals, which in turn causes changes in behavior (Vernon 2005). However, this finding might occur due to the correlation between the EEG signals and behavior. Since correlation does not imply causation, it is not possible to indicate that changes in the EEG signals always result in changes in behavior. On the other hand, behaviors can be changed by applying the "operant conditioning" principles. Thorndike (1898) showed that when the actions are followed by positive reinforcers, they will increase the repeatability of that behavior in the future (Edward Thorndike's Law of Effect). In the neurofeedback technique, the behavior, that is the production of a particular brainwave pattern, is reinforced. Here the reinforcer, which provides information about the success in a particular behavior can be presented either visually or auditory. In other words, external reinforcers can influence physiological changes in the body (Sterman 2000). This technique is based on the basic principle that is when the experimenter rewards the production of a particular brain wave pattern with auditory or visual feedback, then that information acts as a reinforcer for the individual and consequently, the experimenter increases the likelihood of recurrence of that brainwave activity (Thompson and Thompson 2003).

In most EEG experiments, researchers can acquire electrical recordings from multiple sites on the brain. In general, the number of electrodes is called channels. For example, the electrical activity is measured from 64 different places of the brain in a 64-channel recording. The number of channels in an experiment is important if one aims to make source localization for finding the source of the brain activity in a spatial domain.

However, only one (single) or two (dual) electrode mechanisms are usually used in NFT (Demos 2005). In the single electrode recording, the researcher puts the electrode on the brain area that is studied. For example, previous studies showed that recording from the Cz area is critical for attention and Fp area is critical for working memory (Başar et al. 1999). The electrodes are mostly placed on the skull surface according to underlying neuronal structures. For example, in the working memory experiments, one gets the recording from Fp, because the frontal lobes are suggested to be mostly involved in the working memory tasks (Onton et al. 2005). In the single-channel recordings, the reference electrodes are generally attached to earlobes which have neutral electrical potential to ground the electrical activity. On the other hand, if dual-electrode recording is performed, the two electrodes are placed on separate skull regions where one is placed on the source location and the other is placed as a reference point on a separate body region (Demos 2005).

The applications of the neurofeedback are various and can be used for treating specific patient groups including substance abuse (Scott et al. 2005), epilepsy (Monderer et al. 2002, Egner and Sterman 2006), hemiplegic shoulder reeducation (Deniz et al. 2018), and fibromyalgia (Kayıran et al. 2010). Neurofeedback also appears to be a promising alternative for Attention Deficit Hyperactivity Disorder (ADHD) (Lubar et al. 1995, Lansbergen et al. 2011, Yaylacı et al. 2019). For the ADHD patients, NF was shown to reduce the behavioral symptoms and improve cognitive performance (Micoulaud-Franchi et al. 2014). There are three neurofeedback methods applied in children with ADHD. One of them is training in decreasing power of theta (4–8 Hz). Two other parameters contain training in increasing the power of beta (15–20 Hz) and increasing the power of the sensorimotor rhythm (SMR, 12–15 Hz) (Vernon et al.

2004). Most researchers integrate at least two parameters, such as inhibiting theta and enhancing beta power (Lubar et al. 1995) or inhibiting theta, enhancing beta and enhancing SMR (Alhambra et al. 1995). In the literature, to the best of our knowledge, there are only two studies that used self-regulation training of slow cortical potentials (SCP) (Heinrich 2004, Strehl et al. 2006). The results of these studies which focused on self-regulation of theta, beta and/or SMR suggested that neurofeedback treatment reduces ADHD symptoms (Leins et al. 2007, Gevensleben et al. 2014).

The aim of the present study is to examine whether individuals trained to enhance a particular EEG component, namely SMR frequency, and theta activity with neurofeedback technique, would be inclined to better use attentional resources during the Stroop task, which has been claimed to be associated with SMR frequency component (Egner and Gruzelier 2001, Egner and Gruzelier 2004).

We examined attention performance of two healthy groups, the experimental group and the control group. After the NFT, we expected the training group to enhance their SMR activity (12-15 Hz) and inhibit theta (4-7 Hz) frequency. On the basis of previous research (Egner and Gruzelier 2001, Egner and Gruzelier 2004, Vernon et al. 2004), we would expect SMR training to positively influence one's use of attentional resources. The control group was involved only in the pre- and post-attention tasks, without attending to NFT sessions. The attention task employed was the Stroop Task (Stroop 1935, MacLeod 1991) in which subjects were assigned to three subtasks, which were saying the color of a series of geometrical shapes (i.e., rectangles), reading the printed words which were color names, and saying the color of the printed words while avoiding reading the word itself.

Previous findings (Alhambra et al. 1995, Egner and Gruzelier 2003, Vernon et al. 2004) with neurofeedback training suggest that SMR training has effects on attention performance. Specifically, it has been shown that SMR training with neurofeedback is associated with commission error reduction in a go/no-go task, which measures focused attention (Egner and Gruzelier 2003, Vernon et al. 2004). In a go/no-go task, participants are required to choose response to either "go" or "no-go" stimulus. In this sense, a go/no-go task requires response inhibition, which is also associated with one of the main cognitive components measured by Stroop task. Stroop task conditions requiring inhibitory control reflect the information process, in the same manner, a go/no-go task does. Tasks which measure executive functions include both Stroop and go/no-go tasks. These studies also showed that SMR training would not result in significant change in reaction time in a go/no-go task. Based on previous findings, it was hypothesized that

1. Scores in Stroop task administered before and after SMR neurofeedback training would differ from the participants in the control group who were not exposed to SMR neurofeedback training. Specifically, it was hypothesized that the Stroop effect in terms of the amount of time the task takes (that is, the difference in the amount of time between the task of naming the color of the words and reading the words) recorded at the beginning and at the end of 4 weeks would differ in two groups (namely, experimental group which takes NFT, and control group which takes no NFT).
2. SMR neurofeedback training would reduce the time needed to complete the training tasks across sessions, only in the experimental group..

Method

Participants

Fifteen healthy adult participants (thirteen females and two males) who have completed an undergraduate degree were recruited. The age of the participants ranged from 23 to 33 years old (Mean:25.33, SD:2.08). They had normal or corrected to normal vision and had no recorded history of neurological or psychiatric disorders. One of the participants in the neurofeedback group dropped out after three weeks of NFT. Remaining fourteen participants were involved in the study. Finally, participants were instructed not to consume caffeine-related products on the day of the session. Consecutive sampling method was used to recruit these participants. All participants voluntarily participated in the experiment and gave informed consent prior to the beginning of the experiment. This method was approved by Gazi University School of Medicine and was in accordance with the Helsinki Declaration.

Experimental Design

After sampling, participants were randomly assigned to two groups, namely the experimental and the control group (seven participants in each group). The two groups were matched for gender, age and education. In order to test the hypotheses concerning the effects on behavioral attention measures, both groups were assessed on the Stroop task. For the experimental group, NFT sessions were conducted in a private room. Light conditions in the room were adjusted in order to avoid distraction during the course of the NFT sessions. During the NFT sessions, participants were left alone in the training room for better concentration (Figure 1).

Figure 1. One of the participants while taking neurofeedback training

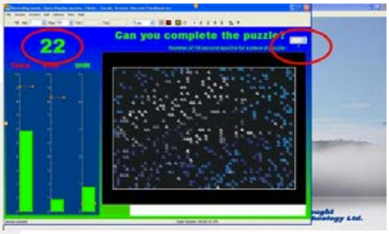

Figure 2. One of the Puzzles-Dolphin used in NFT sessions.

Assessment Instruments and Tasks

Sustained Attention Performance

Selective visual attention was examined using a paper-based standard psychometric test, namely, the Stroop task immediately before and after the end of 4-week training interventions. In the Stroop paradigm, stimuli are divided into three types of trials (congruent, incongruent and neutral), depending on the consistency between words and colors. During the incongruent item condition, words are presented in mismatching colors (e.g., the word green printed in blue) relative to the congruent item condition where words are presented in matching colors (e.g., the word green printed in green). In the first part of the task, participants are instructed to read the words, and in the second part they are instructed to name the color of the words. For the last session, participants are usually instructed to name the color ink while they suppress reading color names. The differences in reaction time between congruent and incongruent stimulus are called the Stroop effect.

In the current study, the participants were presented with three blocks of trials in the same order. In the first block, the participants saw rectangular objects in different colors and they were asked to name the colors of them; in the second block, they were asked to read the words which were printed in different color; and finally in the last block of trials, they were asked to name the color of the words. Reaction times were recorded with a chronometer in each block. Errors and spontaneous-immediately corrected- errors were also recorded by the experimenters if encountered any.

Neurofeedback Training (NFT)

Neurofeedback software was executed in a Casper model computer with 512 MB RAM and 2 GHz Intel(R) Pentium(R) Processor. During the NFT sessions, a commercially available hardware/software package, the BioGraph/ProComp+ biofeedback system, was used with silver coated electrodes. Before the acquisition electro-gel was also used to improve conduction in electrodes. All the data acquisition was performed using the Biograph Infiniti software version 2.5.2 at 160 Hz from the Cz area and the reference electrode was placed to the right earlobe. In this regard, dual-electrode recording was performed. Initially, for preprocessing, the raw signal was A/D converted and then a band-pass filter was used to decompose theta (4–8 Hz), SMR (12–15 Hz) and beta (18–22 Hz) components. Moreover, total power was calculated for each frequency band with using moving average power-spectral analysis.

Afterwards, the two of the decomposed frequency components (SMR and theta) were fed back to the participants as bar graphs. During the puzzle task, these SMR and theta activity were shown to the participants as dynamically changing bar graphs representing total power for SMR and theta frequencies. Here the task for the participants is to increase the height of the bar associated with theta activity and decrease the height of the bar associated with SMR power. When the power in the specific frequency band reaches a specific threshold, the puzzle parts open automatically and the goal of the participants is to maintain the activity in that threshold by focusing on the screen. Therefore, the performance in the puzzle is based on how well the participants change their SMR and theta frequencies. On meeting this goal for a predefined duration (see Figure 2), a tone was presented simultaneously with a symbol on the computer screen that indicates the score of the participants (generally 100 points for completion of each puzzle). Frequency bars (theta and SMR), number of points visible (22) and number of ¼ seconds a piece of puzzle (1) can be seen in Figure 2. It is important to note that participants did not receive additional instructions on how to change their neural activity. They were just instructed to focus on the screen (for visual feedback purposes) to find their own way of improving the neural signals.

Procedure

During the NFT sessions, each participant received two training sessions per week over a 4-week period. Most of the training sessions were arranged on Wednesday and Saturday afternoons. If the participants were not available in those dates, they were randomly allocated for another weekday with none of the participants had any two NFT session occurred in three consecutive days. First, the participants in the experimental group completed the Stroop task before the NFT session. Second, before the experiment, the participants in the experimental group were instructed on how the NFT works and how they can maximize their performance by increasing the theta and decreasing the SMR frequency component (Fishbein et al. 1990). The participants in the experimental group were required to complete two puzzles displayed on the computer screen while having NFT. While three types of puzzles were employed throughout the whole experiment, randomly two of these puzzles were presented in a single session. Therefore, different puzzles were employed for each session (see Figure 3). During this procedure, performance on the puzzles was based on participants' brain activity that was recorded from the Cz area. Similar to the study of Lubar et al. (1995), the NFT sessions took approximately 7-min for each puzzle depending on the performance of the participant. At the end of each NFT session, the participants in the experimental group completed the Stroop task immediately. Finally, participants were debriefed and were asked to describe how they felt about their NFT performance.

The Complete Dolphin The Complete Stop Sign The Complete Tomato

Figure 3. Puzzle set used in the experiment.

On the other hand, the participants in the control group did not receive any NFT session. They just completed the Stroop task before the whole experiment and after four weeks later at the end of the whole experiment. In other words, the control group was involved only in the pre- and post-attention tasks, without attending to NFT sessions. After the final session when the participants in the experimental condition completed the whole experiment, all participants were thanked for their contribution to science by participating in the study.

Results

Stroop Performance

Subtask of Stroop Task: Naming the Color of the Words

The data were analyzed in a 2 (time: before, after NFT) × 2 (group: experimental, control) mixed analysis of variance (ANOVA). The independent variable "time" was within subjects; while the independent variable "group" were between groups. Participants' performance on the subtask of Stroop task, namely, the "naming the color of the words" was assessed. In this regard, the statistical analyses were performed on "reaction time to complete the subtask of Stroop task" and "the number of errors made by the participants" as the dependent measures, respectively. For all of the analyses, the significance was set to .05 alpha level. The means and standard deviations of the Stroop subtask scores (reaction time and errors) of the participants in the experimental and control groups are given in Table 1.

The results indicated a main effect of time on the reaction time (in seconds) to complete the subtask of Stroop task ($F (1,12) = 23.53$, $p = .000$, $\eta_p^2 = .66$), showing that the reaction time to complete the Stroop subtask prior to NFT was significantly longer (M=55.26; SD=2.1) than the reaction time after the NFT session (M=49.39; SD=2.1). However, there was no significant main effect of group ($F (1,12) = 1.12$, $p = .31$) and no significant interaction effect between time and group ($F (1,12) = 3.60$, $p = .08$).

There was no main effect of time on the number of errors at the Stroop subtask ($F (1,12) = .36$, $p = .56$). Similarly, there was no main effect of group ($F (1,12) = .83$, $p = .38$) and no interaction effect between time and group ($F (1,12) = .36$, $p = .56$).

Tablo 1. Participants' Stroop Subtask scores in terms of reaction time and errors (mean±SD)

	Experimental Group		Control Group	
	Before	After	Before	After
Stroop subtask (RT- in sec)	54.29±9.26	46.12±7.83	56.22± 5.87	52.65±7.83
Stroop subtask (Errors)	0.43± 1.27	0.57± 0.56	1.14±1.35	0.71±0.76

M= mean, SD= Standard deviation, RT= Reaction time

Stroop Effect

Differences in performance between the two subtasks, namely, between the "naming the color of the words", and the "reading the words" were examined separately on the "differences in the reaction time to complete the tasks" and the "differences in the number of errors made by the participants" by 2 (time: before, after NFT) x 2 (group: experimental, control) mixed ANOVA. The means and standard deviations of the Stroop effect scores (reaction time and errors) of the participants in the experimental and control groups are given in Table 2.

The results revealed a main effect of time on the differences in the reaction time ($F (1,12) = 5.28$, $p < .05$, $\eta_p^2 = .31$), indicating that the amount of time prior to NFT sessions were significantly longer (M=29.51; SD=1.9) than the amount of time after the NFT session (M=26.40; SD=1.9). However, similar to the subtask of Stroop, there was no main effect of group ($F (1,12) = 1.42$, $p = .28$) and no significant interaction effect between time and group ($F (1,12) = 1.75$, $p = .21$).

The results on the "differences in the number of errors made by the participants" did not reveal a main effect of time ($F (1,12) = .34$, $p = .57$). Similarly, there was no significant main effect of group ($F (1,12) = .73$, $p = .41$) and no interaction between time and group ($F (1,12) = .95$, $p = .35$).

Tablo 2. Scores of Stroop effect in terms of reaction time and number of errors (mean±SD))

	Experimental Group		Control Group	
	Before	After	Before	After
Stroop effect (TS- seconds)	28.17±8.91	23.26±7.16	30.84± 5.64	29.52±7.73
Stroop effect (Errors)	0.57± 1.13	0.57± 0.53	1.14±1.35	0.57±0.79

M= mean, SD= Standard deviation, RT= Reaction time

Puzzle Solving Durations across Neurofeedback Training Sessions

Repeated ANOVA was used to compare puzzle solving durations among seven NFT sessions in the experimental group. The results showed that the amount of time to complete the task did not significantly differ across the sessions ($F (6, 36) = 1.62$, $p > .05$). Moreover, paired samples t-test was conducted to see whether puzzle solving duration (in sec) between the first session and the last session differ from each other. Statistically, session 1 (M=783.57) and session 7 (M=681.29) did not differ in terms of puzzle solving duration (t_6=1.62, p > .05. Table 3 presents the means and standard deviations of the puzzle solving durations across NFT sessions.

Table 3. Means and standard deviations of the participants' puzzle solving durations across NFT sessions

Puzzle Solving Durations (in sec)	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7
Mean	783.57	659.71	763.85	689.71	725.00	659.28	681.29
Standard deviation	231.05	65.22	206.02	88.35	202.95	111.47	129.65

Discussion

The present study was designed to test the effects of NFT on selective attention by using a well-known attention task, namely the Stroop task. The results for the Stroop task, which was administered before and after NFT showed no significant difference between the experimental and the control group but showed a significant main effect of time (before and after NFT). Furthermore, SMR neurofeedback training did not reduce the reaction time needed to complete the training tasks (puzzles) across seven sessions.

The results obtained from the present study did not confirm the previous studies, which explored the effects of SMR training on attentional resources. Previous findings showed that SMR frequency is associated with commission errors in go/no-go tasks (Egner and Gruzelier 2003, Vernon et al. 2004), which are supposed to measure focused attention by requiring participants to respond to a target stimulus but not to a non-target stimulus. In the current study, we aimed to measure a similar cognitive process by using Stroop task, however the results did not show an association between errors and SMR training. The attentional process required in these two attention tasks are different in nature and the tasks measure different aspects of the attentional process. Specifically, the commission error in go/no-go tasks is due to an inability to inhibit a non-target symbol, whereas the error in Stroop task is due to the inability to inhibit reading performance, which is commonly considered as an automatic process (MacLeod 1992). These results suggest that it is important to distinguish different aspects of attention in order to improve selective attention performance and employ the NFT sessions accordingly.

Findings suggest that Stroop task performance not only improved in the experimental group but also in the control group, and this sets forward other questions. The first one is that enhancement in the performance of the experimental and control group might be simply due to familiarity with the Stroop task. Secondly, there is always a possibility that some other experimentally uncontrollable variable such as a sports activity or activities such as going to yoga or pilates might have influenced the individuals' performance. For example, by chance, after the experiment, one of the participants in the control group reported that she has started to attend pilates sessions three times a week in the middle of the NFT period. Therefore, it is possible that conscious participation in body training activities might have a positive effect on mental states and might lead to better concentration (Bernardo 2007, Memmedova 2015). Such a situation might also have happened in the experimental group. Besides that, onset/offset time of sleep and sleep duration of the participants were not controlled, these factors might also have affected the findings. Therefore, one of the main arguments for the decrease in duration of the Stroop performance might be caused by the confounding factors.

Regarding the NFT sessions of the experimental group, the results demonstrated that although there was a decrease in NFT time, this decrement was not significant. In other words, the reduction in the puzzle solving durations among seven NFT sessions have been obtained as expected, although it was not statistically significant. Besides, the first and the last NFT session did not differ in terms of puzzle solving duration. Several factors might have led to these findings. One of them was the number of training sessions. As it has been suggested by a recent study (Davelaar 2017), EEG neurofeedback training requires multiple sessions to detect specific components in attentional processes. It is possible that if the training sessions had been longer, the decrement in NFT time may have been significantly different. Another reason for insignificant NFT time may be due to the lack of attractiveness of the tasks (i.e. tomato, dolphin, stop sign puzzles) used during the training sessions. The puzzles might not be attention-demanding enough and this might influence the participants' motivation in completing the puzzles. Therefore, improving the training program by increasing the number of training sessions and employing a more attention-demanding task in the training sessions might have resulted in an expected effect of NFT.

One of the limitations of the present study was the time interval between the training sessions. Although we randomized the order of the sessions and none of the participants have two NFT sessions in three consecutive days, it might be the case that more frequent NFT sessions might be necessary to induce significant changes in attention performance. Another limitation of the current study is the total number of volunteers and the higher proportion of women volunteers participated in the experiment. Due to its longitudinal nature, such studies have high dropout rates and hard to find volunteers without a strong motivational incentive. Future studies need a larger number of participants and equal proportions of men and women in order to have a definitive conclusion on the effectiveness of NFT. Moreover, it is crucial to compare different cognitive tasks and associate the right frequency components with each variable of attention for future research.

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