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What is This?
Improvement of Neurofeedback Therapy for Improved Attention Through Facilitation of Brain Activity Using Local Sinusoidal Extremely Low Frequency Magnetic Field Exposure

Yasaman Zandi Mehran¹, Mohammad Firoozabadi², and Reza Rostami³,⁴

Abstract
Traditional neurofeedback (NF) is a training approach aimed at altering brain activity using electroencephalography (EEG) rhythms as feedback. In NF training, external factors such as the subjects’ intelligence can have an effect. In contrast, a low-energy NF system (LENS) does not require conscious effort from the subject, which results in fewer attendance sessions. However, eliminating the subject role seems to eliminate an important part of the NF system. This study investigated the facilitating effect on the theta-to-beta ratio from NF training, using a local sinusoidal extremely low frequency magnetic field (LSELF-MF) versus traditional NF. Twenty-four healthy, intelligent subjects underwent 10 training sessions to enhance beta (15-18 Hz), and simultaneously inhibit theta (4-7 Hz) and high beta (22-30 Hz) activity, at the Cz point in a 3-boat-race video game. Each session consisted of 3 statuses, PRE, DURING, and POST. In the DURING status, the NF training procedure lasted 10 minutes. Subjects were led to believe that they would be exposed to a magnetic field during NF training; however, 16 of the subjects who were assigned to the experimental group were really exposed to 45 Hz–360 µT LSELF-MF at Cz. For the 8 other subjects, only the coil was located at the Cz point with no exposure. The duty cycle of exposure was 40% (2-second exposure and 3-second pause). The results show that the theta-to-beta ratio in the DURING status of each group differs significantly from the PRE and POST statuses. Between-group analysis shows that the theta-to-beta ratio in the DURING status of the experimental group is significantly (P < .001) lower than in the sham group. The result shows the effect of LSELF-MF on NF training.

Keywords
local sinusoidal extremely low frequency magnetic field, neurofeedback, attention

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Introduction
Neurofeedback (NF)¹⁻⁵ is a new methodology for changing desired aspects of brain functions, by self-assessment, using EEG rhythm feedback such as a game or sound. NF is composed of 2 aspects: active (traditional NF) and passive. Traditional NF requires the subject to learn and modify some aspects of cortical activity. There are 2 disadvantages: (1) learning by the subjects; (2) how the EEG rhythms are tuned.¹⁻⁵ As a result, this method often encounters problems such as the subject’s intelligence (IQ), emotional quotient (EQ), multiple treatment sessions, and lack of accurate determination of the client’s status during NF. To remove the subject’s role in NF training, Ochs⁶,⁷ used low-energy electromagnetic (ie, radio, light) waves as a feedback, sending them to the subjects and measuring the returned waves. This method is called the low-energy neurofeedback system (LENS),⁶,⁷ which is a passive NF. LENS does not require any conscious effort on the part of the subject. The stimulus is based on the dominant EEG frequency. In contrast, in traditional NF, subjects, through learning stimuli, consciously manage acquired thought patterns.

LENS NF does not require any attention, focusing, or consciousness, and the sessions are fewer than in traditional NF.
Eliminating the subject role removes an important part of the NF system. It also seems that by facilitating the subject’s attempt during NF therapy, passive and active goals are merged. In both NF applications,6-8 some peripheral brain stimulation is used in neurotherapy and brain activity control.9,13 If these deficiencies are removed, NF can be more applicable in many diseases such as depression, attention-deficit/hyperactivity disorder (ADHD), addiction, and even in improvements of attention and cognition.4,5,16-23

In some neurotherapy approaches, to facilitate and affect brain activities, stimulation methods have been used. These aspects can vary because of blood perfusion increment, ion channel effects, neural threshold stimulation, and so on.24 These techniques are used to affect a wide variety of applications, such as neurotherapy, neuropsychiatric treatment, and improvement of attention.16,12,25-28 These methods are based on magnetic, electromagnetic, and electrical stimulations such as transcranial magnetic stimulation (TMS),29 repetitive TMS (rTMS),30 transcranial direct current stimulation (tDCS),31 and electroconvulsive therapy (ECT).12

Also, extremely low frequency magnetic field (<500 µT, 0-300 Hz), called ELF-MF, can affect human physiology based on behavioral, psychological and neurophysiologic changes. There are many differences in experimental investigations and MF characteristics, such as intensity, frequency, exposure time, wave shape and duration. Bell et al30 found that 35% of the subjects, exposed to 93 µT MF, displayed increased spectral power in EEG. Bell et al25 found decreased EEG activity in the occipital region, but not in the central or parietal regions, after exposure to 10-Hz MF. It was concluded that weak MF, applied continuously for 10 minutes, resulted in a reduction in brain electrical activity at the same frequency as that of the MF for 1-minute following termination of the field. Another study reported that 1.5-Hz and 10-Hz MF, 20 to 40 µT, altered EEG activity.31 Ten Hz–40 µT RMS MF (rms = root mean square) was more effective than 1.5 Hz–20 µT RMS MF, in eliciting increase in EEG activity at the frequency of the stimulation. It was reported that applications of electromagnetic fields, in the range 0 to 60 Hz and with the intensity of 20 to 100 µT, altered EEG activity in animals and human subjects during 2-second exposures. Marino et al32 found increases in spectral power, at 10 Hz, higher EEG frequencies, in the central, parietal, and occipital regions at 2 frequencies of 10 Hz and 1.5 Hz both of 80 µT RMS intensity. Heusser et al13 found increases in EEG spectral power in the beta and theta band after 3 Hz MF exposure. Lyskov et al34,35 found significant increases in beta (14-25 Hz) after 15 minutes of 45-Hz ELF-MF to the whole head.

Some researchers have focused on MF effects on the electrical activity of the brain, when cognitive and perceptual effects of MF exposure were explored.36-38 These experiments explored ELF MF effects on cognitive or sensory processing and tasks involving reaction time and memory recall. ELF-MF exposure had a positive effect on recognition memory39 and spatial learning,40 suggesting a crucial role of exposure in central and frontal regions. Cook et al41 found that the magnitude of the p300 component (a mid-latency positive peak that appears 300 ms after stimulus onset) of the event-related potential increased after 6 hours of MF exposure. Also a slight increase in reaction time took place. Crasson et al42 examined the effects of MF exposure 100 µT rms, 50 Hz on dichotic listening (a test of attention to auditory stimuli), with decreased N100 (negative peak, 100 milliseconds post stimuli) amplitude after MF exposure. After MF, prefrontal and parietal cortical activity was worsened. Cook et al.36 reviewed the effects of ELF MF on human cognition and electrophysiological behavior, such as reaction time, trails making test, time estimation, accuracy, affective picture rating, etc. Therefore, there is crucial evidence that ELF magnetic waves can affect brain waves, but no linear correlation is found between the intensities, frequencies of waves, and their effects on EEG records. Therefore, despite these inconsistencies, it is proven that ELF MF has cumulative and conclusive effects. Studies of ELF MF effects on EEG and relative brain activities, such as cognition and perception, conceptual and biophysical effects of field interaction are insufficient and unclear. Yet, based on the theoretical view of magnetic induction effects on cerebral waves, it is possible to systematically impose meaningful changes on EEG signal.43-45 Therefore, it appears that ELF can be used to affect the brain, and even to reduce the role of the subject in traditional NF.

Overall, ELF exposure is implemented through 2 approaches. In the first, the whole brain is exposed. In the second, the exposure is local. In whole brain exposure to ELF, the head is stimulated with Helmholtz coils and the brain is affected globally. In the second approach, the brain is stimulated with small coils which are placed on different regions, locally. Shafiei et al46 exposed human brain to local sinusoidal ELF and investigated relative power spectra at 3, 5, 10, 17, and 45 Hz at T4, T3, F3, Cz, and F4, respectively. These points were exposed to MF with similar frequencies and the intensity of 100 µT. The results indicated that the power value of EEG may alter significantly at the frequency of stimulation, but not necessarily based on frequency. Significant changes in different EEG bands in other regions of the brain were observed, but less than those in the whole exposure. In regions distant from the local exposure point, no significant changes were observed. These changes in EEG bands were not limited to the exposure point, but were fewer than those in global exposure. Amirifalah et al47,48 examined local pulsed exposure to the central regions of C3, C4, and Cz by an intensity of 200 µT when ELF-MF frequencies were 10, 14, and 18 Hz. They found that EEG variations in the central regions took place. In an earlier study, Shafiei et al49 used LSELF at frequencies of 45, 17, 10, 5, and 3 Hz, in 5 separate sessions at T3, T4, F3, F4, and Cz. The difference with the subsequent studies was that each frequency was exposed and investigated in all the 5 points. For example, T3, T4, F3, F4, and Cz were exposed to 45-Hz LSELF with 3 intensities in all 5 sessions. The MF intensities were 100, 240, and 360 µT in contrast with those in sham exposure. The interesting conclusion was that local LSELF MF exposure, at 45-Hz frequency and 360-µT intensity, results in significant theta decrement and
beta increment at the Cz region. Therefore, Amirifalah et al\textsuperscript{47,48} and Shafiei et al\textsuperscript{46,49-51} scrutinized local ELF-MF exposure and indicated crucial effects.

The key idea of this research is to obtain a logical and proper relation between LSELF-MF and its effects on EEG rhythms for NF therapy purposes. This clinically improved NF is a combination of traditional NF and LSELF-MF to achieve a method based on EEG signal rhythms in the case of local sinusoidal ELF effectiveness. Implementation of this idea can be called Neuro-LSELF-MF or LSELF-MF-NF.\textsuperscript{52,53} If the Neuro-LSELF-MF leads to desired results, more efficiency is expected in biological control. It seems that by emphasizing LSELF-MF on EEG rhythms, a novel active and passive NF, based on ELF-MF, can be designed and explored.

### Motivation

NF is a method to affect and manage the brain. Protocols, some with improvements of the NF system, increase attention.\textsuperscript{5,54,55} Scientists showed that increment in sensory motor (SMR) or beta rhythms in healthy subjects increases perceptual sensitivity, and decreases commission errors, on the Connor’s Continuous Performance Test (CPT). Afterward they found that increasing SMR enhances general attention, and 16- to 20-Hz training enhances arousal.\textsuperscript{54} Vernon et al\textsuperscript{4,8} indicated that SMR or beta increment, and theta and high beta decrement, are related to improved attention in healthy subjects, and also showed the same protocol in many studies correlated with attention changes. Research shows\textsuperscript{4,5,8,54,55} that enhancing beta (15-18 Hz), while simultaneously inhibiting theta (4-7 Hz) and high beta (22-30 Hz), at the central regions of the head, improved attention after 10 sessions. As these studies confirmed, in traditional NF, some EEG bands are inhibited while others are enhanced simultaneously at the specified region of the head. These EEG rhythms are correlated with mental activities, as described in Table 1. On the other hand, there are crucial effects of ELF-MF on brain EEG rhythms and related mental activity. Local exposure confines effects more than in whole head exposure.\textsuperscript{46,48} The question is whether LSELF-MF during NF may reduce, but not eliminate, the subject’s role. This may lead to fewer treatment sessions, as well as achieve more NF goals and desired changes. Thus, using LSELF-MF with NF can be implemented and examined.

### Materials and Methods

#### Sample Volume Estimation

Sample volume should be determined before each experiment. In most studies investigating ELF-MF on EEG\textsuperscript{26,36,43,44,46,48,56,57} the number of subjects varies around 10. For NF studies, the number of samples are approximately 10 to 20.\textsuperscript{*} Because we used both ELF exposure and NF training in the experiment group, and only NF training in the sham group, there was an imbalance. In sham, the number of samples can be lower. However, 24 subjects participated for NF attention training.

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\*References 2, 4, 5, 8, 16-18, 20, 21, 23, 54, 55, 58-65.
Sample volume estimation may be the same. As a first step, it is necessary to use sample volume determination in the experiment, based on error types and targets. If a test is used for reviewing differences and error types, and \( \alpha \) and \( \beta \) are considered, then sample volume can be achieved by

\[
n = \frac{(Z_\alpha + Z_\beta) \times (SD_1 + SD_2)}{(\mu_1 + \mu_2)^2}
\]

where SD is the standard deviation of each experiment and \( \mu \) is the mean. This equation is used when the \( t \) test is for comparison of 2 groups and \( \alpha \) and \( \beta \) are considered. If \( \alpha \) is 0.05 then \( Z_\alpha = 1.96 \). \( \beta \) is 20\% and power test is 80\% (\( Z_\beta = 0.84 \)). If we consider expected variations in theta to beta ratio of pilot study, then \( n \) is calculated approximately 8. So according to sample volume estimation, literature, and study goals, 8 are sufficient for the sham group and the experimental group, separately. Based on previous studies, 16 subjects are required for the exposed group and 8 for the sham group.

**Subjects**

Twenty-four healthy subjects (6 females and 18 males) aged between 20 and 28 years (with the mean age of 23.50 ± 2.06 years), in good physical and mental health (no woman attended during women's menstruation period to avoid the interference of the hormonal fluctuations of the menstrual cycle), participated in the study, and were informed about the ELF experiment. Exclusion criteria were checked by biological examination and a health questionnaire as follows: psychiatric diagnosis, diabetes, central nervous system disorders, epilepsy, alcohol intake, drug intake, smoking, and cerebral metallic implant. None had previously taken part in studies involving MF or had surgery. All were asked to refrain from smoking, or drinking coffee and tea, 24 hours before the experiment. Subjects were recruited through advertisements at the Bioelectrical Lab of the Biomedical Engineering Department, and the ethics committee approved the protocol. All were led to believe that they would be exposed to MF during NF training, but just one group (experiment) was really exposed. Subjects of the exposed group were unaware of exposure times. The main experimenter was unaware of the type of exposure (exposed or sham). Sixteen attended the exposed (experiment) and 8 the sham.

**Experimental Setup**

MF requires a signal generator\(^{66,67}\) to provide current for the coils. The generator produced an output signal: ON and OFF. Coil characteristics were measured by an EDC-1630 digital LCR meter, EQ model (\( L = 63.75 \pm 0.125 \) mH). This signal generator produces sinusoidal currents, but its main characteristic is pauses during current generation. In other words, it generates pauses (current cut off) of 1 to 9 seconds, in addition to current generation with frequencies less than 100 Hz. It has 10 internal memories, which save the desired signal after regulation. Frequency, pulse intensity, duration, wave shape of pulse, time exposure, and the ON–OFF time can be regulated, and saved, the first time it is performed. The MF system consisted of a circular coil.\(^{46,48}\)

The NF device (FlexComp Infinity, Thought Technology Ltd, Model SA7550, Montreal-Quest, Canada) has 2 channels for EEG recording. The multimedia biofeedback software (BioGraphINFINITY, Thought Technology Ltd) is the user interface guide of this system. A gold electrode, as an active EEG electrode (EEG-Z Thought Technology Ltd, Model SA9305, Z5417), with 2 ear clips for reference and the earth are used.

Tesla meter (Triaxial ELF magnetic field meter, TES-1394, US Patent No. Des. 446,135) at 1.2 cm below the Plexiglas ring at the axis showed the intensity of ELF-MF as 360 µT\(_{\text{rms}}\). Since MF is not uniform, this tesla meter is based on the rms of ELF-MF in 3 axis directions using 3 internal coils. The skull, and the layers beneath it, mean there is 1.2 cm between the stimulated and target points. Signal generator settings were such that exposure intensity was 360 µT at the stimulated point. We set the coil on the skull, and then measured the desired intensity as rms LSELF-MF.

**The Neuro-LSELF-MF Approach**

In an interesting study, Shafiei et al\(^{46,49,50}\) exposed the head to LSELF-MF at 45 Hz, and magnetic field intensity of 360 µT, for 5 minutes. In that study, the duty cycle (DS) of local sinusoidal ELF exposure was 40\%. If we assume \( T_{\text{ON}} \) is the exposure time (2 seconds ON) of LSELF-MF and \( T_{\text{OFF}} \) (3 seconds OFF) is the nonexposed time, then DS can be defined as

\[
DS = \frac{T_{\text{ON}}}{T_{\text{OFF}} + T_{\text{ON}}}
\]

Subjects were exposed to 45 Hz LSELF-MF. Shafiei et al\(^{49,50}\) showed that in 3 seconds of nonexposed time, EEG increased in beta and decreased in theta at Cz. Some research shows\(^{4,5,54}\) that NF training to enhance beta (15-18 Hz), while simultaneously inhibiting theta (4-7 Hz) and high beta (22-30 Hz), at the Cz region results in increased attention level after 10 sessions. In these studies, the theta to beta ratio is a reverse criterion for attention level, which is verified by CPT. This means that increased attention results in the theta to beta ratio decrease. The question is whether of LSELF-MF during NF training causes more decrease in the theta to beta ratio (accelerates the training rate increment). Electrode placement, attention and the training of NF are the same in both groups. The only difference is that the exposed group receives LSELF-MF, according to the protocol of Shafiei et al\(^{50}\) (DS = 40\%).

In the exposed times (4 minutes totally) subject’s did not receive NF. Therefore, in the exposed group, NF feedback time is less than the sham group and it is exactly 6 minutes. If both groups’ results are equal (the significance of theta to beta decrement), then a second question is raised. Does the
The key idea of this study is that LSELF-MF (45 Hz at Cz region) affects EEG rhythms to increase attention by changing theta and beta.

**The Neuro-LSELF-MF Procedure**

**Procedure.** Participants had either active or sham treatment, but not both. They attended the experiment on every third day from 8:30 to noon. Before the first, and after the 10th session, they completed a computerized questionnaire, verified by Sina Psychiatric Institute CREE test related to creation, CPT, Alternative and Divided related to attention assessment and EQ test related to emotional intelligence. This information was a qualified index to compare EEG rhythms. Some other parameters were determined PRE- and POST-NF. The subjects completed the general form, consisting of 5 questions, rated on an 11-point scale from 0 (minimum satisfaction with attention changes) to 10 (maximum satisfaction with attention changes). Table 2 describes the Neuro-LSELF-MF procedure in each session for the 2 groups. For the sham group, NF lasts for 10 minutes but for the experiment group, because of the Neuro-LSELF-MF protocol, it actually lasts for 6 minutes.

**Neurofeedback Training Protocol.** The NF training protocol is based on attention increase. Both groups attended NF training; however, only the experiment group was exposed. An active electrode and the coil were located on the head of all the subjects. The coil’s position was under the flexible band (Figure 1). An elastic band, glued to the sides of the scalp, holds both the coil and the gold active electrodes, placed on Cz. The impedance was kept less than 2 kohm (measurement abilities of FlexComp Infinity NF system). The 10/20 International System was used, and a reference electrode placed on the left ear, grounded to the right ear (Figure 1).

The feedback consisted of a 3 Boat Race Video Game (Figure 2). The EEG frequency range was divided into: delta 0.5-4 Hz; theta 4-7 Hz; alpha 8-13 Hz; SMR 13-15 Hz; beta 15-18 Hz; high beta 22-30 Hz; gamma 30-45 Hz. With enhanced attention beta increases and theta and high beta decrease. On the screen used for NF training (Figure 2) the middle boat is related to beta, the upper to theta and the lower to high beta. Subjects were asked to drive the middle boat in a 3 boat race. If the subject increases beta and decreases theta and high beta, higher and lower than the defined level, the middle boat is the winner. The subject imagined himself or herself as the middle boat (proportional to beta) to win the race. When the subject obeys 3 conditions, the desired variation (theta to beta) decreases. It is aimed to increase attention, based on the theta to beta ratio.

At the first, second, and third sessions, the 60-40-40 training algorithm was used. If beta is 60% higher than its defined level, and theta and high beta are 40% lower, the middle boat moves. The levels of these 3 bands are defined before the race. This is done at the first session by PRE recording when relaxed, and at the others by using the mean of the previous session. The time of all recording is a second. The training system for the fourth, fifth, and sixth sessions is 70-30-30, and for the 7th until the 10th is 80-20-20. All subjects were studying for their bachelor’s, master’s and PhD degrees in engineering.

**The Neuro-LSELF-MF Implementation**

To produce the Neuro-LSELF-MF NF system, we presented a new configuration, which combines advances in NF, electronics, and magnetic stimulation. The block diagram of the Neuro-LSELF-MF system is shown at Figure 3. The implemented system is shown in Figure 4. An active electrode and coil are located on the head (Figures 1 and 4). Each subject underwent up to 10 minutes of NF, but the feedback actually lasted for 6 minutes, and they received 4 minutes of LSELF-MF. Because of unawareness of exposure times, subjects’ attempts continued. In the sham group only the coil was on the head with no exposure. MF causes noise, which did not occur in the sham group (Table 2).
There are 2 categories of EEG noise. The first may appear in both groups; blinks, electrode placement, head movement, breathing, and electrical line noise (f = 50 Hz). Table 1 describes artifact rhythms that can be removed. The NF system has the ability to filter these types of noise. When the frequency of noise appears, and its amplitude exceeds normal range (signal-to-noise ratio or SNR), it is eliminated. At these times, there is no feedback to the subject. A second kind of noise results from MF during LSELF exposure. When MF is radiated, according to the Faraday induction law, it affects the conductor in the environment, and also an active electrode placed on Cz, which induces electrical current. This MF noise (in the exposed group) changes the EEG. Exposure is unavoidable, so these periods of EEG should not be used for feedback. As shown in Figures 1 and 4, to detect LSELF-MF noise, an aluminum wire is placed around the coil to detect these signals. This wire is connected between the earth and the aluminum shield. To observe the generated pulses this wire is connected to one of the input channels of the EEG NF device (Figure 4). All previous studies used offline, but we used an online method for the local ELF-MF effects on mental activities. The first channel is connected to an active electrode and the second to the wire (Figures 3 and 4). The biofeedback software of the NF device could not be used because of the goals of this study. Both channels of EEG are sent to LabVIEW software (National Instruments; Austin, TX, 2010), which is simultaneously linked to MATLAB (R2012a, Ver. 7.17.0.739) under Windows 7. The first and second images of Figure 5 are recorded signals. Both channels sampled at a rate of 256 Hz (256 samples per second). Two buffers (data collector) are used in LabVIEW. First, there is a 32-sample buffer for the second channel (exposure signal which is indicated as second image in Figure 5). The noise of LSELF, that obscures the underlying processes of EEG investigation and feedback, was eliminated. Therefore, if the energy of these 32 samples exceeds the defined value, there is an exposure. The zero signals to remove noise are shown as the third image of Figure 5. If the EEG is not disturbed by the noise of MF, then the second channel can be used for NF training. In nonexposed time, the signal is by direct transmission. When LSELF-MF affects the brain, or any noise (such as movement) affects the EEG, the threshold is exceeding the normal value. If 32 samples pass 4 times, and the second channel remains under threshold, there is no exposure. At this point, 1 second of the EEG signal (256 samples) is in the 256-sample as a second buffer. This signal is used for NF training. Because of windowing of a signal that causes changes in its spectrum and frequency specification, and to develop nonzero values at frequencies other than its real spectrum, the 256-sample Hanning windows are used to multiply the EEGs as shown in Figure 5. The last image in Figure 5 is the main signal for NF training. As this figure shows, during MF, this image is zero and therefore there is no training. When there is no exposure, 1-second windowed EEG can be used for NF training. The delay in this system varies between 32 samples (0.25 seconds) and 256 samples (1 second), which is acceptable in the NF system. All these signals can be saved in the computer. The first image of Figure 5 indicates channel 1, and the second channel 2. In order to remove LSELF-MF exposure times (removing noise from an active electrode), the signal that is indicated as the third image of Figure 5 is produced by LabVIEW linked to MATLAB. The fourth image of Figure 5 is the Hanning windowed EEG, whose artifacts are removed and used for NF training as an online method. The LabVIEW is also used to play the 3 boats screen as shown in Figure 2. All these signals are saved by LabVIEW for more off-line investigations.

Statistical Analysis

After training and recording, the EEG signals of the groups were analyzed holistic. Each NF attendance (Table 2) consisted of 3 statuses, PRE, DURING, and POST. In the DURING status of the exposed group, the nonexposed EEG Hanning windowed segments were selected and analyzed. In the sham group total windowed signals were used. Frequency analysis of the EEG was carried out, using Fast Fourier transform (FFT), to estimate the power spectrum. After averaging a power spectrum of these segments, and obtaining a mean power spectrum in each status of all the subjects, and along all the 10 attendance sessions, the contribution of theta and beta and their ratio were extracted. Statistical analysis is used to find the most discriminative EEG rhythms, in PRE-, DURING and POST-NF, to distinguish subjects exposed to LSELF-MF from those who were not. Theta to beta ratio for each subject was normalized, related to PRE status of each session, using IBM SPSS Statistics version 21 software. An alpha level of .05 was used for all tests. A comparison of the exposure and sham groups was carried out separately. The Kolmogorov-Smirnov test showed that some EEG rhythms were not normally distributed, so Wilcoxon signed rank test across the statuses of PRE, DURING, and POST were adopted. Mann-Whitney U test was used to compare the 2 groups' theta to beta ratio, as well as
their report of symptoms, EQ, CREE, and POMS parameters, and self-assessment questionnaires. CPT and Alternative and Divided attention tests are not discussed in this article. These results are described using mean and standard error (mean ± SE). Also, repeated-measures analysis is used to investigate the effectiveness of the Neuro-LSELF in changing the theta to beta ratio.

Comparisons showed no significant difference between the groups at pretesting for age, CREE, POMS, and attention tests. The mean age for the exposed group is (23/93 ± 0/55) and for sham (23/87 ± 0/58) years.

**Results**

Comparisons of PRE versus DURING, DURING versus POST, and POST versus PRE in each of the 2 groups are presented next.
The ratios of the mean amplitude for the training frequency, relative to the inhibitory and excitatory frequencies (theta to beta ratio) for each of the 2 groups across the 3 statuses are shown in Figures 6 and 7. As Figure 6 shows, the ratio of theta to beta, from the exposed and sham groups, shows significant results in DURING compared with both PRE and POST, but more decrease occurred in DURING in the experiment group. As Figure 6 shows, the theta to beta ratio of the both groups decreases DURING NF training in comparison with PRE and POST. Also, the theta to beta ratio decreases in POST compared with PRE in the experiment group.

In the within experiment group comparison of PRE versus DURING; DURING versus POST; and POST versus PRE, the significance 2-tailed $P$ values converge to zero, and PRE, DURING, and POST are significantly different from each other ($P < .001$).

In the sham group, the significance level of PRE versus DURING is .013, the significance level of DURING versus POST is .023, and the significance level of POST versus PRE is .535. By comparing the 3 statuses of the 2 groups, the hypothesis that the ELF-MF may result in persistent effects is highlighted. This is because the PRE versus POST in the sham group is different from that in the experiment group, which needs more investigation.

In the sham group, the theta to beta ratio of PRE is significantly different from DURING ($P = .013$). Also, the theta to beta ratio of POST is significantly more than DURING ($P = .023$), but there is no significant change between the PRE and POST ($P = .535$).

As Figure 4 shows, the 10/20 International System of electrode placement is used and the actual placement has a common reference electrode placed at the left ear lobe and is grounded to the right ear lobe using ear clips. An active electrode placed on Cz and coil is fixed on it. An aluminum shielded wire is above the coil to detect the exposure signals and therefore exposure times. EEG recording device is shown as an upper box and ELF exposure system is shown as a lower box. The NF system monitor and operator monitor are placed in front and beside of subject as above.

The difference is because of NF.

As the results of Figures 6 and 7 show, the theta to beta ratio in DURING of each group is meaningfully different from their PRE and POST states. This means that both methods of NF training at DURING result in theta to beta ratio decrement, but more so in Neuro-LSELF-MF. Unlike what we observe in POST and PRE of the sham group, the reduction in the theta to beta ratio in DURING is significant in both groups. Through a comparison of the 3 statuses, the more significant effect of the new approach is confirmed. The ratios of the mean amplitude for the training frequency, relative to theta to beta for each of the 3 states, collapsed across the 10 training sessions, are shown in Figure 8. Variations of the exposed group are less than those of the sham group. Thus there is a more effective method to change the theta to beta ratio. Also, in the experiment group, there is a smooth decrement after the fourth session. In contrast, there is no uniform decrement in the theta to beta ratio of the sham group. Nevertheless, more variations are observed in the sham group. It seems that after the seventh session, both groups converge to steady variations. Total comparison between the 3 groups, across the 3 states of all 10 sessions, is also shown in Figure 8. The mean ratios of the PRE comparison show no significance in theta to beta, especially in the sham group. In contrast, the mean ratios of PRE and POST versus DURING, show significance in the theta to beta difference. The 2 applied methods can affect EEG rhythms, but Neuro-LSELF is more effective. As shown in this figure, the trend and variation between the 2 methods also seem different. The theta to beta ratio showed no difference between the mean of theta to beta and that of POST, but both do show a trend toward decrease in theta to beta ratios in the DURING state, especially after the fourth session in the exposed group, and after the seventh session in the sham group. Friedman test was used to investigate PRE, DURING, and POST, between the sham and exposed groups, that will be published in future studies.

**Discussion**

In this study, we examined a novel method of psychological therapy. It seems that it could investigate the LSELF-MF special effects on human brain activities. Many researchers confirm weak MF effects on mental tasks. Research has
confirmed the reinforcement of living cells as inhibitory, excitatory, or no-effect, in the presence of ELF-MF exposure in some frequencies. This study was motivated by research which showed weak alternating MF on living organisms, and related variations in the ion concentrations within the cells, when the frequency of the applied field is matched with the angular frequency. This phenomenon is called cyclotron or Larmor frequency mechanism, by which biological systems become sensitive to small static and resonating magnetic fields and the existence of a resonating effect on ions. De Ninno et al\textsuperscript{70} described that the Larmor frequency of most of the involved ions, lies between 10 and 50 Hz. The interaction of spin-correlated radical pairs with magnetic fields confirms that Larmor frequency coupling is due to magnetic effects. For example, this study states that the Larmor frequency of Fe\textsuperscript{2+} and Cu\textsuperscript{2+} are 17 Hz and 15 Hz, respectively. The Larmor precession provides a mechanism by which biological systems become sensitive to small static and resonating magnetic fields.

Figure 5. The recorded signals of exposed group from top to bottom: (1) EEG recorded signal in the exposed group and 45 Hz LSELF-MF with duty cycle (DS) = 40%. NF feedback time is less than sham group and really is 6 minutes, the total exposure time is 4 minutes which is shown as the above image; (2) exposure signal, which is indicated as second image, LSELF-MF signals recorded using a wire twisted around the coil. This signal contains a brief series of 2-second segments of 45-Hz sinusoidal exposure and 3-second segments with no exposure; (3) threshold method to remove induction effect; (4) the last image is the main signal for NF training. As this image shows, during magnetic field exposure, this image is zero and therefore there is no feedback. In exposed times, the EEG is windowed by a Hanning filter for a second.
linear relation between ELF-MF exposure characteristics and effects on brain based on EEG rhythms investigations. It seems that by using local, in comparison to whole head, exposure, we get effects that are more limited to the exposure points and fewer side effects. Also, more linearity may be observed. It is hoped that meaningful changes on EEG signal will be implemented in future work.

LSELF-MF-NF, in contrast to traditional NF, showed decreased ratios of theta to beta. PRE and POST failed to show significant changes in the 2 methods of NF. Furthermore, the DURING state exhibited effective changes, under LSELF-MF, in attention and self-assessments. However, all participants showed improved accuracy, but more so in the exposed group. Clinical assessment of outcome was conducted after the completion of the 10 NF sessions. In comparison with before the first attendance session, subjective observations showed an improvement. There is a good correlation between observed clinical improvement and CREE, EQ self-assessment questionnaires (12% and 18%, respectively, compared with before the first session), and the changes in QEEG (more than 26%). These parameters of CPT and A&D tests will be discussed in future.

Cook et al. confirmed durability up to 7 minutes after 15 minutes of exposure, but did not observe any meaningful effect 10 minutes after exposure. However, PRE and POST were recorded 2 minutes before and after NF. This shows that the persistence of 45-Hz SLELF-MF is less than 2 minutes. Long-term effects or sustained benefits, therefore, could not be evaluated from this study. The results show a more effective and novel method in decreasing the session number and the rate of training.

Since theta to beta ratios were obtained from nonexposed segments, ELF-MF persistency is at least 3 seconds (3 seconds OFF). However, because of the investigation of the nonexposed segments, and the equal conditions of both groups, the effect is related to LSELF-MF persistency effects on mental activity. If we determine brain local magnetic response to ELF frequency variation, based on the relation of EEG rhythms and behavior, or electrophysiological and neurological changes, brain control is achieved. An important application is the frequency response of LSELF-MF, in relation to EEG rhythms and mental activity. The use of the effects of LSELF-MF during NF may result in reducing the subject’s role, but not eliminating it. During NF, these effects could be achieved.

Considering active and passive NF disadvantages, the proposal was to induce, or inhibit, rhythmic activity in the cortex by the weak effects of a brief series of LSELF-MF on EEG and related mental activity. For example, MF exposure can change alpha, theta, or beta. These changes should be carried out in a way that increases or decreases mental activity. For instance, a decrease in theta to beta ratio is relative to improved attention, and alpha increase to enhanced cognitive performance.
mental tasks, with fewer side effects, was examined. For more clinical treatments, more studies are needed.

**Conclusion**

To develop traditional NF to modified NF, which we called Neuro-LSELF-MF, we pursued the oriented method to affect brain activity.

Using ELF at Cz to facilitate NF beta increase, as an online method, reduces the subjects’ role but does not eliminate it.

LSELF-MF can be done during NF with more efficiency and less training time. LSELF-MF affects EEG rhythms, such that increased attention via theta or beta, or both, occurred. Beta increase at Cz is relevant to attention increment in humans. Observation of changes in this frequency during NF can warn the operator or physician about attention level.

As implemented, in comparison with TMS or rTMS, the application of such a system is very simple. Better implementation could be designed and investigated in future studies.

Finally, more studies are needed to examine ELF-MF long-term effects, and brain frequency response to LSELF-MF. The significance of the ability of ELF-MF to excite human cerebral cortex, correlating with clinical and behavioral treatment, is unclear, so the methodology of this article can be used to evaluate specific effects. More information on beta, theta, and other EEG rhythms will be published in the future.

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