HUMAN EXPOSURE TO A 60 HZ, 1800 MICROTESLA MAGNETIC FIELD: A NEURO-BEHAVIORAL STUDY

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Abstract

The effects of time-varying magnetic fields (MF) on humans have been actively investigated for the past three decades. One important un-answered question that scientists continue to investigate is the potential for MF exposure to have acute effects on human biology. Different strategies have been used to tackle this question using different physiological, neurophysiological and behavioral indicators. For example, researchers investigating electroencephalography (EEG) have reported that Extremely Low Frequency (ELF, > 300 Hz) MF can increase the resting occipital alpha rhythm [1, 2]. Interestingly, other studies have demonstrated that human motor behavior can be modulated by ELF MF exposure, reporting that such an exposure can reduce anteroposterior standing balance oscillations [3, 4] or decrease physiological tremor intensity [5]. However, the main limitation in this domain remains the difficulty to reproduce these results. This may be due to the large variety of experimental approaches employed. Therefore, the aim of this project is to investigate the effects of a 60 Hz, 1800 µT MF exposure on physiological (i.e. heart rate (HR) and peripheral blood perfusion), neurophysiological (brain electrical activity), and behavioral (postural oscillations, voluntary motor functions, and physiological tremor) aspects in human using a single experimental procedure. Though results from this study suggests a subtle reduction of human standing balance with MF exposure, no effect appeared on other investigated parameters, suggesting that one hour of 60 Hz, 1800 µT MF exposure may modulate human involuntary motor control without being detected in brain electrical activity.

Keywords:

60 Hz Magnetic field; humans; tremor; electroencephalography; standing balance; cardiovascular system; voluntary movements

Introduction

Recent studies have been trying to characterize the effects of Extremely Low Frequency (ELF, below 300 Hz) magnetic fields (MF) on human biology and performance. Despite the amount of work that has been conducted in this area, there remains no consensus as to the effects of ELF MF exposure on humans. The main sources of ELF MF in our daily environment are domestic electrical appliances, distribution and transport power-lines, and residential wiring which are producing power-line frequency MF: 50 Hz in Europe and 60 Hz in North America. General public exposure to power-line frequency MF is on average less than 0.01 µT [6]. Although a few controversial epidemiological studies have reported an increased risk of developing childhood leukemia in populations chronically exposed to MF as low as 0.3 – 0.4 µT on average [7], no reliable acute effects of exposure have been reported for this type of MF. For higher intensities; however, recent researchers have suggested that MF exposure can modulate spontaneous electrical activity in the brain, and high level cognitive processes (see [8, 9] for reviews). The general public is occasionally exposed to these MF intensities. For instance when one uses an electric shaver, a hairdryer, or a hair clipper, the MF generated on the surface of these devices can reach 1500–2000 µT [10, 11]. Moreover, workers of electricity companies are often exposed to MF levels above 1000 µT [11, 12] which raises specific questions; for example, is a worker repairing a live power-line at a greater risk of committing an error, creating a work place hazard, than a worker repairing a deactivated power-line? Organizations such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP) or the Institute of Electrical and Electronics Engineers (IEEE) publish recommendations concerning the levels of exposure for the general public and for workers [13, 14]. Basic restrictions of the ICNIRP guidelines have established that current density induced by MF occupational exposure "should be limited to fields that induce current densities less than 10 mA/m^2" [13]. This recommendation includes a security factor of 10. The ICNIRP and the European Union are currently working on the development of new guidelines and directives regulating the exposure to low frequency MF. In the absence of consensus regarding ELF MF exposure effects on living systems, there is a need to replicate and provide further studies to provide support for these new guidelines [15, 16].

The effects of acute exposure to ELF MF have been studied on number of aspects of human physiology, neurophysiology, and behavior. Electroencephalogram or evoked potentials is an example of a parameter within neurophysiology that has received attention among researchers [1, 2, 17-25]. Although most conspicuous results seem to suggest a higher resting EEG in the alpha rhythm after exposure (8-13 Hz), no consensus exists on the direction of these effects [1,2].

Other studies analyzing the interaction between the cardiovascular system and ELF MF have shown that electrophysiological rhythms can be modified at the peripheral level. For example, it has been reported that an exposure to a 60 Hz MF could induce a slowing of the heart rate (HR) which may or may not be associated with changes in HR variability [26-30]. Again, other researchers have not confirm these findings [31-33]. For a better understanding of the mechanisms underlying observed changes in HR, electrophysiological data should be completed by monitoring hemodynamic parameters such as blood flow.

Another strategy researchers have used to study ELF MFs was to focus on macroscopic neurophysiologic indicators such as human motricity. Any modulation of the normal neurophysiological processing should have functional consequences which may be apprehended with the investigation of neuromotor processes. Indeed, a few studies have demonstrated subtle effects of ELF MF on human standing balance and physiological tremor, but not on simple goal directed movements [3-5, 34-36]. Concerning standing balance, it has been reported that normal anteroposterior balance in healthy subjects can be decreased using a specific pulsed MF at 200 µT [3]. Regarding human segmental micro movements (i.e. fine finger tracking performance and physiological tremor characteristics), though Legros et al. did not report any effect of a 50 Hz, 1000 µT MF on index finger tracking performance, their results suggested that MF exposure facilitated postural tremor decrease in a relaxing situation (tremor recorded at the tip of the index finger, [5]). Interestingly, Cook et al. who demonstrated an effect of a pulsed 200 µT MF on EEG alpha activity also underlined the link between resting posterior alpha activity and the state of relaxed wakefulness [1].

These reported results are subtle, often not replicated, and sometimes contradictory. The difficulties in characterizing the effects of ELF MF on humans can be attributed to the discrepancies in the experimental procedures between studies. The heterogeneity in intensity, shape, and frequency of the MF used, as well as the differences in exposure durations across the studies are introducing confounds which makes the interpretation of these results difficult. Furthermore, results differ with continuous versus intermittent exposure, and depending on whether participant testing is performed during or after the exposure.

The main objective of this study is to evaluate subtle effects of a 60 Hz, 1800 µT MF exposure on human physiology, neurophysiology, and motor functions in a single procedure (EEG, ECG, peripheral blood perfusion, rhythmic voluntary hand movements, physiological tremor, and standing balance). This intensity has been chosen in reference to the ICNIRP basic restriction and to the calculation of Dimbylow in 1998: the ICNIRP basic restrictions of 10 mA/m^2 of induced currents at the level of the central nervous system [13] correspond, according to Dimbylow, to a computed MF value of 1810 μT [37]. Based on results in the literature, we hypothesize that this MF exposure should not affect cardiovascular parameters, increase EEG power in alpha rhythm (especially in the occipital regions); reduce postural oscillations (standing balance); have no effect on the maximum frequency of rapid alternating hand movements; and decrease postural tremor amplitude.

Methods

Subjects

Seventy three participants (age = 28±9) have completed two double blind counterbalanced sessions of testing (real/sham). Each session was given on a separate day and was composed of four sequences of testing (detailed in Figure 1a.). None of the participants have ever experienced an epileptic seizure; have motor limitation; suffer from chronic illness (e.g., diabetes, severe psychiatric, cardiovascular or neurological diseases); or have a cardiac or cerebral pacemaker. They have no history of head, eye or thorax injury involving metal fragments, and they do not wear metal braces on their teeth. Finally, women cannot be pregnant, nor have an intrauterine device.

Apparatus and procedure

A double blind computer driven procedure, controlling for variables, was used such that neither the participant nor the experimenter knew when the real or sham condition occurred (automatic audio directions, visual instructions on a LCD screen; programmed using LabView 8.0, NI Inc., USA). Each session lasted 1 hour and 45 minutes and was composed of four 15 minute blocks of testing spaced by 15 minutes of rest. 1 hour of MF exposure was given from minute 15 to minute 75 (active in the real exposure session, inactive in the sham session). The protocol was approved by the University of Western Ontario Health Sciences Research Ethics Board (# 11956E).

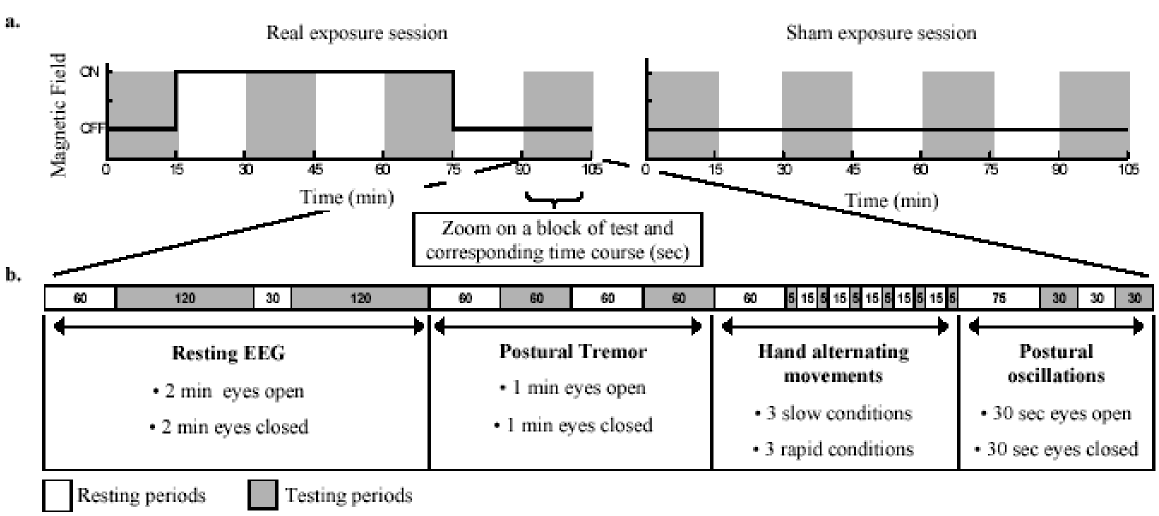


Figure 1: (a.) Time course of the 2 exposure sessions (real and sham). The horizontal black line represents the MF status (OFF when down, ON when up). Note that during the sham exposure session, the MF is never ON. Vertical grey bands represent the four 15-minute blocks of testing. **(b.)** Zoom on the time course of a block of testing (the same for each block). White cells represent resting periods and grey cells represent testing periods (duration is displayed in seconds inside the cells). The table below the time course indicates the tests to which these periods correspond.

For the duration of the experiment, the participant was sitting in an elevated armchair located in the middle of our exposure system (Figure 2), which was composed of 2 octagonal coils, 1.6 meters in diameter each, running parallel to each other 1.2 meters apart. Each coil contained 80 turns of AWG-10 wire mounted with a nonconductive cooling/heating tubing system. The system was configured to generate a homogenous 60 Hz, 1800 μT MF centered at the level of the head (see Figure 3 for an illustration of the calculated MF distribution).

Figure 2: The elevated armchair installed between the two coils of the exposure system. The head of the subject was located in the homogeneous MF region.

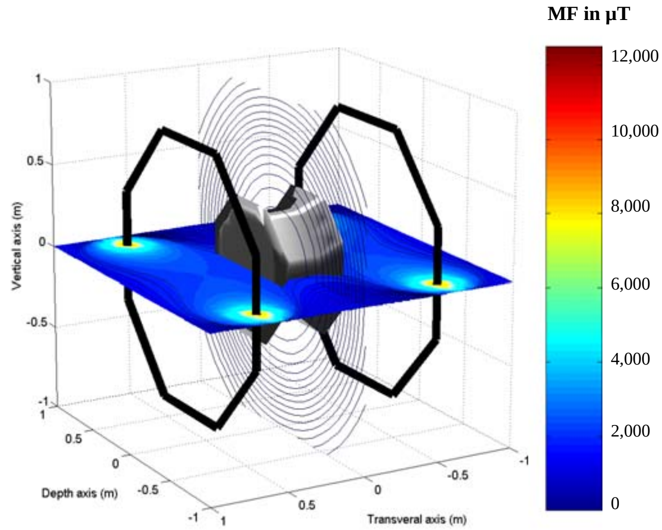


Figure 3: Spatial illustration in 3-D of the MF level (horizontal component) distribution within the exposure system (computed according to the Bio-Savart law). The gray volume in the middle of the 2 coils (thick black octagons) represents the 1800 µT ± 5% homogeneity region. Each circular line in the sagital plan represent 5% intervals. Actual MF measurements confirmed the computed values (Sentron, Sentron AG, Switzerland).

The room temperature was kept at 23 °C. From the beginning of the testing session, both the subject and experimenter wore ear plugs to make it impossible to detect the subtle noise produced by the coils when the field is generated. During the testing time course the MF generation and the data acquisition was entirely automated and computer driven (Labview 8.0 and Data acquisition card NI PCI-6289, National Instrument Inc., USA). Electroencephalogram, ECG, and blood flow data were acquired continuously through the experiment, but specific periods, detailed later, were extracted for analysis. Automatic audio and visual directions were given to the participant throughout the duration of the experiment via a LCD screen and speakers.

Each block of testing followed the same time course (Figure 1b). The participant first relaxed for 1 minute. Then he was requested to stay at rest and relax with the eyes open for the 2 minutes of EEG eyes open data collection. The participant then had 30 seconds of inactivity before being requested to close the eyes for the 2 minutes eyes closed EEG acquisition. EEG and ECG data were sampled at 512 Hz using an ambulatory Siesta ECG-EEG system (Compumedics Inc., USA) with a 32 electrode cap (single reference montage). Fifty seconds of EEG (free of eye movements) and of ECG time series, were exported to Matlab for analysis (Matlab 7.0, The MatWorks. Inc, USA). The MF was turned off during the second minute of both EEG eyes open and eyes closed recordings to keep 1 minute of acquired data free from MF artifact. Amplitudes in the theta (3-7 Hz), alpha (8-13 Hz), and beta (14-35 Hz) ranges were computed for the frontal (F3, F4), central (C3, C4), parietal (P3, P4), and occipital (O1, O2) electrodes using Fast Fourier Transforms (FFT). All listed parameters were used for data analyses. HR was computed as the number of R-waves per minutes. Peripheral blood perfusion was collected, at the tip of the non dominant index finger (PF 5010 Laser Doppler Perfusion Monitoring unit and probe 407-1, Perimed, Sweden), simultaneously to the EEG eyes closed condition.

After EEG acquisitions, the participant was asked to open the eyes and relax for 1 minute before completing the physiological tremor acquisition. Tremor tests consisted of 1 minute of postural tremor recording with eyes open and then 1 minute of postural tremor with eyes closed (1 minute of rest in between). Tremor was recorded at the tip of the dominant index finger using a Class II laser diode pointing down (Micro laser sensor LM10, series ARN11, Matsushita Electronic Work, Ltd., Osaka, Japan, Figure 4a.) located 8 cm above the piece of white cardboard fixed on the finger nail. This system enabled vertical displacement recording at 1000 Hz with a 5 µm resolution (after filtering out high frequencies). A feedback line representing the index finger position was displayed on the LCD screen facing the subject. In this test, the participant had to point the index finger (in extension at the level of the metacarpophalangeal joint) to keep the feedback line centered in the middle of the screen ("zero position") for 1 minute. After another 1 minute rest, the participant performed the same test with his/her eyes closed (no visual feedback). Tremor time series were exported to Matlab where fifteen specific tremor characteristics were computed in the time and frequency domains [35, 38, 39].

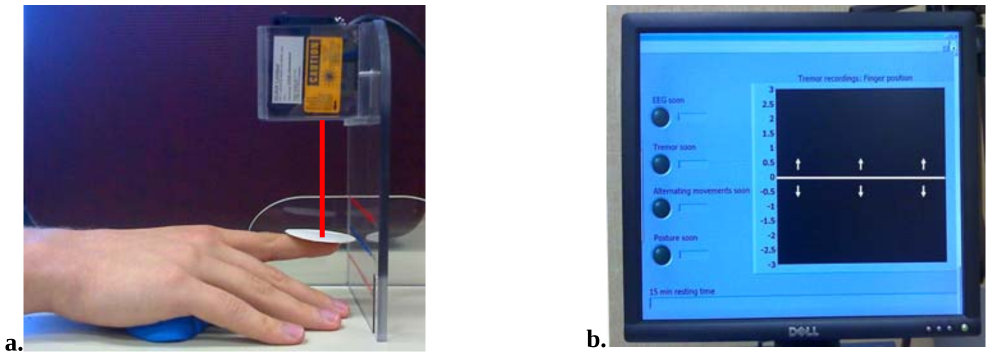


Figure 4: Recording of postural tremor with visual feedback (on the LCD screen) with the laser sensor. **(a.)** The beam of the laser is pointing down in the middle of the white cardboard. **(b.)** The feedback line is given with a LCD screen. The feedback line moves up and down in synchrony with finger tip movements, as shown by the vertical arrows. In the tremor eyes open condition, the subject is requested to keep the feedback line aligned with the “zero” position.

The participant had 1 minute of rest after the end of the laser test and was then asked to extend his arms in front of him, parallel to the floor, and to bend them to a 90° angle at the elbow, with hands open, palms facing each other (Figure 5). From this starting position, he had to execute alternating rotating hand movements at the wrist axis: (1) with the right hand, natural rhythm; (2) with the left hand, natural rhythm; (3) with both hands, natural rhythm; (4) with the right hand, high frequency; (5) with the left hand, high frequency; and (6) both hands, high frequency. For the high frequency conditions, the participant was asked to rotate his hands “as fast and as far as possible". Recordings lasted 5 seconds each, with a 15 seconds resting period between every condition. Data were acquired using a Liberty 3-D tracking system (Polhemus Inc., USA), with 2 transducers fixed like watches on the dorsal side of the wrists and allowing recording of movement kinematics with 6 degrees of freedom at 200 Hz (3 dimensions and 3 angles of rotation, accuracy of 0.03 RMS for X, Y, Z positions and 0.15° RMS for orientations). The Liberty system is an electromagnetic tracking system and therefore, during MF exposure session, the exposure had to be turned off during each 5 sec recording periods so as not to affect data. Data were preprocessed with Matlab and exported to specifically designed analysis software (Neuro 2.1, Doco Microsystèmes, Canada) for performance quantification (eleven indexes computed [40]).

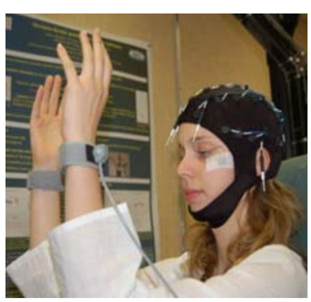


Figure 5: Starting position for the hand alternating rhythmic task. The transducers are fixed on the wrists.

Finally, the armchair with the subject was pulled backwards, opening the access to a force-plate underneath the chair. The participant had 1 minute and 15 seconds to step onto it and take the standardized posture (standardized socks, feet parallel, 1 cm apart) and to relax before his postural sway was recorded for 30 seconds eyes open, and then 30 seconds eyes closed, with a 30 second resting period in between. The 3-D force plate, used in previous works ([3, 4, 41], OR6-7-1000, AMTI, Watertown MA), was mounted on the floor in the centre of the MF exposure system and recorded the force and momentum applied by the subject's feet at a sampling rate of 1000 Hz. These measurements were converted to centre of pressure (COP) values, i.e. the perpendicular projection of the centre of gravity through the force plate. Postural sway is represented as the change in COP over time (i.e. its trajectory). Ten specific postural sway characteristics were computed on COP trajectories [3, 42].

As detailed in Figure 1b., this block of testing is given 4 times per session: 15 minutes before the beginning of the exposure period, 15 minutes after the beginning of the MF exposure, 45 minutes after the beginning of the MF exposure, and 15 minutes after the end of the MF exposure.

The skin temperature was monitored throughout the entire experiment. After each block, the participant answered the Field Status Questionnaire (FSQ, [26]) to assess his ability to detect the presence of the field. The ambient geomagnetic static field was measured in the chamber as 47.6 µT (± 0.5%) using a fluxgate magnetometer (Fluxgate FGM 3D2, Walker Scientific Inc, USA). The ambient ELF MF was recorded as 0.139 µT (± 0.5%), also measured with a fluxgate magnetometer (Mag-03, Bartington Instruments, England). Additional background vibration was recorded with a seismic accelerometer (Model 393A03, PCB Piezotronics, USA) between the coils. When the MF was turned off, the background vibration was 1.70×10^{-2} m/s^2, compared to 1.74×10^{-2} m/s^2 (± 4.9×10^{-5} m/s^2) when the MF was on. This difference is well below reported values for human linear velocity and acceleration thresholds [43] and thus we were satisfied that the participant was not exposed to vibrations as a result of the field generation.

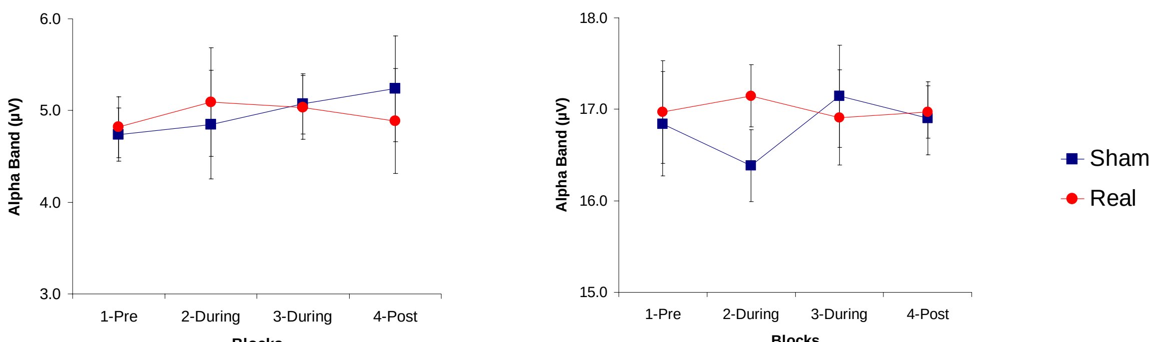
Statistics

Repeated measures ANOVAs were conducted on each characteristic and were computed for each test using SPSS (SPSS 16.0, USA). Probability values were corrected for lack of sphericity using the Greenhouse-Geisser epsilon. Bonferroni pair wise comparisons were conducted when main or interaction effects were found. For concision, results for only one representative characteristic for each of the above mentioned tests is reported here. The complete results are in the process of being published in several articles.

Results

EEG

A repeated measure ANOVA 2 (Sham/Real) x 4 (Blocks) x 2 (Eyes) has been conducted on the amplitude in the theta, alpha, and beta frequency bands for electrodes F3, F4, C3, C4, P3, P4, O1, and O2. Only results in the alpha frequency band are presented here (Figure 6). Results from the electrode O2 have been selected as representative of overall EEG results concerning the alpha rhythm. As expected, higher EEG alpha activity was found with eyes closed ($F = 102.08$, $p < .001$, $eta^2 = .68$) than with yes open. No significant Sham/Real ($F = .20$, $p > .05$, $eta^2 < .01$), block ($F = 1.16$, $p > .05$, $eta^2 = .02$), or interaction effects were found.



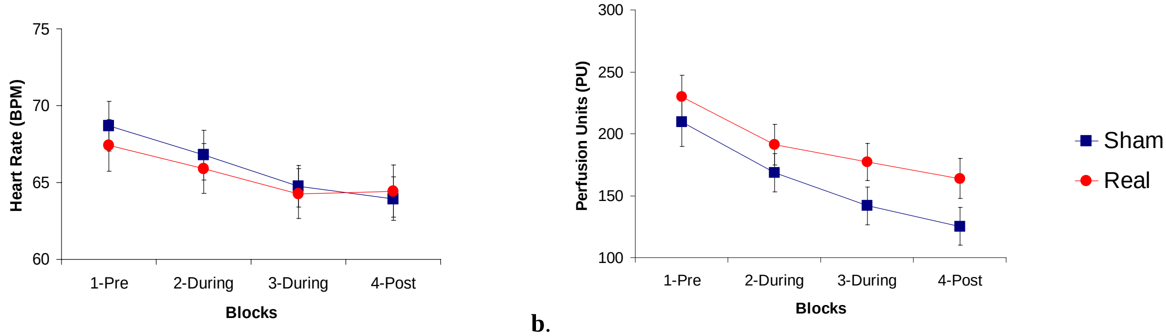
a. **b.**

Figure 6: Alpha rhythm amplitude recorded from the O2 electrode in the eyes open **(a.)** and eyes closed **(b.)** conditions for each block of the sham and real sessions. Error bars represent one standard error of the mean (SEM).

HR and peripheral blood perfusion

Repeated measure ANOVAs 2 (Sham/Real) x 4 (Blocks) have been conducted on HR and peripheral blood perfusion data. A significant main block effect was observed for HR ($F = 17.56$, $p < 0.001$, $eta^2 = .31$). Bonferroni adjusted pairewise comparisons showed block 1-Pre was significantly different from blocks 2-During, 3-During, and 4-Post ($p < 0.05$), and that block 2-During was different from blocks 3-During, and 4-Post ($p < 0.05$). No significant session ($F = 0.30$, $p > 0.05$, $eta^2 < 0.01$) or interaction effects were observed (Figure 7a.).

A significant main block effect was found for peripheral blood perfusion ($F = 19.10$, $p < 0.001$, $eta^2 = 0.31$). Bonferroni adjusted pair wise comparisons showed block 1-Pre was significantly different from block 2-During, 3-During, and 4-Post ($p < 0.05$), and that block 2-During was different from block 3-During and 4-Post ($p < 0.05$). No significant session ($F = 3.99$, $p > 0.05$, $eta^2 = 0.09$) or interaction effect were observed (Figure 7b.).



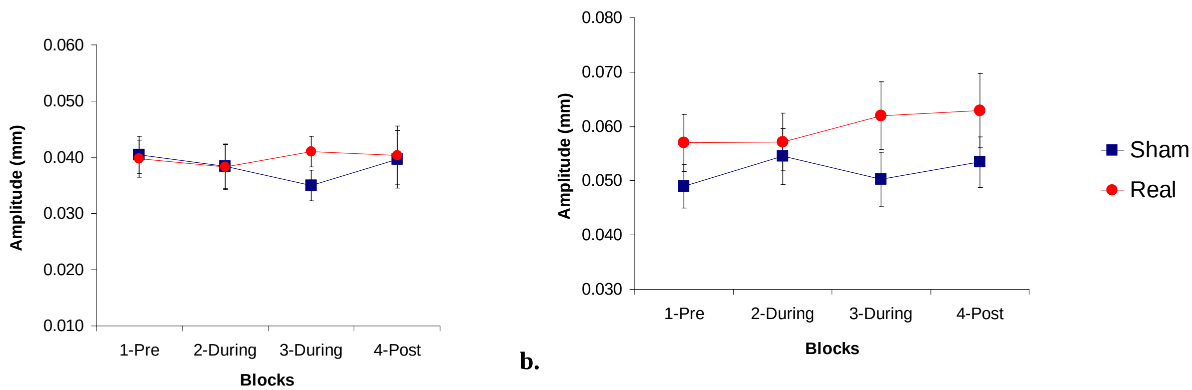
a. b.

Figure 7: **(a.)** HR measured in beat per minute over the four blocks of testing in each experimental session. **(b.)** Mean absolute values of peripheral blood perfusion (measured in Perfusion Units) over the four blocks of testing in each experimental session. Error bars represent one SEM.

Physiological tremor

A repeated measure ANOVA 2 (Sham/Real) x 4 (Blocks) x 2 (Eyes) has been conducted on each of the fifteen computed tremor characteristics. Only results corresponding to tremor amplitude (i.e. average oscillations size in the 2-20 Hz frequency range) are presented here (Figure 8). Tremor amplitude was found to be higher in the eyes closed than in the eyes open condition ($F = 45.79$, $p < .001$, $eta^2 = .41$). No significant Sham/Real ($F = 2.81$, $p > .05$, $eta^2 = .04$), block ($F = .67$, $P > .05$, $eta^2 <.01$) or interaction effects were found (Figure 8). However, a non significant trend (non significant Real/Sham x Blocks interaction ($F = 1.03$, $p > .05$, $eta2 = .01$)) suggests an increase of tremor amplitude during exposure in the real session when compared to the sham session (Block 3-During, Figure 8a. and b.).

a.

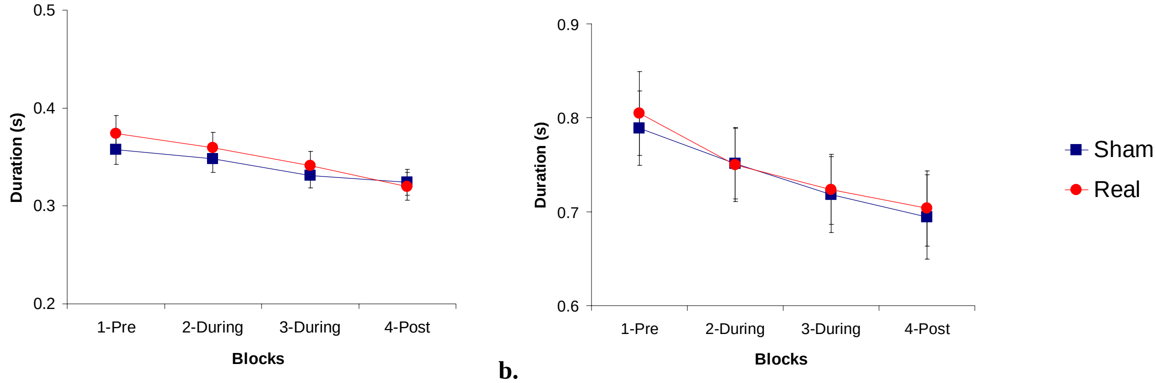


b.

Figure 8: Tremor amplitude for eyes open **(a.)** and eyes closed **(b.)** conditions for each block of the sham and real sessions. Error bars represent one SEM.

Alternating hand movements

A repeated measure ANOVA 2 (Sham/Real) x 4 (Blocks) x 2 (Frequency) has been conducted on each of the eleven computed characteristics. Only results corresponding to alternating hand movement duration (i.e. average time to make a back and forth wrist rotation with the hands) are presented here (Figure 9). As expected, a higher duration was found in the natural frequency than in the high frequency condition ($F = 141.60$, $p < .001$, $eta^2 = .78$). Also, a significant main Block effect ($F = 16.05$, $p < .001$, $eta^2 = .29$) demonstrated a tendency to increase movement frequency over the course of the experiment. A significant Block x Frequency interaction ($F = 4.82$, $p < .05$, $eta^2 = .11$) showed that this increase in frequency over the blocks is stronger for the natural frequency than for the high frequency condition. No other significant effects were found.

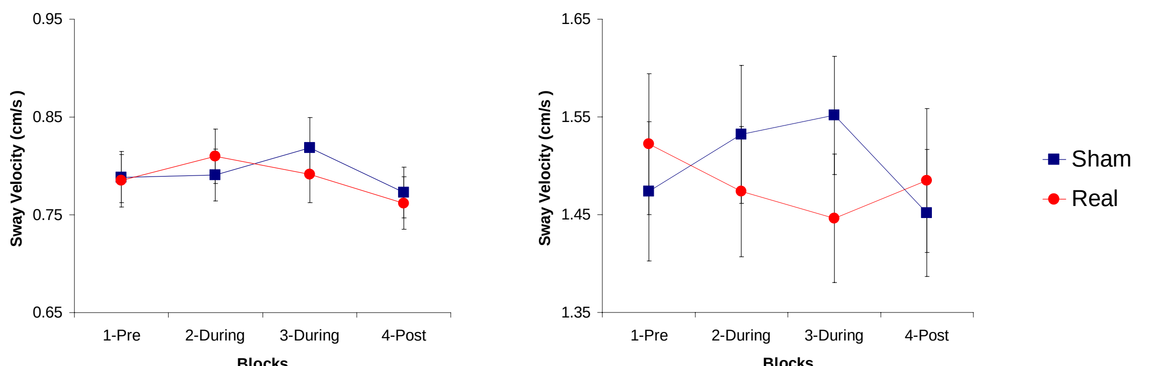


a. **b.**

Figure 9: Average duration of alternating hand movements in the natural **(a.)** and high **(b.)** frequency conditions for each block of the sham and real sessions. Error bars represent one SEM.

Standing balance

A repeated measure ANOVA 2 (Sham/Real) x 4 (Blocks) x 2 (Eyes) has been conducted on each of the ten standing balance computed characteristics. Only results corresponding to sway velocity (i.e. the average velocity of oscillations over a period of recording) are presented here (Figure 10). As expected, a higher sway velocity was found in the eyes closed than in the eyes open condition ($F = 245.17$, $p < .001$, $eta^2 = .788$). No Sham/Real ($F = .044$, $p > .05$, $eta^2 < .01$) or block effect was found ($F = 1.27$, $p > .05$, $eta^2 = .02$). Interestingly, a significant Sham/Real x block x eyes interaction ($F = 3.13$, $p < .05$, $eta^2 = .05$) demonstrated a lower sway velocity while exposed to the MF in the eyes closed condition only (during blocks 2-During and 3-During sway velocity was smaller in the real exposure than in the sham exposure session, illustrated in Figure 10b.).



a. **b.**

Figure 10: Sway velocity in the eyes open **(a.)** and eyes closed **(b.)** conditions for each block of the sham and real sessions. Error bars represent one SEM.

Discussion-Conclusion

EEG alpha activity was not modulated by the 60 Hz, 1800 µT MF exposure. However, studies using different exposure protocols have reported ELF MF effects on EEG alpha rhythms suggesting that EEG modulations may be stimulus specific [1, 2, 18-23, 25, 44]. The difference between protocols indicates that the underlying mechanism of action is associated with the frequency of MF exposure and is not the consequence of the field intensity alone.

The continuous decreases of HR and peripheral blood perfusion within testing sessions are indicative of a relaxing process [45, 46]. No effect of MF exposure was found on HR which supported the results of Graham and Kurokawa [31-33]. The absence of effects of the 60 Hz MF on peripheral blood perfusion confirms our hypothesis and is consistent with the previously works in humans [47], as well as with animal researches conducted in our laboratories. For example, McKay et al., 2009 found no effect of 60 Hz MF at 100, 200 and 500 µT flux densities on peak skeletal blood velocity (unpublished data in rats).

As anticipated, results from the alternating wrist movement were not affected by the MF. This task was presented as a pilot trial to study the potential modulations of voluntary movements caused by ELF MF. However, although this task was designed to diagnose specific neurodegenerative impairments [40], it has shown its sensitivity to the current protocol by demonstrating a spontaneous tendency of individuals to produce faster rhythms over time within an experimental session. It may not be sensitive enough task, however, to pick up a subtle MF effect if it exists.

Our hypothesis supporting a reduction of tremor intensity as a result of MF exposure was not supported. However, an interesting, non significant tendency suggested a small increase in tremor amplitude during exposure, (after 45 minutes of MF on). These results contradict findings from previous studies which suggest a decrease of tremor intensity with MF exposure [5], supporting the aforementioned hypothesis that specific responses occur according to specific stimuli: whereas the current study used a 1800 µT at 60 Hz, our previous study that used a 50 Hz, 1000 µT MF exposure [5].

The most significant results attained from this study shows that standing balance oscillations produced during MF exposure were slower in comparison to standing balance oscillations produced in the sham exposure. This result is in accordance with our hypotheses and supports results from previous studies conducted by our group, which demonstrated a reduction of anteroposterieur natural oscillations with a specific pulsed 200 µT MF exposure [3]. Normal standing balance is mainly controlled by three feedback loops: the visual loop, the proprioceptive loop, and the vestibular loop. Because the effect of the MF exposure was present only in the eyes closed condition, i.e. when the visual loop is not processing, we hypothesize that the ELF MF may act on either the vestibular or proprioceptive functions. Further research needs to be conducted in this area to further study this effect.

Several complementary analyses regarding the tests discussed in this paper are currently in process of being completed to investigate whether the presentation of session order (real first or sham first) is a confound, as suggested by Cook et al. regarding EEG [20]. The complete results regarding the EEG, the cardiovascular, the physiological tremor, and standing balance sections of this study are in the process of being published in several different articles. The main strengths of this project are its large sample size, its positive control results (eyes open vs. closed effects for EEG tremor and standing balance; natural vs. high frequency for rhythmic hand movements; relaxing effect for HR and peripheral blood perfusion), and its wild range of investigated function and processes in the same procedure. In summary, the results from the current study suggest that one hour of 60 Hz, 1800 µT MF exposure does not seem to modulate neurophysiological processes involved EEG, physiological tremor, or voluntary rhythmic movement generation. However, as already reported by our group [3], results show that MF exposure may decrease standing balance oscillations. Since this effect appears only during the eyes closed condition, it suggests that the exposure may act on proprioceptive and/or vestibular functions. These findings tend to show that an acute global exposure of an intensity corresponding to the ICNIRP basic restrictions level may be detected in humans. Further investigations should be conducted to reliably establish a threshold at which systematic effects can be described, and to provide a solid basis to characterize the involved mechanisms.

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