EXPOSURE TO A 60 HZ 3000 ΜT MAGNETIC FIELD HAS AN EFFECT ON RESTING BRAIN BLOOD FLOW: A FUNCTIONAL MAGNETIC RESONANCE IMAGING STUDY

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Exposure to a 60 Hz 3000 µT magnetic field has an effect on resting brain blood flow: A functional magnetic resonance imaging study

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The effects of a 60 minute 60 Hz 3000 µT MF exposure on resting brain blood flow were investigated using arterial spin labeling, a functional magnetic resonance imaging technique. Fourteen subjects participated in this study; seven were exposed to the MF, which they were unable to detect. Significant changes were found in resting brain blood flow in the exposed and sham group. These changes were consistent with previous EEG studies of MF exposure. Additional subjects are required to further explore the results and to determine the duration of MF effects.

Long Abstract

INTRODUCTION

The Institute of Electrical and Electronics Engineers (IEEE) has recommended a maximum level for human Magnetic Field (MF) exposure of 2700 µT at 60 Hz, the power line frequency in North America [1]. Studies using electroencephalography (EEG) have observed modulation of human neurophysiology by extremely low frequency (ELF) MF [2]. Using functional magnetic resonance imaging (fMRI) to investigate the effects of a 30 minute 60 Hz, 1800 mT MF exposure on brain activation during a tapping task, found more activation was required to complete the task in the exposed condition as compared to sham [3]. This work was extended to observe the effects of a 60-minute 60 Hz, 3000 mT MF on brain activation during: 1) rest; 2) a tapping task; and 3) a mental rotation task [4,5]. The results of our analysis of the tapping task data and mental rotation task have been presented elsewhere. They demonstrated significant differences in activation, as inferred by fMRI (BOLD), in very specific regions associated with neuroprocessing during these tasks when subjects exposed to the MF were compared to subjects in the sham condition [4,5]. From these results we hypothesize that resting brain blood flow will be modulated by exposure to a 60-minute, 60 Hz, 3000 μT MF. This work, to the best of our knowledge, is the first study to investigate the effects of an ELF MF exposure on resting brain blood flow with an adapted fMRI technique called Arterial Spin Labeling (ASL).

MATERIALS AND METHODS

Fourteen, healthy right-handed subjects (age = 25.3 ± 5.7; 7 females, 7 males) were recruited from the university community. Participants were randomly assigned to 2 groups: a real exposure group (7 subjects) and a sham exposure group (7 subjects). Informed written consent was obtained from each subject before a 2-hour session in a 3.0 Tesla research MRI (Siemens/Verio Erlangen, Germany). Each session began with the acquisition of a structural anatomical image for resting brain blood flow fMRI data registration. Subjects then completed three pre-exposure tasks including resting blood flow (finger-tapping and mental rotations are the two other tasks and they are reported elsewhere [4,5]), where subjects were asked to close their eyes, relax and let their minds wander. The resting blood flow data were acquired with ASL, a non-invasive and direct method of measuring blood flow through the manipulation of the magnetic properties of arterial blood [6]. Subjects then underwent a 60-minute rest period within the MRI, during which the participant was either exposed to a sham condition (7 subjects) or a 60 Hz, 3000 μT sinusoidal MF (7 subjects) created by the Z gradient coil programmed to create the MF exposure (maximal at cortical level). During this rest period subjects were asked to remain awake and motionless. An audio clip mimicking the sound of the MF was played for the sham exposure group during this 60-minute rest period to ensure a coherence of the auditory environment for both groups.

Following the 60-minute rest period subjects completed the same three pre-exposure tasks, including the resting task during which the ASL data were collected.

Upon completion of the study, participants completed a Field Status Questionnaire (FSQ) [7] to determine if the subjects were aware of their exposure condition. A chi-squared test was used to treat the results of this questionnaire.

The ASL data was analyzed with Statistical Parametric Mapping software (SPM8, Wellcome Department of Imaging Neuroscience, University College, London, UK, http://www.fil.ion.ucl.ac.uk/spm). Images for each subject were realigned, reoriented, coregistered, normalized to the T1-template image and smoothed (8x8x8 mm kernel). Contrast images from a first level analysis were used in a random effects group analysis. Areas of significant activation were identified at the voxel level for $p < 0.05$, applying a minimum cluster extent size of five contiguous voxels. To determine statistically significant differences in resting blood flow between the sham and exposure groups, a comparison was conducted with a two-sample t-test of contrast images from the seven subjects included in both groups. Areas with significantly different blood flow were identified using a cluster extent threshold (5 voxels), $p < 0.001$ corrected for multiple comparisons.

RESULTS

Subjects were unable to determine their MF exposure condition as demonstrated by the results of the chi-squared test applied to the Field Status Questionnaire (FSQ: $\chi 2 < 0.001$, $p < 0.05$; level of certainty = 2.6 out of 5). The two-sample t-test of the contrast images revealed significantly higher resting blood flow in the real exposure group (post-exposure) in the right posterior lobe (Figure 1.) and left temporal lobe; whereas significantly higher resting blood flow was found for the sham exposure group (post-exposure) in the left corpus callosum, left occipital (cuneus) lobe and left precuneus (see Table 1.).

CONCLUSIONS

Our previous results demonstrated that a 3000 μT MF at 60 Hz could modulate brain activation in specific regions involved in the performance of both a finger-tapping task and a mental rotation task [4,5]. The aim of the present work was to investigate brain activation patterns at rest before and after the MF exposure. According to our results one hour of ELF MF exposure (here, a 60 minute, 60 Hz, 3000 μT MF) can modulate brain resting blood flow as measured using ASL. These results also further demonstrate that fMRI is a valuable tool, which can be used to investigate the effects of ELF MF exposure in humans. The differential increase in resting brain blood flow observed in the two groups suggests that MF exposure has a selective effect on specific regions involved in resting blood flow. Although no previous work has used fMRI to observe the effects of MF exposure on resting blood flow, a study by Cook et al. [2] using EEG to study the resting state network found that exposure to a 15 minute pulsed MF (0-500 Hz) did have an effect on the resting state network, characterized by an increase in alpha activity (8-13 Hz) in the occipital and parietal regions. Additional sessions are required to further explore the results of this pilot study and to determine the duration of MF exposure effect. Future work may include hybrid EEG/fMRI studies determining if resting blood flow is disturbed in the same regions as EEG activity.

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Figure 1.
Increased activation in the right occipital lobe of the real exposure group.

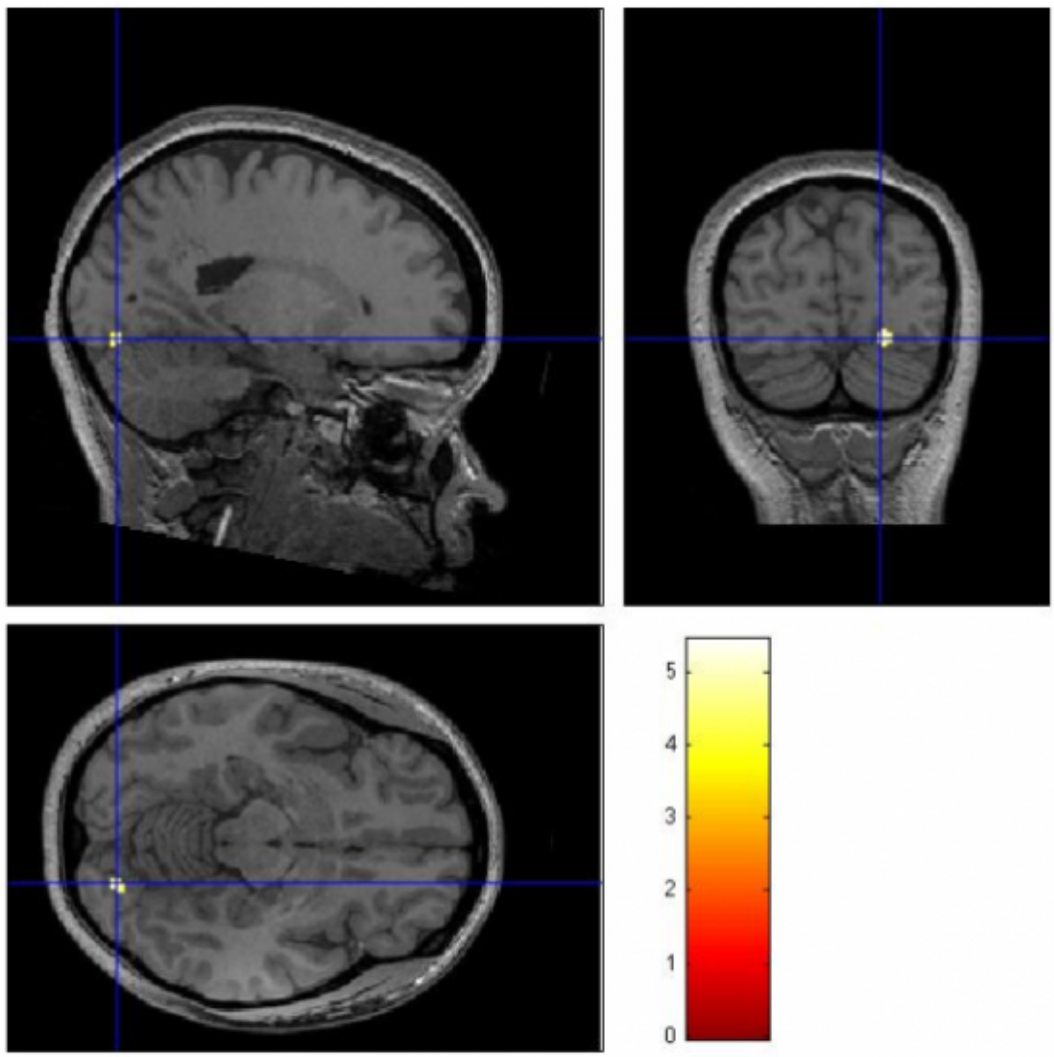

Table 1.
Activation sites for resting blood flow after magnetic field exposure.

Regions	Voxel Z	Pcorrected	x,y,z
Right posterior lobe*	3.60	0.000	18,-78,-12
Left temporal lobe*	3.66	0.000	-42,-44,-18
Left occipital lobe	4.02	0.000	-14,-84, 16
Left precuneus	3.25	0.001	-12,-62, 30
Left corpus callosum	3.35	0.000	-16,-44,-12

* indicates real exposure group