A fMRI Pilot Study on Power-Line Magnetic Fields and Brain Activation

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Abstract— **10 subjects will be tested in our 1.5 T MRI scanner (Siemens Avanto, Erlangen, Germany) at rest, and while performing Stroop and finger tapping tasks, by July, 2007. They will complete a 1.5 hr session: 30 minutes of testing, 30 minutes of exposure (active or sham) and another 30 minutes of testing. ASL (Arterial spin labeling) images will be collected at rest, and BOLD (blood oxygenation level dependent) images for finger tapping and Stroop tasks. The exposure (active or sham) will consist of a 1800 µT, 60 Hz magnetic field (MF) generated at the level of the head by the MR system itself. Five subjects will complete a sham–active session and five a sham–sham session. Subject awareness of the exposure will be tested using the Field Status Questionnaire (FSQ). BOLD and ASL images will be processed using dedicated software (Brain Voyager, Brain Innovation, The Netherlands, http://www.brainvoyager.com). Activation maps will be compared using within-subjects analysis including a between subjects factor (group).To date, two subjects have performed a finger tapping task before and after 15 minutes of exposure. Activation maps show less motor cortex activation following exposure, but no statistical comparison has been performed yet. Preliminary Results will be presented at the meeting.**

Keywords— **ELF, magnetic field, brain activation, fMRI**

I. Introduction

Domestic electric appliances, distribution and transport power-lines, and residential wiring are among the numerous sources of extremely low frequency (ELF, < 300 Hz) magnetic fields (MF) present in our modern-day environment. General public exposure to power-line frequency MF (50/60 Hz) is on average less than 0.01 µT [1]. Recent results suggest that MF exposure can modulate spontaneous electrical activity in the brain, involuntary motor control, and high-level cognitive processes [2, 3]. The general public is occasionally exposed to these MF intensities. For instance, when using an electric shaver, a hairdryer, or a hair clipper; the MF generated on the surface of these devices can reach 1500–2000 µT [4, 5]. Moreover, workers of electricity companies are often exposed to MF levels above 1000 µT [5, 6]. 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 [7, 8]. 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 10mA/m2" [7], which corresponds to a computed MF value of 1800 µT at 60 Hz according to specific models [9].

The objective of this pilot study is to investigate the effects of an acute exposure to a 60 Hz MF, with an intensity corresponding to the highest induced current values recommended by international safety guidelines [7], on human brain activation, using an innovative method in this field: functional Magnetic Resonance Imaging (fMRI). More specifically we will investigate the effects of an exposure to a 1800 µT, 60 Hz MF on human brain activation during selected cognitive and motor tasks.

A. 60 Hz MF - Resting brain activation

EEG-correlated fMRI has been used to identify BOLD (blood oxygenation level dependent) signal changes associated with spontaneous oscillations in the alpha rhythm (8-12 Hz) during relaxed wakefulness [10]. This electrical potential is believed to arise from the oscillation of postsynaptic potentials in the neocortex [11]. Functionally, alpha has been interpreted as an idling rhythm that diminishes when eyes are opened or during mental activity. Interestingly, a negative correlation has been found between the two signals: BOLD activation was lower when alpha oscillations were stronger. Since a MF induced increase of EEG power in the alpha band has been reported in the literature [12-15], we hypothesize that MF exposure will decrease the BOLD activation signal.

B. Stroop test - 60 MF – Brain activation

The Stroop test [16] is a selective attention task routinely used for many years in normal and patient cognitive studies. It exploits the conflict between well learned or automatic behaviours and a decision rule that requires this behaviour to be inhibited as a cognitive interference, and therefore provides information relative to the attentional performance. The areas of the brain activated during the completion of a Stroop test have been investigated and it has been shown that this test specifically activates the anterior cingulate, the insula, the premotor and inferior frontal regions [17]. The reaction time for an incongruent stimulus was reported to be 224 ms longer than for a congruent stimulus, and the error rate was 0.8 on average for six incongruent presented stimuli. We hypothesize a decrease of the BOLD activation signal after MF exposure.

C. Finger tapping - 60 MF – Brain activation

A simple finger tapping task is known to activate the controlateral Supplementary Motor Area (SMA) and the controlateral Primary Motor Area (SM1). Moreover, it has been demonstrated that the level of activation of these areas was positively correlated with the frequency and the amplitude of the tapping task ([18, 19], see [20] for a review). Interestingly, it has been shown that ELF MF exposure decreases the amplitude of spontaneous motor activity of healthy subjects while studying human postural oscillations [21] and postural tremor [22, 23]. Based on these observations and on the above mentioned results suggesting a decrease of brain electrical activity with MF exposure [12-15], we hypothesize that for an index finger tapping task performed at natural frequency, the MF exposure will induce a decrease of the spontaneous tapping frequency associated with a decrease of BOLD activation.

II. Method

A. Functional Magnetic Resonance Imaging

Functional Magnetic Resonance Imaging (fMRI) is a fairly recent technique [24, 25] which has sparked a flurry of discoveries in the field of neurosciences [26]. The technique is based on the rapid acquisition of MRI volume image of the brain during the performance of a task and a control condition. The signal detected by fMRI sequences is very sensitive to the local magnetic susceptibility of the brain tissue. It was observed that during functional activation of the brain, the local increase in demand of oxygenated blood sparks a hemodynamic response which quickly brings about an influx of oxygenated blood overwhelming the demands. Since oxygenated blood (oxyhemoglobin or Hb) has diamagnetic properties similar to the rest of brain tissue and deoxygenated blood (deoxyhemoglobin or dHb) has paramagnetic properties which reduce local MR signal intensity, the large increase in capillary and venous blood oxygenation level observed during brain activation can be detected as an increase in MR signal intensity. Software tools allow for the statistical comparison of signal intensities in each image element (voxel) during the rest and task performance period. Voxels showing significantly different signals during the task performance period are said to be activated (significant increase) or de-activated (significant decrease) by the performance of the task.

B. Using the MR scanner to produce an ELF exposure

In order to produce a slowly varying (low frequency) electromagnetic exposure to a user-defined waveform in between MR imaging sessions, one can use the gradient coils of the MR scanner to play the ELF exposure waveform. The Siemens Avanto clinical scanner can produce gradient strengths varying from 0-40 mT/m with slew rates in the order of 200 T/m/ms and 100% duty cycle. This is quite sufficient to produce a continuous 60 Hz exposure. In this pilot work the Z gradient coil is used to produce a 60 Hz sinusoidal exposure with the brow line of the subject's head positioned at the isocenter, which generated the highest intensity of time varying fields in the cortical gray matter areas at the top of the head (1800 µT).

C. Subjects

10 males and females between the ages of 18 and 55 will be recruited to participate in this pilot study. None of the participants will have ever experienced an epileptic seizure, will not have motor limitations, nor suffer from a chronic illness (e.g. diabetes, severe psychiatric disorders, cardiovascular, or neurological diseases), nor will they have a cardiac or cerebral pacemaker. They will have no history of head, eye or thorax injury involving metal fragments, and they will not have metal dental appliances. Finally, women cannot be pregnant, nor have an intrauterine device. They will also be given the field status questionnaire (FSQ) [27] after each experimental condition to confirm that they are naïve of the field status.

D. Procedure

Subjects are currently tested in the 1.5T MRI scanner (Siemens Avanto, Erlangen, Germany). They have to complete two different sessions given on two separate days including or not one hour of 60 Hz MF exposure generated by the MR system itself (real or sham). These sessions are given in a counterbalanced order, following a blind procedure. Each session last two hours: 30 minutes of test, one hour of exposure (real or sham) and 30 minutes of testing. Arterial spin labelling (ASL) signal might be used instead of BOLD signal at rest [28] (will be determined after further data acquisition), and then BOLD signal will be recorded in finger tapping task and during the completion of a Stroop test.

E. Data processing and analyses

BOLD images are processed using dedicated software (Brain Voyager, Brain Innovation, The Netherlands). Activation maps for each condition (e.g.: finger tapping) is transformed into a common brain model (e.g.: Talairach space) and compared using within-subjects analysis to determine the effects of the MF.

III. Preliminary results

At this point, we have completed six subjects in a preliminary trial. The procedure consists of acquiring brain images of the subjects while performing three different tasks (finger tapping at 1 and 4 Hz, and counting backward before and after a period of 45 min of exposure to a 60 Hz MF at 1800 μT).For the first five subjects studied, the exposure was not provided by the scanner. The six subjects had been exposed by the gradient coil of the scanner and the BOLD signal was recorded in an index finger tapping task before and after a period of 15 minutes of exposure. Activation maps are presented in Fig.1. The activation maps have been adjusted to the same False Discovery Rate (FDR) and a correction algorithm applied to the individual pixel comparisons. While no statistical comparison between the two sets has been performed (at this point, n=1 and there has been no sham condition to account for the repeated testing), it appears as though there is less activation in the motor cortex following 60 Hz exposure.

IV. Conclusive remarks

Until now, to detect brain activation patterns, we have used a method based on BOLD contrast. This method is adapted to provide reliable information on the neuroanatomy underlying transient sensorimotor and cognitive functions, i.e. occurring on a short period of time. Recent results suggest that a perfusion contrast is more suitable for studying relatively long term effects on cerebral blood flow both at rest and during activation: the arterial spin labeling (ASL) method [28-30].

Tapping activation pre-exposure **Tapping activation post-exposure**

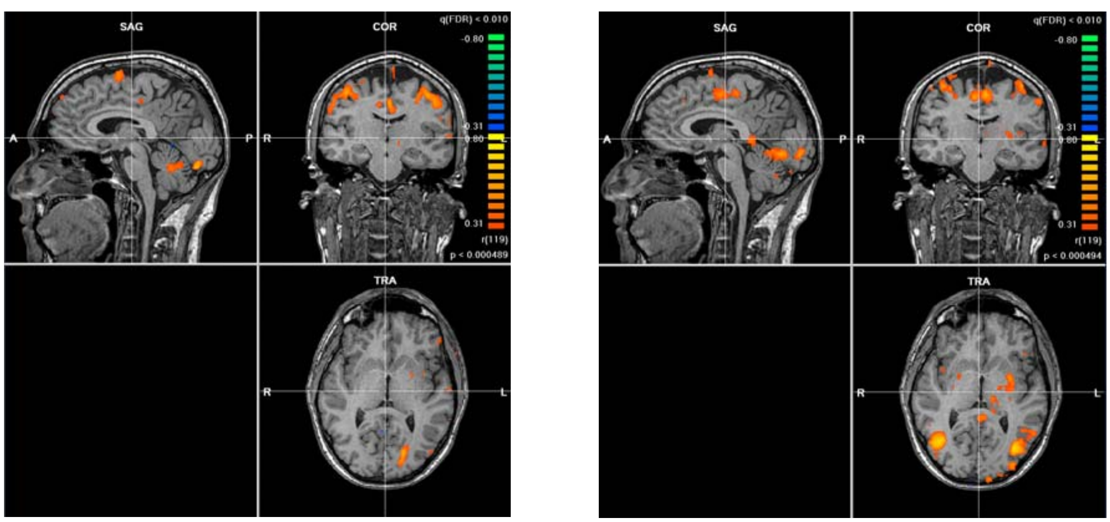

Fig.1: 3D reconstructions (view centered on the center of the brain) of linear correlation maps produced with Brain Voyager showing activation associated with finger tapping. Slices in the sagital, coronal and axial plans are shown (clockwise from top left).

With ASL, water in arterial blood is magnetically labeled and cerebral blood flow is determined by the change in the MR signal as the labeled water flows into brain tissue. The two major differences between these two methods are 1) BOLD measures relative changes in activation, whereas ASL directly measures cerebral blood flow; 2) BOLD is primarily restricted to phasic activation patterns, whereas ASL does not have this limitation. Therefore, if one wants to compare brain activation before and after a period of one hour, ASL would be more appropriate. We will decide after completing our pilot trials whether or not the ASL method should be used to compare brain activation at rest before and after the hour of MF exposure.

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