Functional Brain Activation During Finger Tapping Is Modulated After A 60 Hz, 3000 μT Magnetic Field Exposure

Alexandre Legros[1,2*], Jodi E. Miller[1,2], Julien Modolo[1,2], Michael Corbacio[1,2], John R. Robertson[1,2], Daniel Goulet[3], Jacques Lambrozo[4], Michel Plante[3], Martine Souques[4], Frank S. Prato[1,2], Alex W. Thomas[1,2]

[1]Bioelectromagnetics, Imaging Program,Lawson Health Research Institute, London, ON, Canada,[2]Department of Medical Biophysics, University of Western Ontario, London, ON, Canada, [3]Hydro-Québec, Montréal, QC, Canada,[4]Service des Études Médicales, EDF, Paris, France

[*]Corresponding author e-mail: alegros@lawsonimaging.ca

INTRODUCTION

Recent studies suggest that human exposure to Extremely Low Frequency (below 300Hz, ELF) Magnetic Fields (MF) may interact with brain rhythms and motor functions. Electroencephalographic (EEG) rhythms and evoked potentials have been shown to be modulated by ELF exposure in healthy subjects [1,2]. Spontaneous motor activity such as standing balance [3] and physiological tremor [4] also seem responsive to time-varying MF. Based on these observations, we recently proposed, in a pilot study using functional Magnetic Resonance Imaging (fMRI) as a tool, to investigate if brain activation patterns induced by a finger tapping task can be modulated by a 30 minute exposure to a 60 Hz, 1800 μT MF [5]. Indeed, it is well documented that a simple finger tapping task activates the contralateral Supplementary Motor Area (SMA) and the contralateral Primary Motor Cortex (M1). The corresponding level of activation is correlated with the frequency and the amplitude of the task [6]. Since our pilot work has been successful in showing a higher task-induced activation with MF exposure in specific brain regions (including the somatosensory cortex (S1)) [5], the aim here was to extend our results to a longer exposure period and a higher field intensity (1 hour of 60 Hz MF at 3000 μT). Based on our pilot results, we expect a higher task-induced activation associated with MF exposure.

MATERIALS AND METHODS

Healthy right-handed volunteers (ongoing study, n=10 to date, mean age=23.9; range=19-35) were tested in a pseudo-double blind experiment (the experimenter discovered the exposure condition only after direct interaction with the subject is finished). The experiment consisted of collecting functional brain images while participants tapped their thumb and index fingers together at a spontaneous rhythm, before and after a 1 hour resting period. During this resting period, 6 participants were exposed to a 60 Hz MF at 3000 μT (at the cortical level – exposed group) and the remaining 4 were not (sham group). The exposure was produced by the Z gradient coil of the scanner, specially programmed by one of our physicists. BOLD images were acquired with a 3 Tesla MRI system (Siemens Verio, Erlangen Germany).

RESULTS

Data were analyzed with Brain Voyager QX 2.0.8.1480 (Brain Innovation, The Netherlands). Functional and anatomical images were co-registered and normalized into a Talairach space. As

expected, the tapping task induced activation of the contralateral M1, SMA and S1, as well as the anterior lobe of the ipsilateral cerebellum (M1, SMA and S1 activation are illustrated in Figure 1, left). For each experimental group, Post- minus Pre-exposure comparison images were produced. Interestingly, though no differences in activation between Post- and Pre-exposure conditions were found for either group in the premotor cortex and the cerebellum, the level of activation appeared to be higher Post-exposure but not Post-sham in S1 (Figure 1, Middle and Right respectively). S1 was defined as a Region Of Interest (ROI), and corresponding Beta weight values were exported into SPSS for further analysis. A within subjects ANOVA with a between subjects factor was then performed. No main effect was found (group: $F=0.29$, $p>0.05$; Pre/Post: $F=1.28$, $p>0.05$). However, a significant interaction confirmed that Post-exposure was higher than Post-sham activation as compared to their respective Pre-exposure levels ($F=7.13$, $p<0.05$).

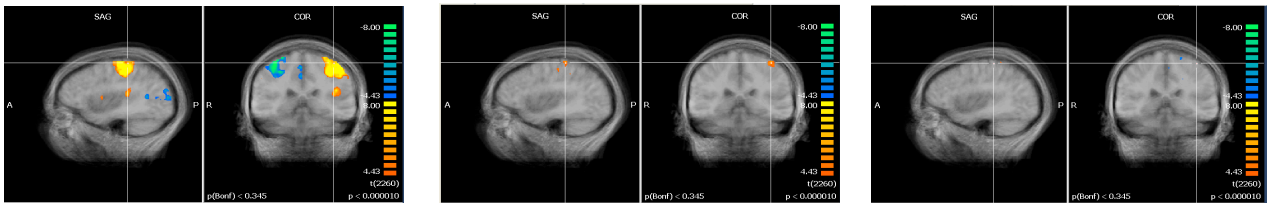

Figure 1: Left – Tapping: Pre-exposure group image (n=10). Middle – Tapping: Post- minus Pre-exposure condition (exposed, n=6). Right – Tapping: Post- minus Pre-exposure condition (sham, n=4).

CONCLUSIONS

As expected, the rhythmic thumb vs. index finger opposition task activated M1, SMA, S1 and the cerebellum. After 1 hour of rest, the same level of activation is required in these areas to produce the same task, which supports the reliability of the test. However, if the subjects are exposed to a 60 Hz 3000 μT MF during the rest period, this is not true anymore in S1, which shows a higher level of activation as compared to sham. This is coherent with the results of our previous work [5] and suggests that the MF interacts more at the perceptive level (S1) than atthe motor level. This is an ongoing study and final results will be presented at the workshop.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Jean Théberge for programming the 60 Hz into the scanner's gradient coil allowing its use as an active MF exposure device. This research is funded by Hydro-Québec (Canada), EDF-RTE (France), CIHR (Canada) and LHRI.

REFERENCES

[1] C.M. Cook, A.W. Thomas, and F.S. Prato. Resting EEG is affected by exposure to a pulsed ELF magnetic field, Bioelectromagnetics. Vol. 25(3): 196-203, Apr 2004.

[2] S. Ghione, C.D. Seppia, L. Mezzasalma, and L. Bonfiglio. Effects of 50 Hz electromagnetic fields on electroencephalographic alpha activity, dental pain threshold and cardiovascular parameters in humans, Neurosci Lett. Vol. 382(1-2): 112-117, Jul 2005.

[3] A.W. Thomas, D.J. Drost, and F.S. Prato. Human subjects exposed to a specific pulsed (200 microT) magnetic field: effects on normal standing balance, Neurosci Lett. Vol. 297(2): 121-124, Jan 2001.

[4] A. Legros, P. Gaillot, and A. Beuter. Transient effect of low-intensity magnetic field on human motor control, Med Eng Phys. Vol. 28(8): 827-836, Oct 2006.

[5] A. Legros, J. Weller, J. Robertson, M. Corbacio, S. Dubois, A. Beuter, R.Z. Stodilka, D. Goulet, J. Lambrozo, M. Plante, M. Souques, F.S. Prato, and A.W. Thomas. Is human brain functional activation modulated by a 60 Hz, 1800 μT magnetic field exposure? BIOEM Proceedings, P-120: 439-440, June 2009.

[6] N. Sadato, V. Ibanez, G. Campbell, M.P. Deiber, D. Le Bihan, and M. Hallett. Frequency-dependent changes of

regional cerebral blood flow during finger movements: functional MRI compared to PET, J Cereb Blood Flow Metab. Vol. 17(6): 670-679, Jun 1997.