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Title: Magnetophosphenes perception threshold and EEG response in humans exposed to 20, 50, 60 and 100 Hz MF up to 50,000 μT

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Short Abstract (up to 750 characters): 746 characters

OBJECTIVE: Quantify human magnetophosphene perception and associated electroencephalographic (EEG) response to 20, 50, 60 and 100 Hz magnetic fields (MF) up to 50 mT.
METHODS: Magnetophosphene perception and EEG collected during 55 MF conditions at each frequency.
RESULTS: The magnetophosphene perception threshold is at 15 mT at power frequencies (50/60 Hz) for a global head exposure. Associated EEG alpha activity is decreased above this threshold.
CONCLUSIONS: Results from a first experiment (n=51) at 50 and 60 Hz provide a preliminary estimate of magnetophosphene perception thresholds, and associated EEG changes. Results from a second experiment (n=80) additionally testing exposures at 20 and 100 Hz will be presented at the conference.

Long Abstract (1,500-12,000 characters): 10,074 characters (1356 words)

INTRODUCTION

Guidelines from the International Commission for Non-Ionizing Radiation Protection (ICNIRP) and standards from the Institute of Electrical and Electronics Engineers (IEEE) are providing international recommendations regarding human exposure to Extremely Low Frequency Magnetic Fields (ELF MF, below 300 Hz) [1, 2]. For power-frequency exposures, these recommendations are based on the extrapolation of existing experimental data on magnetophosphene perception thresholds, as reported by Lövsund in the early eighties [3]. However, uncertainties persist regarding the threshold for magnetophosphene perception in humans at power-frequency [4, 5]. Indeed, this threshold is reported to be the lowest at 20 Hz (between 5 and 10 mT), and to increase with frequency [6, 7]. In addition, the threshold is only extrapolated at 60 Hz and no experimental data acquired in humans are actually available. The current project is therefore aiming to establish the thresholds for systematic acute, objective and quantifiable responses in humans exposed to ELF MF (including 50 and 60 Hz) of up to 50 mT. The selected outcomes include magnetophosphene perception and associated brain electrical activity as measured by electroencephalography (EEG). Based on the fact that visual perception is associated with a decrease in EEG alpha activity, we hypothesize that magnetophosphene perception will be associated with a decrease in EEG alpha (8-12 Hz) spectral power in the visual/occipital cortex.

MATERIAL AND METHODS

In a first experiment, two groups of healthy volunteers (n = 26 at 60 Hz and n = 25 at 50 Hz) were each tested in two localized exposure conditions (eyeball and occipital cortex using a small coil) and in one global head exposure condition. Each frequency group is scanned with 11 magnetic flux density conditions (from 0 to 50 mT_{rms}, 5 mT increments) lasting five seconds each. Flux density conditions are each repeated 5 times and separated with five seconds without exposure. A computer program (developed in LabView, National Instruments, USA) randomly assigns the order of presentation of the MF flux density conditions. During this protocol, participants are sitting eyes closed in a dark room, and are asked to report magnetophosphene perception by button-press, while their occipital EEG activity (O2, O1 and OZ electrodes) is continuously recorded. Each experimental condition starts after 5 minutes of adaptation to darkness. An MRI-compatible EEG system/cap/cable (Neuroscan-Compumedics Inc., Melbourne, Australia) is used, allowing EEG recording during 50 mT MF exposure without saturating EEG amplifiers (the procedure has been tested and validated using EEG phantom recordings and analyses). This protocol is approved by the Health Sciences Research Ethics Board of Western University (HSREB #18882). A second experiment following the exact same procedure in 4 frequency groups (20, 50, 60 and 100 Hz, n=20 in each group) is currently being completed.

RESULTS

The first experiment testing for 50 and 60 Hz exposures is already completed, analyzed and presented here. The data from the second experiment will be presented at the conference. So far, the group results show magnetophosphene perceptions reported by button press both at 50 and 60 Hz (n=25 and 26 respectively) for retinal (Figure 1, left panel) and global (Figure 1, right panel) exposures, for flux densities below 50 mT. Repeated measures ANOVAs with a between-subjects factor testing for MF flux density (11 flux density modalities: 0 to 50 mT) and MF frequency (2 frequency modalities: 50 and 60 Hz) effects were conducted on this first set of data.

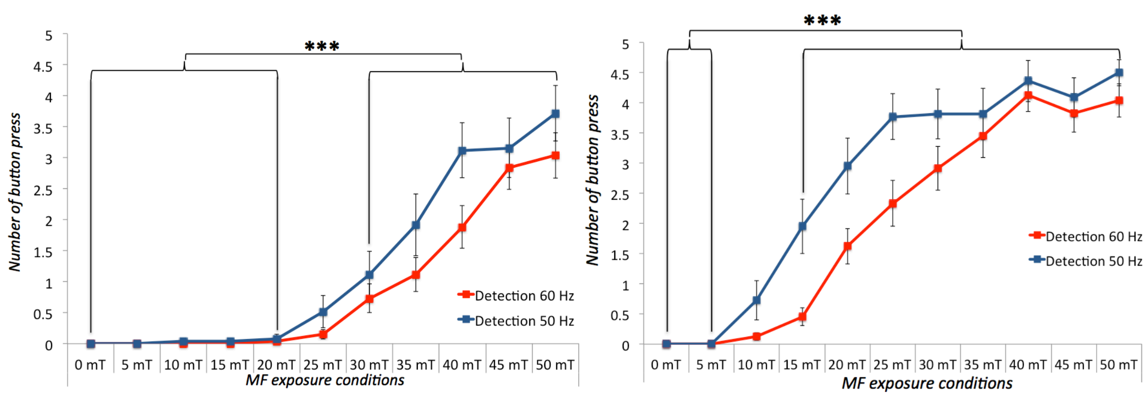

Figure 1: <u>*Left panel:*</u> Averaged number of button-press in the 50 Hz exposed group (n=25) and in the 60 Hz exposed group (n=26) as a function of MF flux density - retinal exposure, showing a magnetophosphene perception threshold significant at 30 mT in this exposure configuration. Higher flux densities lead to a higher detection rate. <u>*Right panel*</u>: Averaged number of button-press in the 50 Hz exposed group (n=25) and in the 60 Hz exposed group (n=26) as a function of MF flux density - global head exposure, showing a magnetophosphene perception threshold significant at 15 mT. Again, higher flux densities are associated with a higher detection rate.

Results showed a significant main flux density effect for both retinal and global exposure conditions (**Retinal exposure** – Figure 1, *left panel*: F= 94.21, p<.001, Partial Eta^2=.66, Power=1 ; **Global exposure** – Figure 1, *right panel*: F=133.91, p<.001, Partial Eta^2=.70, Power=1), indicating a lowest detection threshold occurring at 15 mT when the head is entirely exposed. Interestingly, the data confirmed a differential frequency response, showing better perception rate at the lower frequency [6]: the magnetophosphene threshold is lower in terms of flux density at 50 Hz than at 60 Hz in the **global** (Figure 1, *right panel*: F=3.69, p<.01, Partial Eta^2=.06, Power=.89) exposure but it is only a non-significant trend in the **retinal** exposure condition (Figure 1, *left panel:* F= 2.14, p>.05, Partial Eta^2=.043 Power=.50).

Corresponding EEG signals from the occipital electrodes O2, O1 and OZ have also been analyzed. No effect has been found in the occipital and in the retinal exposure conditions, but an interesting diminution in the alpha rhythm in the higher flux density condition when the entire head is exposed has been observed (Figure 2 presents the results specifically for the O2 electrode).

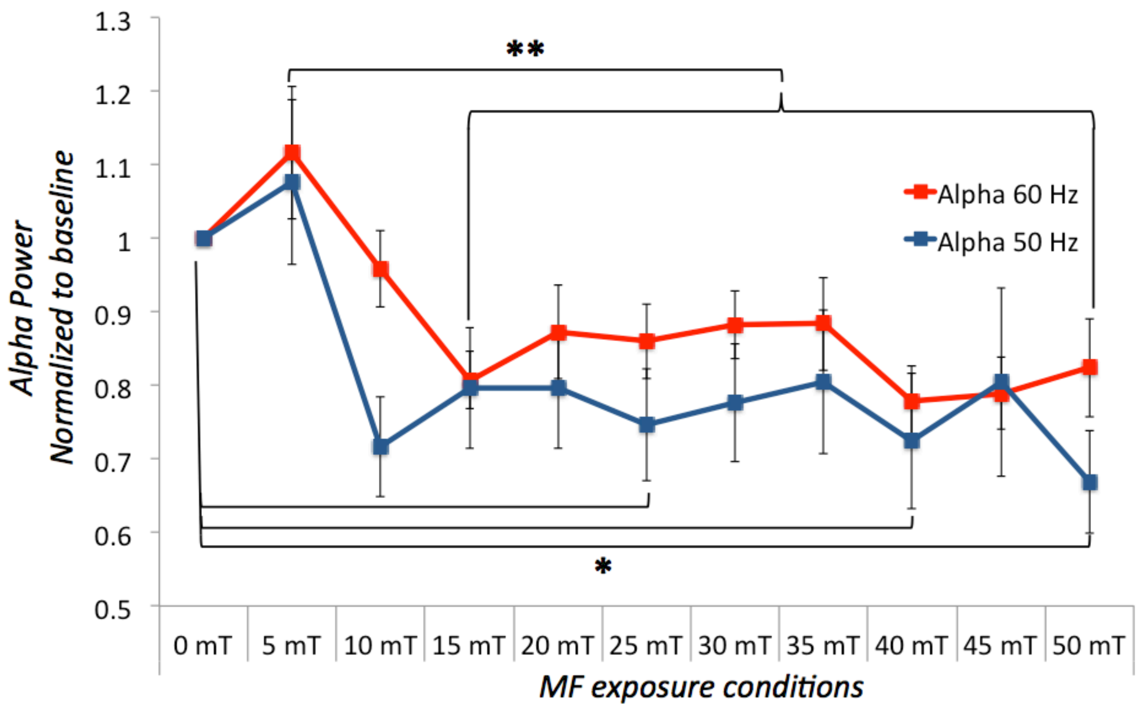

Figure 2: Evolution of the EEG alpha power in the global exposure condition at 50 (n=25) and 60 Hz (n=26) for MF flux densities between 0 and 50 mT. Above 15 mT, EEG alpha power is becoming significantly decreased, i.e. above the magnetophosphene detection threshold.

Results showed a significant main flux density effect (F=9.1, p<.001, Partial Eta^2=.149, Power=1), and indicating a threshold in EEG alpha decrease at 15 mT, corresponding to the magnetophosphene perception threshold reported by button press. However, as opposed to the magnetophosphene perception report presented in Figure 1, there was no differential effect between the 50 and 60 Hz conditions (F=0.795, p>.5, Partial Eta^2=.015, Power=.33). This suggests that, despite a significantly higher magnetophosphene perception rate at 50 Hz as compared to 60 Hz in the global condition, this is not large enough to be associated with a significant interaction in the corresponding EEG response (i.e., the decrease in EEG alpha power due to magnetophosphene perception is comparable at 50 and 60 Hz).

CONCLUSIONS

This project allows the experimental testing of ELF MF exposures of up to 50 mT in humans, with results from a first experiment conducted at power frequencies (50/60 Hz) presented here, and results from a second experiment also testing 20 and 100 Hz to be presented at the conference. These studies concomitantly investigate a self-reported perception (magnetophosphenes) and an objective neurophysiological outcome (EEG), both acquired during MF exposure. Based on this first set of data, the threshold for magnetophosphene perception is at 30 mT at for a local unilateral retinal exposure, and at 15 mT for a global head exposure. Global head exposure is more effective in generating magnetophosphene perception than local eye exposure, possibly because of the inhomogeneity of the field produced by the local exposure system allows to expose only one eyeball, and that even this eyeball is in homogeneously exposed with a lower field level in the part of the eye more distant from the coil. The differential frequency-response as reported by Lövsund et al. (1980) is confirmed, showing a lower threshold at lower frequency. This will be further experimentally documented with our second experiment also testing 20 and 100 Hz. The absence of effect in the occipital exposure condition as opposed to the efficacy of a single eye exposure to generate magnetophoshenes confirm that the interaction site is in the retina and not in the occipital cortex as it was still under consideration [8], which supports the findings from Laakso and Hirata [9]. This project will provide solid experimental data acquired in humans to refine exposure guidelines, which may also offer opportunities for translational research.

ACKNOWLEDGEMENTS
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