Threshold for a systematic neurophysiological response to 50 and 60 Hz magnetic fields of up to 50 milliTesla

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INTRODUCTION

International agencies such as the ICNIRP (International Commission on Non-Ionizing Radiation Protection) and the IEEE (Institute of Electrical and Electronics Engineers) are publishing guidelines proposing exposure limits aiming to protect the general public and workers' health against documented biological effects of electromagnetic fields [1, 2].

These guidelines are mainly based on the best estimate available to date of an acute biological effect in humans: "ICNIRP now considers the effect on the retina as a model of effects in the brain and the phosphene threshold provides a basis for limiting exposure" [1].

Phosphene perception (little flickering dots in the visual field) during magnetic field exposure (originating the name "magnetophosphenes") is explicitly mentioned as being this biological "threshold" effect in the low frequencies, which supports international guidelines.

The estimated threshold for magnetophosphenes perception in humans is associated with exposure levels above 5 mT at frequencies in the order of 20 Hz, corresponding to induced electric fields between 50 and 100 mV/m [1, 3-6]. However, these levels at 20 Hz are still not clearly established, and a few scientists remark that the methods used thirty years ago are not entirely described, which makes these studies "difficult to evaluate" [7]. Moreover, the threshold for the perception of magnetophosphenes estimated by ICNIRP at 50 and 60 Hz is extrapolated from values reported at 20 Hz, and no experimental confirmation is available to date at these frequencies. Indeed, it appears that "the guidelines are based upon very limited data and assumptions regarding phosphenes" [8]. There is thus a need to clearly establish the threshold for the perception of magnetophosphenes in humans at 50 and 60 Hz experimentally.

Since 2005, our group has studied the effects of 60 Hz magnetic exposures in human volunteers at levels reaching 1.8 mT (2005-2007), then 3 mT (2008-2010) [9-11]. These results have a considerable scientific value in terms of fundamental research, but their main limitation is that they do not identify a clear "threshold value" above which an effect could systematically and objectively be detected in humans.

We are therefore initiating a new research project with the primary objective of establishing a magnetic field exposure threshold at which magnetophosphenes are systematically perceived in humans. With this project, we are willing to experimentally address the question of the magnetophosphenes detection threshold in humans exposed to magnetic field levels between 0 and 50 mT at 60 and 50 Hz.

This project will also aim to objectively characterize the neurophysiological responses associated with magnetophosphenes perception. In this perspective, we are analyzing brain electrical (using electroencephalography – EEG) and metabolic (using functional Magnetic Resonance Imaging - fMRI) activity in two distinct experiments testing this threshold for magnetophosphenes perception.

EXPERIMENTAL DEVELOPMENTS

Two experiments (double blinded, sham controlled and counterbalanced) are being set up to address the objectives.

A first experiment tests 50 and 60 Hz exposures of up to 50 mT on the perception of magnetophosphenes in healthy volunteers (n=30). Local (retina and occipital cortex) and global (entire head) exposures conditions (0 to 50 mT, 5 mT steps) will be delivered. Five repetitions of each exposure condition will be given to the subject in a random order (blinded and computer driven). The subject will be asked to press a button each time he perceives magnetophoshenes. Corresponding brain electrical activity (measured with EEG) will be recorded and analyzed in order to complete the subjective perceptive threshold evaluation with an objective measurement of neurophysiological interactions. Exposure, button-press, and EEG recording will be synchronized for analyses. The protocol may be altered after pilot data are collected.

In order to further study the neurophysiologic interactions associated with exposure, a second experiment is set up. It will sequentially and simultaneously use two cerebral imaging techniques: fMRI and EEG. This experiment will test the effect of exposure sequences (50 and 60 Hz, 8 mT) of different durations (from 2 second to 10 minute sequences) on electrical and metabolic brain activity at rest (EEG and fMRI – used sequentially and simultaneously). It is important to note that we are programming our MRI scanner to use it as an active exposure device (50 and 60 Hz, 8 mT). This is implemented within our MRI-compatible EEG facility.

The EEG/MRI portion of this project is already approved by the University of Western Ontario Health Sciences Research Ethics Board (HSREB 17816) and an application corresponding to the second experimentation is already conditionally accepted (the final protocol will be accepted and pilot data will be presented at the conference).

In addition, our experimental results will be completed with mathematical modeling [12]. Indeed, computational neurosciences allow using mathematical equations to predict neuronal electrical activity, both from single neurons and neuronal networks when exposed to a magnetic or electric stimulus [13]. This approach will allow us to propose new original theoretical arguments that will be discussed in relation to experimental results, and will therefore offer another perspective on the involved mechanisms.

CONCLUSION

This is an ambitious project that aims to experimentally identify, for the first time in humans, a magnetic field amplitude threshold at 50 and 60 Hz above which an objective physiological response can systematically be detected in humans. Regarding the results from the literature currently available on magnetophosphenes, the project innovation lies in the complementary factual observation of effects (EEG, EMG and fMRI) whereas previous results were based on perceived effects in volunteers.

This project is made possible by imaging techniques allowing to characterize the involved brain structures and to follow their electrophysiological activity in real time. Besides, a mathematical framework allows proposal of solid theoretical hypotheses in terms of mechanisms of action.

These results will overcome a limit explicitly mentioned in the ICNIRP guidelines, i.e. the need to validate with experimental data collected in humans the current reference values, which are presently estimates derived from theoretical works or from *in vitro* studies.

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