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Communication

Transient effect of low-intensity magnetic field on human motor control

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Abstract

There is no consensus with respect to how extremely low frequency (ELF) magnetic fields (MF) affect biological systems. However, this information is crucial to establishing new guidelines for: (i) the new design of electronic devices, (ii) working conditions of exposed workers (e.g. electric linepersons), and in a general manner (iii) policies for human risk management. This study evaluates the effect of a sinusoidal 50 Hz, 1000 μT MF centered at the level of the head on human postural tremor of the index finger, using the wavelet analysis method. In addition to the detection of transient events in tremor time series linked with MF, this method was used to evaluate the differences between MF "on" and "off" conditions and between real and sham exposure in a counterbalanced protocol. Results indicate that neither transient events nor "off–on" or "on–off" MF transition effects were present in the postural tremor time series. Surprisingly, an unexpected significant time dependent decrease in tremor average power was noted along the 20 s recordings. Interestingly, this effect was significantly more pronounced in the presence of MF. These results suggest a relaxing effect of ELF MF on motor control resulting in an attenuation of postural tremor intensity.

Keywords: Postural tremor; Wavelet analysis; ELF magnetic field; Relaxation

1. Introduction

Distribution and transport power lines or domestic electric appliances are some of the numerous environmental sources of extremely low frequency (ELF, 50 Hz in Europe and 60 Hz in North America) magnetic fields (MF). For example, workers in electric companies work in the immediate proximity of equipment producing alternating currents and can occasionally be subjected to MF of 1000 μT [1,2]. Moreover, when people use an electric shaver, a hairdryer or a hair clipper, the MF generated on the surface of the apparatus can reach 1500–2000 μT [3,4]. In spite of their ubiquitous presence in our environment, the effects of ELF MF on human physiology are still unclear and more research is required [5]. Several studies have examined the effects of MF via electroencephalogram (EEG), electrocardiogram (ECG), cognition, evoked potentials or motor behavior, but no consensus has been established yet regarding their possible effects on human behavior (see [6,7] for a review). Moreover, most of the studies evaluate the effect of MF before and after but rarely during the exposure, due to the presence of artifacts in the recorded data caused by the MF itself (see for example [8]). However, it is necessary to have precise information concerning the effects of ELF MF on human central and peripheral nervous systems during the exposure [5]. One way to proceed is to study the nervous system output: motor behavior.

Among the few studies that explored ELF MF effects on human motor control, Thomas et al. (2001) showed that normal human standing balance can be improved by a specific 200 μT pulsed MF centered at the level of the head

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[9]. Another highly sensitive motor control parameter is human physiological tremor. Briefly, physiological tremor is an involuntary, irregular and continuous movement of a body part [10]. It is characterized by its amplitude (generally weak and variable between persons) and by its frequency (generally organized around 8–12 Hz [11]). The central and peripheral nervous systems contribute to the production of physiological tremor [11–14] in proportions which vary according to environmental and health conditions, but three main mechanisms are described (see [11,12,15,16] for a review): (1) mechanical resonance of the limb (around 17–30 Hz for metacarpophalangeal joint [17]), (2) feedback resonance and (3) central oscillations. Feedback resonance is itself represented by three feedback loops: (i) the short latency spinal reflex arcs from afferent stretch receptors, (ii) the long loop transcortical or transcerebellar reflex pathways from these receptors, and (iii) central feedback from motor neurons via the spinal cord. The loop time for spinal segmental stretch reflex in the finger is about 50 ms, and favors the generation of 10 Hz tremor [18]. More than 37 known factors are able to modify physiological tremor [19], and these modifications appear sometimes in the amplitude of tremor and sometimes in its frequency organization. Therefore, physiological tremor is highly sensitive to modifications in a person's neurophysiological state and constitutes a valuable parameter to detect the acute effects of ELF MF exposure on humans.

In previous studies, we explored the effects of a 1000 μT, 50 Hz MF, corresponding to the highest intensities commonly present in our daily environment, on human tremor [20,21]. Although our results showed a significant difference in the spectral content of human postural tremor across conditions when the MF was present versus absent, no clear MF effect has been established [20]. One of the limitations of this study was the absence of analysis of the effect of MF transitions: whether or not human motor behavior was transiently modified when the MF was switched "on" or "off" (see Fig. 1 for MF arrival illustration). Indeed, Thomas et al. (2001) estimated the delay of action of their MF on human postural sway between 3 and 43 ms [9]. Contrary to our previous study [20] the effect persisted during MF exposure, raising the question: "could such a short latency effect be detected if it does not persist in time?" Therefore, a detailed study of MF transitions might be helpful to evaluate and characterize the effect of MF on biological systems. Indeed, studies using intermittent exposure (1 s "on" and 1 s "off" for example [22,23]) to ELF MF seem to show more reliable results (see [6] for a review), which could mean that MF effects would be maximized when the field is turned "on" or "off".

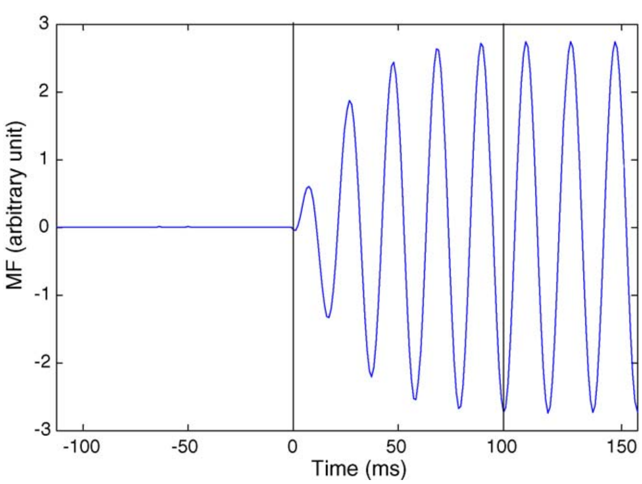

Fig. 1. Zoom on the MF "off–on" transition. The MF takes 100 ms to reach its maximum peak value (after five cycles at 50 Hz, period included between the two vertical lines).

The nervous system is considered as a preferential site of interaction with ELF MF because the tissues involved are sensitive to electrical signals. Various possibilities could be considered including a delayed or transient effect of MF on the stretch reflex and a delayed action on a central oscillator modulating physiological tremor. Thus, the main purpose of this work is (1) to investigate whether or not the exposure to a common environmental ELF MF can be detected in human physiological tremor by studying potential transient MF effects on postural tremor induced by its sudden arrival or departure and (2) to confirm or rebut the absence of MF effect during the exposure previously found [20].

2. Materials and methods

2.1. Subjects

Thirty-six volunteers, all men between the ages of 20 and 50 years (37.8 ± 8) were recruited from the personnel of a French electric company ("Eléctricité de France": EDF) and completed the experiment. None of them had previously taken part in studies involving MF exposure. Before testing, they were required to complete a screening questionnaire to ensure that: they did not use drugs or medications regularly; they had never experienced an epileptic seizure; they had no limitation of hand or finger movements; they did not suffer from chronic illness (e.g., diabetes, psychiatric, cardio-vascular or neurological diseases); they had no cardiac or cerebral pacemaker; and they had no metallic implant in the head or in the thorax. This information was verified by EDF's occupational medical service. All subjects were asked to refrain from smoking or drinking coffee the morning of the experiment. The study's protocol was reviewed and approved by the Operational Committee for Ethics of the life sciences section of the CNRS (Centre National de la Recherche Scientifique, France).

2.2. Procedure/experimental design

Subjects were tested at the same time of day (9:00 am) during a single session [24] and no artificial light was used [25]. The room temperature was controlled at 23 °C [26]. Before testing, subjects confirmed and signed the screening