Does a 10 minutes, 1800 µT, 60 Hz magnetic field exposure modulate collective oscillations of a cortical network model?

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INTRODUCTION

Experimental evidence indicates that exposure to extremely low-frequency (ELF) magnetic fields (MF) may impact nervous system function as measured by electroencephalography (EEG) or functional magnetic resonance imaging (fMRI) [1,2]. One possible mechanism is that ELF MF exposure may interfere with the regulation of synaptic function, a phenomenon known as spike-timing dependent plasticity (STDP). To investigate the potential of ELF MF to affect resting brain oscillations by modulating synapses efficiency, we study the behavior of cortical tissue biophysical model exposed to an ELF MF.

MATERIALS AND METHODS

We simulated using the Python-based simulator BRIAN [3] a network of 1000 Izhikevich [4] cortical neurons (800 excitatory, 200 inhibitory) eventually exposed a 1800 µT, 60 Hz magnetic stimulus. Additive white noise of 3 mV and a STDP rule (τ^+=20 ms, τ^-=20 ms, A^+=0.1, A^-=0.12) were included. MF exposure induces in brain tissue an electric field resulting in membrane depolarization $\delta V(t)$ [5] proportional to polarization length λ_p and cell orientation θ (here, θ=1 for 25% of cells, θ=0 otherwise). Let $\omega=2\pi f$ (f=60 Hz), then $\delta V(t)=\pi R B_0 f \lambda_p \cos\theta[\cos(\omega t)+\omega\tau\sin(\omega t)]/(1+\omega^2\tau^2)$, where τ is the Maxwell-Wagner time constant and R the exposure radius (here, τ=20 ms; R=5 cm). For each condition (sham or exposed), 20 periods of 10 minutes were simulated. Firing rate (spikes per time bin) was computed using a time bin of 5 ms, and was used to compute the power spectrum of neuronal activity from which delta (1-4 Hz), theta (4-8 Hz), alpha (8-12 Hz) and beta (13-30 Hz) frequency bands were extracted using Matlab®. A one way ANOVA for independent variables was performed on the power computed in each frequency band using SPSS® to discriminate if MF exposure affected any of these frequency bands.

RESULTS

The power spectrum for the last 5 seconds of simulation, averaged over the 20 runs of each condition, is plotted in Fig. 1. The ANOVA revealed that MF exposure did not significantly modulate any frequency band power, as can be seen in Table 1.

Table 1. Spectral power for frequency bands studied, mean value and ANOVA p-value.

	Delta (1-4 Hz)		**Theta (4-8 Hz)**		**Alpha (8-12 Hz)**		**Beta (13-30 Hz)**	
	Exp	*Sham*	*Exp*	*Sham*	*Exp*	*Sham*	*Exp*	*Sham*
Mean power	4.646	4.706	1.648	1.692	2.487	2.631	2.369	2.381
p value	0.83		0.613		0.362		0.899	

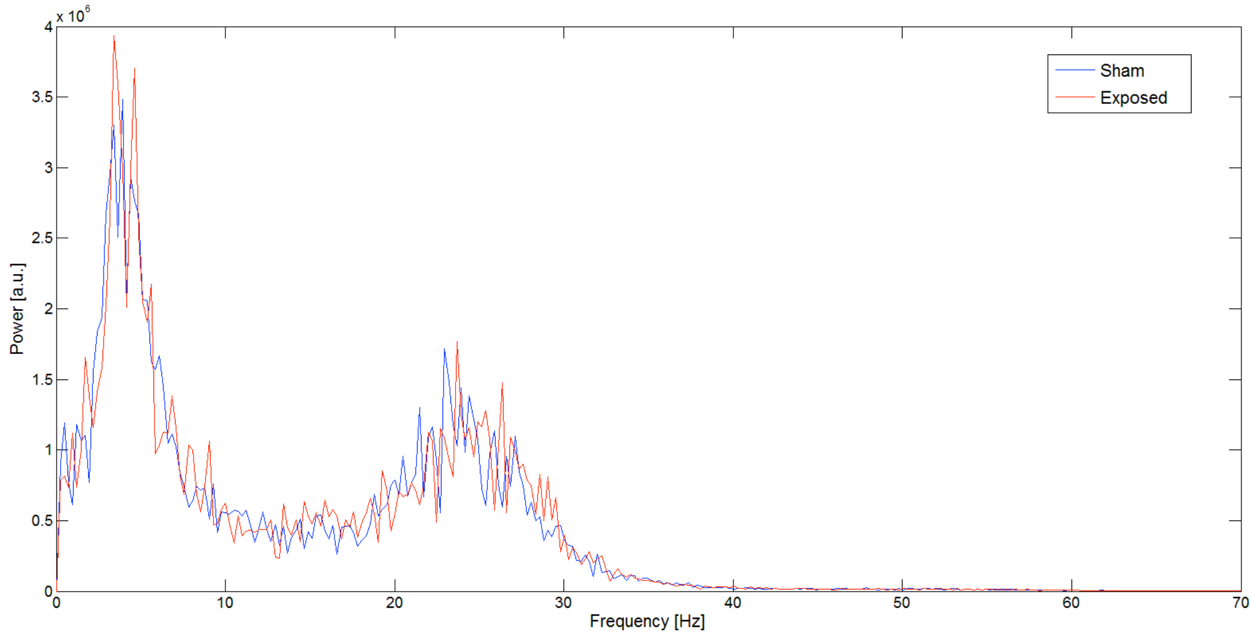

Figure 1. Comparison of the average power spectrum (over the 20 runs for each condition, sham or exposed) of neuronal activity computed for the last 5 seconds of the 10 minute stimulations, for each condition. Blue curve: sham, red curve: exposed.

CONCLUSIONS

Our results suggest that a simulated 10 minute exposure to a 1800 µT, 60 Hz MF does not significantly effect the main frequency bands of neural activity in a biologically plausible model of cortical tissue. This result is consistent with previous EEG studies from our group investigating a 60 minutes exposure to a similar MF (1800 µT, 60 Hz) in humans, where no significant change of the theta, alpha, beta or gamma bands was observed [6]. One possible extension of this work would be to predict a critical intensity and duration of exposure above which any of these frequency bands is significantly impacted.

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