WI-FI ELECTROMAGNETIC FIELDS EXERT GENDER RELATED ALTERATIONS ON EEG

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Abstract

The present study investigated the influence of electromagnetic fields, similar to that emitted by Wi-Fi system, on brain activity. Fifteen female and fifteen male subjects performed a short memory task (Wechsler test), both without and with exposure to a 2.4GHz Wi-Fi signal. For each subject, radiation condition and electrode, the amplitude in the frequency domain of the EEG signal was calculated from the recordings of 30 scalp electrodes, using the Fourier transform.

The presence of radiation had no effect on the energies of alpha and beta band of male subjects, while it reduced these energies of female subjects, resulting in significantly lower energies, as compared to those of males.

Delta and theta band energies did not experience any noteworthy effect from gender, radiation condition and their interaction. Conversely, there was a significant interaction effect (gender x radiation) on the energies of alpha and beta rhythms.

Interestingly, this pattern was observed for a number of electrodes, which formed two distinct clusters· one located at right- anterior and the second at occipital brain areas.

The present data support the idea that Wi-Fi signal may influence normal physiology through changes in gender related cortical excitability, as reflected by alpha and beta EEG frequencies.

1. INTRODUCTION

A lot of research has been done in the last years on the possible effects of Radio Frequency Electromagnetic Fields (RF - EMF) on biological matter. The majority of this research regards the potential health impacts of cell phones and other mobile communication emitters.

There are several studies involving subjects who perform various tasks while exposed to RF [1-6], which conclude that some aspects of cognitive function and some measures of brain physiology may be affected by the exposure to RF of the type emitted by cellular phones. Interestingly, the RF effect was found to be gender related [7, 8].

Based on the reviewed publications examining possible biological effects of RF exposure, the evidence suggests that the exposure to RF affect the human brain and its subsequent output in the form of cognition and behavior. This assumption is in line with recent reviews by Cook et al., (2006) and Valentini et al., (2007) [9, 10]. However, there are also reports contradicting this assumption Kleinlogel et al., (2008) [11].

Very common and constantly increasing sources of RF exposure are wireless networks that allow high-speed internet access and services, such as Wi-Fi. Inevitably, there has been concern about possible health effects from such exposure; however little research has been devoted to investigate the possible effects of Wi-Fi signal on biological systems.

Most of the studies that have been conducted, investigating the biological effects of Wi-Fi on humans, are mainly dealing with the amount of energy absorbed in human tissue and therefore limited in the measurement of the Specific Absorption Rate (SAR). There are also dosimetry studies ongoing, measuring RF levels around the globe, including that coming from wireless local area networks (WLANs) [12] and others which indicate that the exposure level is low compared to other sources [13]. Another approach, involved experimental procedures for whole-body RF exposure of animals in order to investigate the possible effects of Wi-Fi signal on biological systems [14].

In view of the above considerations, it can be hypothesized that the electrophysiological brain activity, as reflected by Electroencephalography (EEG) – alpha, beta, theta, delta bands – in association with cognitive task operations, could be of value in identifying possible pathophysiological alterations evoked by Wi-Fi signals and their connection with gender. Thus, the present study was designed to determine whether the presence of Wi-Fi signal affects the patterns of EEG activity elicited during a short memory task (Wechsler test).

2. METHODS

2.1. Participants

Thirty healthy individuals (15 men and 15 women, mean age = 23.76 ± 1.67 years, mean education = 16.9 ± 1.06 years) participated in the experiment. The participants were homogeneous with regards to age and educational level and had no history of any hearing problem. Informed consent was obtained from all subjects.

2.2. Experimental setup and Measurement Procedure

The subjects were evaluated with the digit span Wechsler Auditory test. A warning stimulus of either high (3000 Hz) or low frequency (500 Hz) was presented through earphones to the subjects, who were asked to memorize the numbers that followed. The warning stimulus lasted 100msec. A one second interval followed the onset of the warning stimulus and then the numbers to be memorized were presented by a female voice. At the end of the number sequence presentation, the same signal tone was repeated. The signals were recorded for a 1500msec interval, which means 500msec before the warning stimulus (EEG) and 1000msec after that (ERP), as described in previous articles [8, 15]. The numbers were recalled by the subject in the same (low frequency tone) or in the opposite order (high frequency tone) than that presented to the participant. The total task consisted of 52 repetitions for a period of about 45min. The subjects performed the tasks twice, with and without radiation, with an interval of two weeks between the measurements. The order in which the subject was exposed at the EMF (exposure at the first or second visit) was random. The EMF was emitted by a Wi-Fi access point that was operating at 2.4 GHz frequency. The Wi-Fi signal was radiated by a dual dipole antenna, with 20dBm power and

OFDM modulation. The access point was placed at a distance of 1.5m from the right part of their head. The field strength was 0.49V/m at the point where the subjects' head was standing. According to E. Kapareliotis et al. [16] there is no evidence that a Wi-Fi signal causes interference at the EEG recordings at the distance of 1.5m from the EEG electrodes.

The experiment was conducted in a Faraday room, which screened any electromagnetic interference that could affect the measurements. The attenuation of the mean field was more than 30 dB.

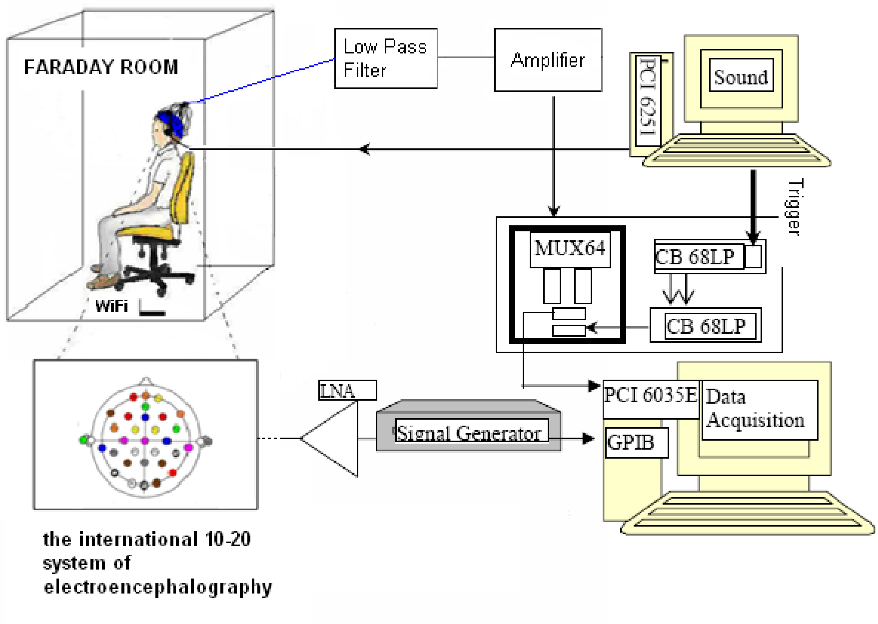

Figure1. Experimental Setup

The electrophysiological signals were recorded with Ag/AgCl electrodes. Electrode resistance was kept constantly below 5 kΩ. EEG activity was recorded from 30 scalp electrodes (FC6, FC2 F8, F4, Fz, AFz, Fp2, Fz, Fp1, P3, T3, FC1, FC5, F3, F7, T6, P4, CP6, CP2, T4, C4, O2, Oz, O1, Pz, Cz, T5, CP1, CP5, C3) based on the International 10-20 system of Electroencephalography [17], referred to both earlobes. Linked ear lobes served as reference. The bandwidth of the amplifiers was set at 0.05 – 35 Hz. Eye movements were recorded with the use of electro-oculogram (EOG) and recordings with EEG higher than 75 μV were excluded. The evoked bio potential signal was submitted to an analogue-to-digital conversion, at a sampling rate of 1 KHz and was averaged by a computerized system.

2.3. Data Transformation

For each question 1500 data points, each corresponding to time segments of 1msec duration for each electrode were saved. In order to optimize the signal to noise ratio for each subject and each channel all EEG values were average referenced on the basis of the grand average across the 52 repetitions of the EEG values. This procedure was done separately for each EMF condition. The final data for analysis for each subject and condition consisted of 1500 amplitude values for each electrode, expressed in μVolts corresponding to the 1500msec of the time period [8, 15], 500ms before the onset of the first warning stimulus (EEG), and 1000 ms after the onset (ERP).

For each subject, each radiation condition and each electrode, the amplitude in the frequency domain was calculated using the Fourier transform (FFT) (EEG). This analysis confirmed the expected pattern of the spectral distribution of the signals, with the appearance of peaks within the range of the four basic rhythms d (0–4 Hz), θ (5–7 Hz), a (8–13 Hz) and b (14–30 Hz) in all EEG series.

2.4. Statistical analysis

The EEG energies were log-normalized so that their distribution for all the electrodes and both experimental conditions did not deviate from normality. For each band, the energies at the thirty electrodes were subjected to multivariate analysis of variance with gender (male-female) and radiation condition (on-off) as the independent factors, followed by post-hoc pair wise comparisons with Bonferroni corrections. The significance level was set at 0.05.

3. RESULTS

Multivariate analysis of variance did not reveal any significant effect of gender, radiation condition and their interaction on the energies of the delta and theta bands. Conversely, there was a significant interaction effect (gender x radiation) on the energies of the alpha and beta band. The nature of this interaction effect can be clarified by Figure 2, which shows the average values at the alpha band for male and female subjects, for the two radiation conditions at electrode F8. As this figure shows, at the absence of EMF the alpha band energies of the two genders are practically the same. The presence of radiation did not have any effect on the energy of male subjects, whereas it reduced the energy of female subjects, resulting in a significantly lower energy, as compared to the energy of male subjects.

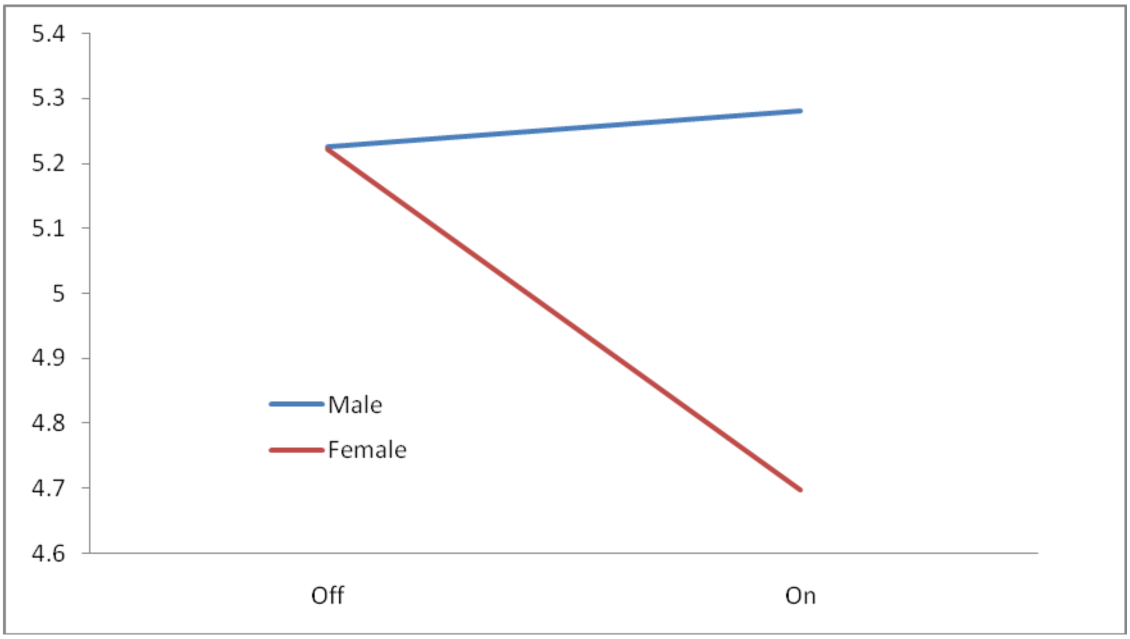

Figure 2. Average values at the alpha band for male and female subjects, for the two radiation conditions at electrode F8

The same pattern was observed for a number of electrodes (FC6, F8, Fp2, Fpz, C4, O2, Oz and O1). As Figure 3 shows these electrodes form two distinct clusters, one located at right- anterior and the second at occipital brain areas. Interestingly, analysis revealed that the beta band energies have practically the same behavior.

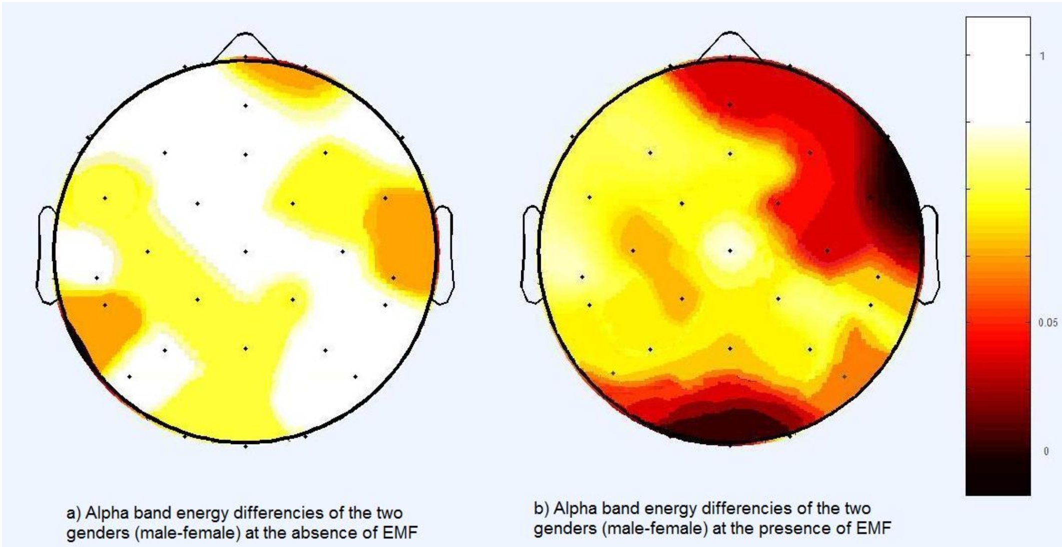

Figure3. p-values of the differences between male and female subjects in the absence and presence of the Wi-Fi signal

3. SUMMARY - DISCUSSION

The comparison between experimental conditions showed that the presence of radiation did not have any effect on the energies of the alpha and beta band of male subjects, while it reduced these energies of female subjects, resulting in significantly lower energies, as compared to the energies of male subjects.

Additionally, the energies of the delta and theta bands did not experience any significant effect from gender, radiation condition and their interaction. Conversely, there was a significant interaction effect (gender x radiation) on the energies of the alpha and beta rhythms.

Interestingly, this pattern was observed for a number of electrodes, which formed two distinct clusters, one located at right-anterior and the second at occipital brain areas.

The results of the present study may be interpreted in the light of the psycho physiological and brain-imaging studies related to EEG functional anatomy. The quantification of EEG was proven a useful and appropriate method in measuring the level and topographical distribution of cortical activation during cognitive task performance. In general, the functional significance of varying brain activity can be seen in the vicinity to the underlying neural circuits. For instance, it is assumed that alpha band activity reflects an increased excitability level of neurons in the certain cortical areas, which may be related to an enhanced information transfer in thalamocortical circuits and is strongly correlated with working memory as well as with long-term memory engramms [18-21]. Beta bursts being related to cortico-cortical interactions shift the system to an attention state that consequently allows for gamma synchronization and perception [22-24].

The effect of Wi-Fi exposure (significant interaction effect -gender x radiation-on the energies of the alpha and beta bands) are in accordance with previous studies of our team regarding gender related differences in the EEG under EMF exposure of 900MHz and 1800MHz similar to that of mobile phones [8, 15, 25, 26, 5, 7]. Also Smythe and Costall (2003) [27] have reported sex-dependent effects of EMF exposure on human memory during a memory task.

Although, the biological basis for these sex differences remains elusive, emerging evidence provides plausible mechanisms for the explanation of these differences. In particular, central nervous system effects of EMFs have been considered to be secondary to damage to the blood–brain barrier (BBB) permeability [28-31].At this point is reasonable to consider the existence of gender-related blood-barrier differences, a fact which would explain the fundamental differences between males and females in the intrinsic cognitive processes and in the way they are affected by different types of electromagnetic radiation [32-34]. Furthermore research also indicates that EMF exposure affects the melatonin release, specifically it has been demonstrated a reduced excretion of the urinary metabolite of melatonin among persons using a mobile phone for more than 25 min per day [35]. This observation would be better understood taking into account that in a study of pubertal individuals it has been found significantly higher total, nocturnal and diurnal 6-sulfatoxymelatonin excretion in girls [36].

It is concluded that Wi-Fi may influence normal physiology through changes in gender related cortical excitability as it is reflected by the alpha and beta EEG frequencies.

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