Mobile Phones, E E G And Mental Activity

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Abstract

Background: The published results about possible mental effects of mobile phone (MP) exposure are still inconsistent and inconclusive.

Methods: The sigmoid arousal-frequency correlation combined with the brain rate concept is used to characterize the effects of mobile phones on mental states.

Results: MP exposure leads to pronounced asymmetries and individualities in brain rate values, characterizing EEG spectral shifts towards overarousal or underarousal.

Conclusion: The mental consequences of mobile phone use could be, in principle, detrimental or beneficial, depending on the individual initial EEG spectra and the different exposure frequencies from mobile phone technologies. Thereby, brain rate can serve as a useful preliminary indicator.

Introduction

Worldwide concern about possible mental effects of mobile phone (MP) exposure lasts for more than two decades [1-2]. However, the published results are still inconsistent and inconclusive [3-5]. So, in two recent documents from competent organizations (World Health Organization - WHO and International Commission on Non-Ionizing Radiation Protection - ICNIRP) it is stated, respectively: “To date, results of epidemiological studies provide no consistent evidence of a causal relationship between radiofrequency exposure and any adverse health effect. Yet, these studies have too many limitations to completely rule out an association”[4]; and: “The evidence for neurobehavioral effects on brain electrical activity, cognition, sleep and mood in volunteers exposed to low frequency electric and magnetic fields is much less clear”[5].

The aim of this article is to present a possible explanation for the ambiguous and inconsistent evidence about MP effects on mental activity. In addition, the applicability of brain rate concept [6] for indicating MP influences is considered.

Empirical evidence

This study is restricted to mental activity, which is characterized by arousal, defined by the nobelist Kahnemann as the “general activation of the mind” [7]. Starting key question is: which EEG frequencies are relevant for mental activity? The well established empirical results show that these are frequencies in the extremely low (ELF) range of below one hundred Hz. Moreover, it appeared that the states of arousal are somehow proportional to EEG activity represented by different frequency bands: from delta (0.5-4 Hz) till beta (14-30 Hz). Thereby, the empirical data have shown that the delta band corresponds to deep sleep stages 3-4, theta to drowsiness and sleep stages 1-2, alpha to relaxed state, while beta to alert state and anxiety [8].

It is important, and yet often overlooked, that ELF frequencies of the same range are also emitted by MPs of different technologies. For instance, the TDMA (Time Division Multiple Access) technique produces pulse modulation at 8.34 Hz, while in the case of TETRA (Terrestrial Enhanced Trunk Radio) technology the transmission is pulsed at 17.6 Hz [1, 9]. In addition, GSM (Global System for Mobile Communication) emission may be characterized by 2 Hz or 4.25 Hz, depending on transmission mode [9]. More specifically, various spectral components in the MP ELF appear to correspond to different modes: 8 Hz – talk; 2, 8 Hz – listen; 1-32 Hz – standby [10, 11].

Consequently, an influence of MP on EEG and mental activity is quite feasible and could be diverse [9, 12].

Modeling

Analysing the empirical input-output activation, arousal can be represented as a sigmoid function [13]. An analytical expression of the same sigmoid dependence has been derived by a quantum theoretical approach, based on the transition probabilities from the interaction of brain electric field with neuronal dipoles [14]. Combining these theoretical results with the mentioned empirical data, a summarized arousal-frequency correlation is obtained [15].

However, the actual electric field in the brain (both endogenous and externally modulated) is not monochromatic, but spectral, characterized by a
time-changing frequency distribution. Consequently, a spectrum weighted frequency (brain rate) parameter was introduced [6], as a useful general indicator of mental state (in parallel with temperature, blood pressure or hearth rate, indicating different bodily states).

Defined as the mean frequency of brain oscillations weighted over the all bands of the EEG potential (or power) spectrum, the brain rate (fb) can be calculated by Eq.1, with Eq.2, where the index i denotes the frequency band (for delta i = 1, for theta i = 2, etc.) and Vi is the corresponding mean amplitude of the electric potential (or power).

**Results**

The brain rate values for different mental states (sleep stages and some mental disorders), showing underarousal or overarousal, are displayed in Illustration1.

The distribution of mean brain rate values (for 40 healthy adults, eyes closed), indicating the changes in different cortical regions (Frontal/Back, Left/Right and midline) are shown in Illustration2.

By definition, brain rate is a quantitative measure of EEG spectrum shift and thus can also serve as an indicator of MP effects on brain electrical activity. In what follows, summarizing some published results, pronounced asymmetries and individualities of MP exposure effects on human EEG, are deduced, leading to corresponding variations of brain rate.

So, in a recent double-blind study using Helmholtz coils with six stimulation frequencies from 4 to 50 Hz, significant brain-region dependent changes in alpha and beta bands have been obtained [16]; in terms of brain rate, this means the corresponding increase in frontal region and decrease in back region. Some other investigations on effects of ELF (1.5, 2, 10 or 40 Hz) electromagnetic fields on the intrinsic electrical activity on the human brain [17-20] have shown that the EEG time variability and/of spectral power density have changed individually, both in intensity and in laterality; this leads to correspondingly volatile brain rate. The EEG spectrum effects of GSM MP on event-related synchronization/desynchronization during cognitive processing [21] imply that in both active MP cases (encoding and recognition) the brain rate diminishes.

**Discussion**

External ELF fields emitted by MPs can have subtle non-termal effects, including the perturbation of endogenous electromagnetic activity in the brain, thus influencing mental activity and EEG.

Actually, a number of recent comprehensive articles on humans have confirmed this kind of MP effects [e.g. 3, 9, 22]. Thereby, variable results have been obtained, with strong interindividual differences. In particular, the reaction time appeared to be shorter or with no change, the accuracy – poorer or no change, the memory – worse or not replicable, while the sleep – delayed.

In addition, the introduced brain rate, indicating the EEG mental activity changes, could be employed as a complementary biofeedback training parameter, characterizing the whole EEG spectrum (as distinct from e.g. theta-beta ratio). The rationale is that, in practice, whenever a certain band is trained, the other bands are affected too: it may even appear that e.g. “…the changes that occurred as a result of stimulating in the alpha frequency were not in alpha but were in beta...” [23]. This effect may also partially explain the volatility of MP influences on EEG and mental activity.

**Conclusions**

The inconsistent and inconclusive evidence about MP mental effects could be due to subtle interplay of spectral individualities and radiation specifics, representing neurophysical substrate of mental processes. Having in mind pronounced individual differences concerning EMF effects, it is suggested to refine accordingly the sampling procedure, differentiating specific subgroups for studying.

Actually, the mental consequences of MP could be detrimental or beneficial, depending on the individual initial EEG spectra and the different exposure frequencies from MP technologies. Moreover, MP use can be considered as a sort of transcranial magnetic stimulation or of neurofeedback training (but still random and not “knowledge based”).

Thereby, EEG spectrum weighted frequency (brain rate), characterizing the level of mental arousal, can serve as a useful preliminary indicator of possible MP influences on mental activity.

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Authors contributions

JPJ contributed to neurophysical modeling. NPJ contributed to neuromedical studies. Both authors participated in the design and approved the final manuscript.

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Illustrations

Illustration 1

Mapping of brain rate

Illustration 2

Brain rate for sleep stages and some mental disorders

(Combining the results from [24] and [25])
Illustration 3

Eq. 1: \[ f_b = \sum_i f_i \frac{V_i}{V} \]
Eq. 2: \[ V = \sum_i V_i \]
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