Effects from 884 MHz mobile phone radiofrequency on brain electrophysiology, sleep, cognition, and well-being

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Abstract

There is an increasing concern about possible neurobiological effects from radiofrequency fields (RF) emitted from cell phones. In a double-blind laboratory exposure study, we assessed the effects on electrophysiological, cognitive, and self-rated measures from 3 hour exposure to 884 MHz. RF exposure resulted in prolonged time to reach deep (Stage 3) and shortened deep (Stages 3 and 4) sleep, enhanced cognitive performance, and more headaches as compared to non-RF sham exposure. Participants with self-attributed symptoms during regular cell phone use differed from those with no such symptoms. Results suggest that RF exposure, of this magnitude and duration, results in effects indicative of non-specific activation of brain's general arousal and/or stress response systems. There is a need for additional studies that target possible mechanisms contributing to these findings.

1. Introduction

The rapid increase in the use of cell (mobile) phones has been accompanied by an increasing lay concern for and research interest in possible health effects from their use. The focus has been on possible biological effects from exposure to radiofrequency fields emitted from mobile phones, as well as exposure to radiofrequency fields emitted from base stations.

In humans, the radiofrequency-health research has focused on three main areas: 1: cancer; 2: neuro-biological functions and 3: self-rated health. The current paper focuses on neurobiological and self-rated findings related to exposure to radiofrequency fields emitted from GSM mobile phones. A majority of the published human exposure studies has failed to control for a number of critical factors. These include allowing sufficient time for participants to get accommodated to the experimental conditions, stratifying for participants' purported sensitivity to cell phones, and allowing for sufficient and ecologically relevant exposure conditions. Due to the lack of well-standardized studies as well as numerous possible confounders affecting studies to date, the need for additional studies has also been pointed out in the conclusions from a 3 day international workshop [1] in Stuttgart, Germany, 2007, as well as in a 2008 report from the U.S. National Research Council [2].

Regardless of methodological concerns, published studies point to the relevance, as does plausible biological mechanisms, to pay special interest to possible effects from cell phone exposure on neuro-physiological and cognitive functions, and the brain's complex and life-sustaining stress response system.

The purpose with the current project was to study possible effects from 884 MHz GSM cell phone exposure on electrophysiological and cognitive measures, self-rated quality of sleep, and well-being. The recruitment strategy was to include an equal number of participants reporting that they did, as well as did not, have symptoms they attributed specifically to cell phone use.

2. Participants and Methods

The study design consisted of a double blind within-persons provocation comparing effects during exposure to radiofrequency (RF) and sham exposure, and between-persons comparisons of a 'symptomatic (SG)' and 'non-symptomatic' (NG) group. The active RF exposure was consistent with the exposure to 884 MHz (frequency permitted for research). The three hours exposure was conducted between 7.30 p.m. and 10.30 p.m. A habituation session proceeded the two exposure sessions. The provocation sessions were performed in a specially designed laboratory that allowed for maximal shielding to external RF as well as other forms of electromagnetic fields. The participants were informed that there would be no active exposure during the habituation sessions and that the subsequent two test sessions would consist of one active and one sham exposure, the order of which unknown to both participants and researchers on site.

2.1. Participants

The participants were between age 18 and 45 years of age (mean age 29+/-7). Exclusion criteria were attribution of symptoms to electrical equipment other than mobile phones, medical or psychological illness; a history of brain injury; present medication, sleep disorders, hypertension and ongoing pregnancy. The final study population consisted of 71 subjects, 33 men [(SG) =14; (NG) =19] and 38 women (SG =24, NG = 14). All participants received written information of the study and all subjects gave written consent. The Ethical committee for research at the University of Uppsala approved the study (Dnr: 2004: M-146). The HIC, Wayne State University approved secondary analysis of the data (013006P2X). The subjects received reimbursement for their participation. For detailed information about study design, please refer to [3].

2.2. Exposure and Dosimetry

The applied exposure simulated the maximum human exposure during a GSM phone conversation at a carrier frequency of 884 MHz, i.e., a temporal change between GSM basic at all tissue (non-DTX psSAR10g of 1.95W/kg with an averaged interval duration of 11 seconds and DTX psSAR10g of 0.23W/kg with an averaged duration of 5s) resulting in time averaged psSAR10g of 1.4W/kg. Hence, the exposure was well within the ICNIRP guidelines of 2 W/kg (ICNIRP, 1998). The exposure was applied by a patch antenna on the left side of the head simultaneously exposing all possible exposure footprints of mobile phones [4]. Furthermore, the exposure was designed to maximize the exposure of that brain tissue in the left hemisphere that may be exposed during actual usage of GSM phones. The exposure signal simulated the modulation by the GSM frame structures but not the higher frequencies as introduced by random code modulation. The low-weight, stacked micro patch antenna was fixed on a headset and worn by the subjects. A hanging construction balanced the weight of the headset and allowed the subject to move/rotate the head within a limited area without changing the exposure distribution. The RF power was fed into the device through a cable. The antenna was placed on the left side of the subject's head. A two degree increase in skin temperature of left ear lobe was induced by laser heating of a small ceramic plate during all exposure sessions. The setup fulfils the requirements of electromagnetic field (EMF) exposure in the context of health risk assessments of mobile phones [4, 5]. The signal unit was computer-controlled allowing double blind exposure protocols. The exposure setup was developed, installed and monitored, controlled and recorded in an encoded file by the Foundation IT'IS (Zurich, Switzerland). At the applied time-averaged psSAR10g value (all head tissues) of 1.4 W/kg, the psSAR1g of the grey matter was 1.8 W/kg. The all-brain grey matter averaged values and thalamus were 0.2 W/kg and 0.18W/kg respectively.

2.3. Outcome Measures and Analysis

As a cognitive assessment, spatial memory was tested using a Virtual Morris Water Task (vMWT), modeled after the Morris Water Maze, and further developed and validated previously by Moffat [6]. The task environment was a circular water pool surrounded by several cues, which could be used to guide navigation. Hidden beneath the surface of the arena was a platform, and the task required the participant to locate the platform as quickly as possible by 'moving' through the virtual environment using a joystick. Because the platform was invisible, the participants must locate its position with reference to the external objects and cues. The primary dependent variable used in the analysis was the distance traveled on each trial of the vMWT. For the sleep recording a standard EEG/EOG/EMG electrode montage was used and the signals recorded on portable equipment for later visual sleep scoring and spectral analysis. The electrophysiological activities of the brain traced from leads mounted to the head and signals was recorded using portable tape recorders for later determination of the power of the EEG as well as the various stages of sleep. Likert-type scales were used to record participants' self-rated well-being, including prevalence of headaches. Participants were also asked to rate, after each session, whether they believed they had been exposed to RF or not. Statistics used included repeated measures and general linear models. Statistical significance was set at $p<.05$.

3. Results

Detailed study results have been published elsewhere [3, 7]. The prevalence of headaches was tested using random effects logistic regression. There was a significant group (symptoms attributed to cell phones vs no-symptoms) * exposure (RF vs Sham) interaction effect. Non-symptomatic participants reported more headaches following exposure as compared to symptomatic participants.

Participants, regardless whether they attributed symptoms to cell phone use or not, were not able to detect the true exposure status (RF or Sham) any better than by chance alone.

Following 2.5 hours of RF/Sham exposure, participants exhibited faster learning, that is, spent less distance prior to finding the platform in the Virtual Morris Water Task.

Time to reach Stage 3 sleep was delayed following RF exposure (M 0.37; S.D. 0.33 hour) as compared to Sham exposure (0.27; 0.12; F=.9.34; p=.0037). RF exposure was also associated with less time spent in Stage 4 (M 37.2; 28 minutes) as compared to Sham (45.5; 28; F=10.7; p=.0019).

4. Discussions

The current controlled, double-blind radiofrequency (884 MHz) exposure study incorporated many of the factors pointed out to be possible confounders in prior studies. Thus, we allowed the participants to familiarize themselves with the exposure set-up; we used ecologically-valid and sufficiently long exposure conditions; and we minimized the participants' ability to detect any exposure-related queues. We also stratified the sample based on pre-exposure reports on having symptoms attributed specifically to cell phone use.

Results suggest significant effects on self-rated well-being, cognitive performance and the brain's electrophysiology. The aggregate pattern of enhanced cognitive performance, headaches, and increased difficulties reaching and remaining in deep sleep, suggest that the exposure set-up resulted in an activation of the brain's arousal system and/or its stress defense system.

5. Conclusion

It is suggested that future studies should direct increased interest towards the brain's general activation and stress response systems as a possible mediator between RF exposure and neuro-cognitive and electrophysiological functions in humans. Moreover, since no plausible biological mechanisms has been identified that would explain effects from cell phone radiofrequency exposure in humans, the possibility that the brain's general arousal and/or the stress defense systems represent such a link makes it especially intriguing to further elucidate such a possibility.

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7. References

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