Workshop

"Sleep Disorders, EEG-Changes, Altered Cognitive Functions – Is there a Connection with the Exposure to Mobile Communication RF Fields?"

Abstracts

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EMF-Net

State Ministry of Environment,
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CONTENTS

SCOPE

The installation of mobile phone base stations or of other types of transmitters in residential areas often leads to complaints of residents who claim to suffer from various, often unspecific symptoms due to Radiofrequency (RF) emission. A similar situation is observed regarding the use of cordless phones (e.g. DECT telephones) in homes. Often, sleep disorders are claimed to be an immediate consequence of permanent field emissions. Although these fears to date could not be proven scientifically, they must be taken seriously and have to be carefully examined.

This situation has not considerably changed since four years ago a FGF workshop in cooperation with the Ministry of Environment Baden-Württemberg and COST 281 took place under the title “Can electromagnetic fields used in mobile communications provoke sleep disorders?” in Immenstaad (Baden-Württemberg, Germany), 7. - 10. December 2003. (For presentations and results please see:
http://www.fgf.de/fup/tagung/thema/FGF-Schlaf-Workshop_2003.pdf (in German),
http://www.fgf.de/english/fup/meeting/thema/Short-report-FGF-sleepworkshop2003.pdf (in English),
http://www.cost281.org/documents.php?node=55&dir_session=,
Somnologie - Schlafforschung und Schlafmedizin, Volume 9, Number 4 / November, 2005:
http://springerlink.com/content/q22353766852/?p=fa86fa98af6c47f1879dbd10e1310062&pi=5.)

During the general discussion of this meeting the invited experts agreed on the following statements:

- Biological effects may not be equated with health effects.
- Whenever possible, dose-effect relations have to be determined.
- Good statistics and dosimetry with generally accepted standards should be asserted for sleep research.
- Studies should be as far as possible independently replicated to gain scientific validity.

Research in this area went on and brought out significant new results. Participants of the workshop will present the current state of research and evaluate the progress that has been achieved.

Since the main foci have slightly changed, the workshop topics will include sleep research as well as influences of RF fields on the EEG of awake persons, on cognitive functions such as reaction time and behavioral parameters, and on regional blood flow in human brain regions. Of special interest is the repeatedly reported effect of pulsed - but not continuous wave - RF fields on EEG and cognitive functions, at least from the results of one research group. Additionally, a main part of the workshop is dedicated to the progress in dosimetry for human laboratory as well as epidemiological studies.

The workshop is meant to bring together representatives of the working groups which recently have worked on these topics, and shall offer broad space for discussing their results. Specialists from sleep and cognitive research should specifically evaluate methodology and results of studies and, if necessary, give recommendations on follow-up investigations. RF dosimetry specialists shall evaluate field application technology of experimental set-ups and provide a realistic assessment of present and future exposure of the general population from base stations, mobile phones, and similar devices.

The results of the workshop will be presented in a consent report. Possibly, scientifically based recommendations on follow-up experiments and/or studies shall be derived.

Provisional course and contents of the workshop:

1. Medical basis of EEG, cognitive functions and sleep
2. Exposure conditions in residential areas close to base stations (GSM, UMTS, DECT, WLAN, WiMAX, …) and terminal equipment
3. Dosimetry for experiments with human volunteers
4. Presentation of results from laboratory and epidemiological studies
5. General discussion

MEASURING COGNITIVE FUNCTION IN THE HUMAN BRAIN WITH EEG

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Brain function can be studied non-invasively by measuring its electrical activity on the intact scalp. The possibility of these so-called electroencephalogram (EEG) recordings has been discovered in the twenties of the 19th century by the German Psychiatrist and Neurologist Hans Berger. The EEG arises from rhythmic changes of scalp voltages generated by a summation of post-synaptic potentials from a large number of neurons. Since its first discovery, EEG recordings have been widely used in clinical settings as a brain function test of a gross correlate of brain activity for monitoring and diagnostic purposes. The EEG is typically described in terms of (1) rhythmic activity and (2) transients, e.g. single events. The rhythmic activity is divided into bands by frequency. The frequency composition of the EEG typically depends on the state of the individual (e.g., degree of alertness, sleep stage, cognitive processing); it might be altered in neurological and psychiatric disorders and is affected by certain drugs. In research settings, the EEG is used as a non-invasive technique to investigate brain function. It allows determining the orchestration of brain activity with a high temporal resolution in the range of milliseconds in contrast to other brain imaging techniques such as functional magnetic resonance imaging (fMRI). However, EEG has a relatively poor spatial resolution so that the brain electrical sources of the potentials recorded at the scalp can only be approximately identified. For research purposes studying cognitive processes, mostly the event-related potential (ERP) technique is employed. ERPs contain only electrical brain activity, which is time-locked to a stimulus or an event. Most ERP experimental paradigms involve a subject being presented with a stimulus to which an overt or covert reaction is required. There are often at least two conditions that vary in some manner of interest to the researcher. As this stimulus-response is going on, an EEG is being recorded from the subject. The ERP is obtained by averaging the EEG signal from each of the trials within a certain experimental condition. The resulting voltage time course contains voltage peaks or valleys (positive or negative voltage deflection), which are typically labeled according to their polarity and latency (e.g., P3: the third positive peak; or alternatively P300: a positive peak with a peak latency of 300 ms after stimulus onset). These voltage peaks are frequently referred to as ERP components which are thought to reflect certain cognitive processes. For instance, the N2 (or N200) component recorded at the fronto-central scalp is assumed to index executive attention and is enlarged in tasks which require the inhibition of inappropriate responses. The P3 (or P300) component is thought to index working memory updating and is enlarged when a task-relevant stimulus is attended to. The advantage of EEG or ERP recordings in research setting is their non-invasive nature and their high temporal resolution so that subtle activity changes which last only a few milliseconds can be detected. EEG recordings may reveal subtle differences in brain function, which are not always accompanied by behavioral performance differences. The disadvantage of EEG measurements is their low spatial resolution and the fact that it only reflects synchronous electric activity of large neural assemblies. For a fine-grained analysis, intracranial recordings of single cells are necessary. It should also be noted that contamination of EEG recordings by artifacts (eye or head movements, external electric noise) can compromise the interpretation of the data if artifacts are not properly removed or rejected. Despite these limitations, EEG measurements are an important tool to elucidate cognitive functions in the human brain non-invasively.

SLEEP - DEFINITION, SLEEP STAGES, DISORDERS, AND METHODS OF INVESTIGATION

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Humans spent a third of their life asleep. Sleep is not just the absence of wakefulness but has its own internal structure with a well programmed sequence of sleep stages. Today we know much about sleep physiology, the functions of sleep stages and the neural and humoral processes which take place during sleep. Physical recreation, mental recreation and consolidation of memory are important tasks being fulfilled during sleep.

In order to quantify sleep and sleep stages, polysomnography is the electrophysiological recording method to be chosen. Polysomnography uses digital acquisition and analysis techniques. The digital recording has become the standard of practice over the past 20 years. Many investigators have developed strategies to record and analyze sleep in a quantitative way. Initially, digital recording and analysis were restricted by technical limitations. With current technology, the technical limitations of computer acquisition, data storage, or analysis are less constraining and the development of recommendations for the specifications and scoring of sleep can be more clearly guided by the goal of characterizing physiologic phenomena.

With the development of an AASM standard of practice for polysomnography the issue of digital acquisition, display, and analysis has now been addressed. In order to develop such recommendations and specifications, a literature search, evidence review, and standardized consensus process focused on five questions regarding computer-assisted sleep recording and analysis. These questions addressed included: 1) the reliability of computerized scoring of sleep stages, 2) the analysis of elemental events and waveforms, 3) the physiological and/or clinical significance of digitally-analyzed signals, 4) the importance of proposed changes in standardized scoring that could incorporate digital analysis, and 5) the potential advantages and disadvantages of computerized sleep recordings The evidence review suggested that computer scoring and quantitative analysis of sleep is still in the stage of development. For many technical specification decisions, little or no direct evidence was found, although basic engineering principles or standard practices provided some rationale which was utilized to develop the recommendations formulated during on the subsequent UCLA/Rand standardized consensus process.

Now we have well documented methods to investigate sleep and also sleepiness during daytime by applying defined test situations to the subjects under investigation.

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GENERAL PUBLIC EXPOSURE AROUND MOBILE PHONE BASE STATIONS

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The presentation focuses on typical general public exposure around mobile phone base stations. The following questions will be discussed:

1. What are typical exposures close to mobile phone base stations?
2. How does the exposure distribute around base stations?
3. Which factors influence exposure and which do not?
4. How does the base station exposure compare to that of other RF sources?

Extensive measurements around stations with both GSM and UMTS systems [1] show typical exposures between 0.01 % and more than 10 % of the ICNIRP [2] field strength limit. This corresponds to 10^{-6} and more than 1 % concerning the power density limits. The median values are about 1-2 % (field strength) and 0.01-0.04 % (power density), respectively. These values are spatial *peak values* and extrapolated to the *maximal operational state* of the base stations as demanded for in relevant exposure guidelines. *Space and time averaged* measurements, which were carried out in another project [3] of the German Telecommunication Research Program, show exposures which are typically 20 dB below the maximized values of [1].

The lateral distance, which is often used as exposure measure in epidemiological studies or even for the definition of an "exclusion area" around "sensitive areas" (schools, kindergartens, …) by local authorities, has proven not to be a significant factor for exposure. In contrary, due to the highly directional radiation pattern of typical base station antennas, the exposure very close to the station (up to several 10 m) is often smaller than beyond that area. Also the number of visible base stations does not really influence the individual exposure. The one factor which mainly effects exposure is the orientation to the main lobe of the antenna as well as the sight conditions to the station.
It has also been found, that from the cell size or the transmit power no conclusion can be drawn on the resulting exposure. The highest exposure were measured in microcell scenarios, which were operated with smaller transmit power than typical roof or mast installations, but use antennas mounted under the ceiling. GSM dominates exposure at about 85 % of all measurement points, which is due to higher installed transmit power, broader main lobe and smaller exposure limits compared to UMTS.

Concerning a comparison of mobile phone base station exposure to the exposure content of other sources comprehensive measurements show, that maximal exposures result from sources with close to body or body contact operation like mobile phones, DECT phones or WLAN cards. Concerning radio and TV broadcast services the exposure to LMS services seems to dominate. It can reach values in the same order as in the direct vicinity of base station an therefore must not be underestimated in a global comparison of different exposure contributions.

This work was funded by the German Federal Office for Radiation Protection (BfS) and the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) within the German Mobile Telecommunication Research Program

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PERSONAL EXPOSURE FROM COMMONLY USED WIRELESS SHORT RANGE COMMUNICATIONS EQUIPMENT

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In recent years, despite mobile phones, a variety of other wireless communication equipment has been increasingly deployed in almost everyone's personal and occupational environment. Wireless LAN (WLAN), Bluetooth, cordless phones, baby surveillance devices, wireless computer peripherals and wireless audio and video transmission systems are only a few of the technologies which are frequently used in daily life today. Although the radio frequency (RF) power radiated by these devices is comparably low, concerns about the extent of personal exposure from these devices have been raised. However, based on recently published scientific data [1-6] it can be shown that the personal exposure caused by the mentioned equipment can usually be expected far below current exposure limits [7].

Numerous indoor and outdoor measurements in the environment of WLAN equipment according to IEEE 802.11b,g (2.4-2.48 GHz, max. transmit power 100 mW EIRP) as well as computations under several different WLAN exposure conditions reported in [1-5] clearly showed that the maximum peak power density caused by WLAN equipment at distances >30 cm can be expected to be in the order of 90 mW/m^2. Typical time averaged exposure at distances of at least 1m next to a data transmitting WLAN device can be expected clearly below (in most cases far below) 1 mW/ m^2 which corresponds to clearly below (in most cases far below) 0.01% of the reference level according to [7]. For larger distances correspondingly lower exposure will appear. Exposure from WLAN equipment operated under worst case conditions directly on the body (touching the body) was assessed in [2-3] and was reported to be below 1 W/kg (SAR_{10g}) which corresponds to below 50% of the basic restriction [7].

Exposure from Bluetooth class 1 devices (max. 100 mW) can be expected similar as the figures given for WLAN due to the similar frequency range and transmit power of the devices. Exposure due to Bluetooth class II (max. 2.5 mW) and class III (max. 1 mW) devices is correspondingly lower [2-3].

Peak power densities caused by DECT cordless phones (1.88-1.90 GHz, max. 250 mW) at distances of 1 m and 3 m were reported to be well below 50 mW/m^2 and 5 mW/m^2, respectively [2-3], [6]. Time averaged exposure from DECT devices is correspondingly lower due to their fixed time frame structure, i.e., lower by a factor 24 for a device handling only 1 call (e.g., mobile part). This reduction factor decreases linearly with increasing number of handled calls, e.g., to a factor of 12 for a fixed part (base station) handling 2 calls. Maximum 10g averaged specific absorption rates (SAR_{10g}) in the users head due to DECT mobile parts operated on the ear were assessed in [2] and were reported to be lower than 0.1 W/kg.

Personal exposure caused by transmit stations of wireless audio headsets (864 MHz) and wireless Webcams (2.45 GHz) has been demonstrated to be comparably low [3]. The maximum power density caused by these devices in 1 m distance were reported to be less than 0.1% of the corresponding reference level given in [7].

Finally several types of wireless baby surveillance systems operating in different frequency bands (40 MHz, 446 MHz, 864 MHz, 2.45 GHz) and at different specified output power levels (up to 500 mW) were investigated in [2-3]. Measured maximum incident power density values in 1 m distance from the 446 MHz / 500 mW device were found to reach approximately 2% of the reference level specified in [7]. As close as 10 cm from this device the incident power density exceeded the mentioned reference level. However, SAR measurements with the device touching a flat body phantom showed that it is compliant to the basic restrictions in terms of maximum 10g averaged SAR (max. measured value 0.13 W/kg compared to the basic restriction of 2 W/kg).

In the presentation a brief overview of the technical specifications of WLAN, Bluetooth, DECT-cordless phones and some other wireless communication technologies frequently used in the personal environment will be given, followed by some important aspects related to the measurement methodology required to reliably assess the electromagnetic fields emitted by these devices. Finally the extent of personal exposure as assessed in numerous typical as well as worst case exposure conditions will be presented.

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EXPOSURE ASPECTS OF NEW AND EVOLVING WIRELESS SYSTEMS – SPECTRUM OF POWER VARIATIONS

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The use of modern digital communication devices like GSM, UMTS, HSPA, WIMAX and WiFi shows different aspects of the exposure of electromagnetic waves towards the users, be it from handsets or base station antennas. Assuming that the power level and its variation on a slow and fast time scale are the important parameters, these new systems are discussed. Experimental results are included where possible; especially the spectrum of the power fluctuations is seen as a convenient and compact way of describing very complex system behavior. The results should be of interest for scientific studies in epidemiology, human and in vitro studies, and especially for comparing experimental exposures of seemingly identical situations.

The physical significance of the SAR concept is that it is the source of heating. This may be of significance in the mobile phone case, but is insignificant in the base station case. Thus it is relevant to study other possible aspects of the radiation, and theoretically there is a possibility of nonlinear phenomena such that low frequency power fluctuations generate low frequency currents in the tissue. This is the reason for the interest in power fluctuations, where the spectrum of the power is shown for the various communication systems. It is appropriate to note that in the communications community the power spectrum is the usual measure of the occupied spectrum around the carrier, but the two measures are different (technically speaking the power spectrum is the Fourier transform of the autocorrelation of the signal, while the spectrum of the power is the Fourier transform of the square of the signal). Considering the complexity of modern systems it is recommended that future studies include the spectrum of the power variations as easy documentation of a complex system.

An example of measurement of a WiFi signal is shown for two different frequency regions in Figure 1. Over the low frequency region (Fig. 1 a) there is a broad spectrum with a maximum near 500 Hz, and for the higher frequencies a line spectrum at multiples of 1MHz.

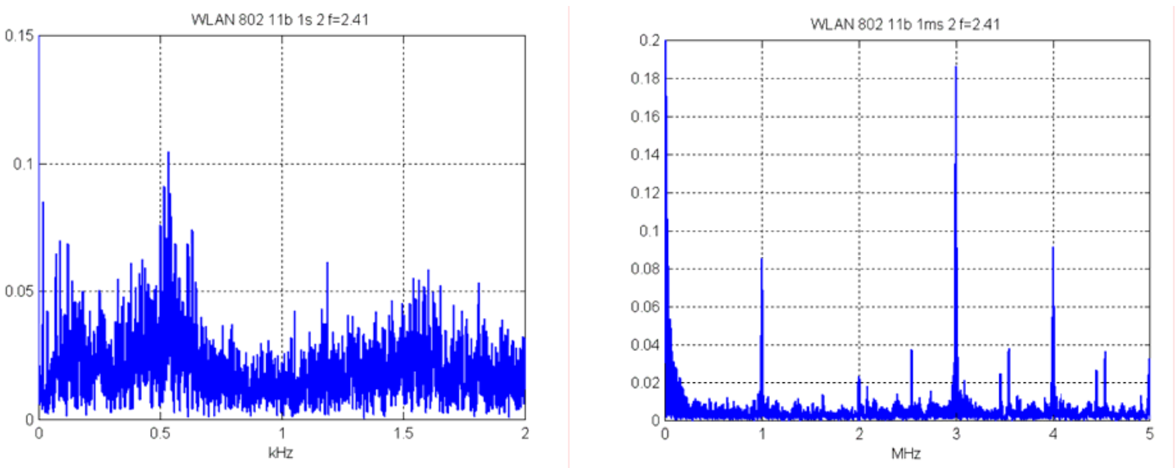

Figure 1. a) Spectrum of power variations from downloading a file from a WiFi access point, time span 1 s. b) same over a time span of 1ms.

ANALYSIS OF RF EXPOSURE OF CHILDREN AND ADULTS HEAD TISSUES

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Wireless systems are nowadays increasingly used. In line with this children are also using increasingly cellular handsets or cordless phones at home. Even if international recommendations have been set up to protect people some questions are still open and need investigation. The brain exposure and in particular the children brain exposure is one of these questions. Studies have been conducted but the results are representativeness of the phantom used. In this presentation we will analyze the SAR distribution in the tissues of different adult and children head and we compare SAR in children and adult. Adult heads have been collected from various international labs, dealing with children model have been built from MRI data.. The SAR in different tissues has been estimated using the well known FDTD. Depending on the phantom the maximum SAR over 10 g can be affected by large variability but no significant difference are observed between child and adult. We analyze the exposure of specific tissues. The total power absorbed by tissues has been analyzed. For instance with a commercial like handset operating at 900 MHz at 900 MHz. the skin of the 12 years old child head absorbs 32% of the power, 26% is absorbed by the muscle, 9% by the CSF, 9% by the skull and 23% by the brain. But such analysis has limited because of the highly inhomogeneous exposure of tissues. Because of that the maximum SAR of 1g of tissues (skin, brain, cerebellum..) have been analyzed.

In adult head the ratio between the Maximum SAR over a cube of 10g (IEEE procedure) and the maximum SAR over 1 g of continuous tissues has been analyzed. Depending on the phantom this ratio varies from 1.5 to 3.4 with a median and a mean value of 2.5 and a standard deviation of 0.6. The ratio between the Maximum SAR over 1g in cerebellum and the Maximum SAR over 1 g in brain has also been analyzed in adult at different frequencies and different source located close to the ear. This ratio is about 0,4 with standard deviation up to 20%. In the children head the ratio between Maximum SAR over a cube of 10g and the Maximum SAR over 1g in brain tissues is about 1.5 and a standard deviation of 0.3.This study seems to show that the maximum SAR over 1 gram of peripheral brain tissues of children up to 8 years old is higher than in adults. This is certainly due to the thinner pinna, skin and skull.

The results obtained with different phantoms point out the large variability and the difficulty to conclude on one phantom. The SAR induced by a same source in different heads is varying with a standard deviation of 30% for maximum SAR over 10g and about 50% for the maximum SAR over 1g in the brain.

The question of uncertainty is now the main challenge of the dosimetry.

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N.N.

to be announced

RADIO-FREQUENCY ELECTROMAGNETIC FIELDS: EFFECTS ON BRAIN PHYSIOLOGY

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Usage of mobile phones is rapidly increasing and there is rising concern about possible adverse health effects of radio frequency electromagnetic field (RF EMF) exposure at intensities even below the general threshold in guidelines. In recent years we investigated the effects of RF EMF on the electroencephalogram (EEG) during sleep and wakefulness, on waking regional cerebral blood flow (rCBF), and on cognitive performance. In seven studies, we applied different types of RF EMF: a pulse-modulated EMF (pm-EMF, "handset-like signal), approximating the spectral content emitted by GSM mobile phones, and a base station-like signal, approximating the signal emitted by a GSM base station. These two exposure conditions included the same ELF modulation components; however, the spectral power of these components was considerably higher in the handset-like signal (for signal characteristics see Huber et al., 2005). Furthermore, we used a non-modulated continuous-wave signal (cw-EMF), as well as a sham exposure, which served as a control condition.

All experiments were performed in a double-blind, crossover design in the sleep laboratory of the Institute of Pharmacology and Toxicology at the University of Zurich. Healthy, young men were exposed during an entire night-time sleep episode to an intermittent radiation schedule (Borbély et al., 1999) or for 30 min during the waking period prior to waking or sleep EEG recordings (Huber et al., 2000, 2002, 2003, 2005; Regel et al., 2007a, b).

Effects on the EEG:

We consistently demonstrated that exposure to pm-EMF increased spectral power of the non-REM sleep EEG in the spindle frequency range (Borbély et al., 1999, Huber et al., 2000, 2002, 2003; Regel et al., 2007b). In line with these findings, the most recent study revealed first indications of a dose–response relationship between EMF field intensity and the increase in spindle frequency activity (Regel et al., 2007b). Exposure to pm-EMF also increased spectral power in the alpha frequency range prior to sleep onset (Huber et al., 2002) and 30 min after exposure in relaxed wakefulness (Regel et al., 2007a). No effects were observed for cw-RF EMF (Huber et al., 2002; Regel et al., 2007a).

Effects on rCBF:

Handset pm-EMF exposure increased relative rCBF in the dorsolateral prefrontal cortex ipsilateral to the exposure side (Huber et al., 2002, 2005).

Effects on cognitive performance:

In a first study, we observed a significant 'condition' effect on speed for pm-, but not cw-exposure in two out of five investigated tasks (2- and 3-back task). Moreover, in the 3-back task, accuracy was affected with increasing exposure duration (Regel et al., 2007a). In a second study, including the same tasks, reaction speed decelerated with increasing field intensity in the 1-back task, while accuracy was not affected in neither task in a dose-dependent manner (Regel et al., 2007b).

Our results provide evidence that the pulse modulation of a RF EMF is necessary to induce changes in the EEG during waking and sleep. Moreover, these changes may outlast the exposure period and may be dose-dependent. While the effects on the EEG were homogeneous, results on cognitive performance remain inconsistent.

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EFFECTS OF EMF ON BRAIN ELECTRIC OSCILLATIONS AND COGNITIVE PROCESSES

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This presentation reviews and discusses recent findings on the effects of EMF on brain electric oscillations and human cognitive processes. Results from both behavioural and electrophysiological (EEG) studies will be presented and discussed. Several of the reviewed studies have reported effects of EMF on cognition and also on the EEG, especially during the performance of cognitive/memory tasks. However, the observations remain controversial. The mechanisms underlying the observed effects and the inconsistency in the findings remain unexplained. What conclusions can accurately be drawn from statistically significant, not replicable and subtle effects of EMF on behaviour and the EEG?

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EFFECT OF MODULATED 450 MHZ MICROWAVE ON HUMAN EEG RHYTHMS AND COGNITIVE PROCESSES

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Introduction

Effects of microwave radiation on human brain bioelectrical activity have become of major interest with increasing applications of telecommunication devices. The difficulties in independent replication of the experimental results cause doubts in these effects and mechanisms behind the effects are still unclear.

The summary of our studies during last years on evaluation of the effect of modulated low-level microwave radiation on human EEG and visual cognitive processes is presented [1-9 et al.].

Our presumptions were:

1. Microwave exposure as a weak physical stressor causes only small changes in EEG and the effect is hidden in natural variability of the EEG signal [10]. This is also a reason for doubts in microwave effects. Therefore we used special signal processing methods sensitive to reveal small hidden changes in the EEG signal.
2. Effect of microwave exposure differs for individuals, some of the subjects under investigation may be significantly affected and the others not affected. Therefore, the effect of microwave can become statistically significant for some individuals whereas insignificant for the group.

Methods

The experiments on EEG were carried out on four different groups of healthy volunteers subjected to 450 MHz microwave radiation modulated at different frequencies:

- 1-st group, 19 persons (aged 19-23), 10 male and 9 female, modulation 7 Hz;
- 2-nd group, 13 persons (aged 21-30), 4 male and 9 female, modulation 14 and 21Hz;
- 3-rd group, 15 persons (aged 21-24), 8 male and 7 female, modulation 40 and 70 Hz;
- 4-th group, 19 persons (aged 21-24), 8 male and 11 female, modulation 217 and 1000Hz.

The experiments on visual memory tasks were performed on a group of 100 and method of face masking on a group of 10 healthy volunteers at 7 Hz modulation frequency.

The field power density at the scalp during all experiments was 0.16 mW/cm^2. Ten cycles of the exposure during EEG recordings (1 min off and 1 min on) at fixed modulation frequencies were applied. The EEG channels for recordings were chosen to cover the entire head: frontal- FP1, FP2; temporal- T3, T4; parietal- P3, P4; occipital- O1, O2. EEG signals recorded in the theta (4-6.8 Hz), alpha (8-13 Hz), beta1 (15-20 Hz), and beta2 (22-38 Hz) rhythms frequencies were analyzed. For EEG analysis two methods were proved most effective: 1) the method of modulation with further integration of energy and 2) the multifractal method of scaling analysis based on the length distribution of low variability periods.

Results and discussion

Our experimental results showed that:

- the effect of the modulated microwave on the human EEG differs at different modulation frequencies and becomes more evident at modulation frequencies within the EEG physiological spectrum;.

- microwave exposure caused an increase in the EEG alpha and beta rhythms energy (average increase up to 17% for group, up to 150% for individuals);
- changes occurred in majority in temporal and parietal EEG channels;
- changes appeared in beginning of the exposure and adaptation of the brain followed;.
- neurophsychological tasks associated with attention and short-term memory showed a significant increase in variances of errors in the exposed group versus the sham exposed group;
- stimuli recognition in face masking task was better under the sham exposure conditions (actual difference 5%).

The rate of subjects whose EEG was significantly affected differs with modulation frequency: 3 subjects (16%) at 7 Hz; 4 subjects (31%) at 14 Hz, 3 subjects (23%) at 21 Hz, 3 subjects (20%) at 40 Hz, 3 subjects (20%) at 70 Hz, 3 subjects (16%) at 217 Hz and 0 subjects at 1000 Hz modulation frequency.

These values are even higher than the rate of multiple chemical sensitivity occurrences that is estimated to be between 2 and 10 % in the general population [11]. Increased beta absolute power was also observed in alcohol-dependent subjects [12].

Conclusion

Our experimental results showed that exposure to modulated at low frequencies 450 MHz microwave caused significant increase in the EEG beta rhythms energy for 13 - 31% of the subjects. Changes in visual cognitive processes were small, however statistically significant.

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DOES THE EXPERIMENTAL OUTCOME OF HUMAN PROVOCATION STUDIES DEPEND ON THE DESIGN SPECIFICS OF THE EXPOSURE SETUP?

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In the past few years, the IT'IS Foundation collaborated with various research groups on several experimental provocation studies investigating the effects of exposure to RF EMF on human brain activity [1, 3, 4, 5, 6, 7, 8, 15, 16, 17, 18, 19] and conducted dosimetric post-analyses of several third party studies [2, 9, 10, 11, 13, 14]. These studies investigated the RF effects on EEG (during sleep and wakefulness), on waking rCBF, cognitive performance, sleep quality, subjective symptoms, etc. The overall findings indicate that RF EMF affect human brain activity. Furthermore, the results suggest dependence of the effect on the exposed tissues and on the ELF spectral content of the amplitude-modulated signal [1, 5, 7]. The results from these studies, however, are not always consistent, particularly in comparison to the available literature on the RF effects on brain activity. Some of the discrepancies may be explained by differences in the experimental design, exposure setup, sample size, blinding, age and gender of the subjects, etc. We will discuss how the differences in the exposure (exposure duration, signal characteristics, induced fields as a function of brain tissues and time of day of the exposure) may explain some of the discrepancies. We will also illustrate that many early studies insufficiently characterized the exposure by not providing the minimal dosimetric quantities as suggested in [12]; thus, in-depth interpretations or adequate replications/verification of the studies were not possible. Our objective is to derive optimal exposure parameters for future studies to further clarify the interactions of RF exposure on brain activity.

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THE HUMAN BRAIN UNDER MOBILE PHONES EXPOSURE: EFFECTS ON NEUROPHYSIOLOGICAL, COGNITIVE AND BEHAVIORAL FUNCTIONING

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In our society ever more people use mobile phone (MP) technology and this trend will dramatically increase in the next years. As a consequence, it is increasing the interest toward the possible effects on users' brain activity.

During the past years in our laboratory we focused on the effects of MP exposure on several parameters of human cerebral functioning: vigilance and attention, working memory and subjective symptoms, resting EEG and evoked potentials, inter-hemispheric functional coupling of EEG and cortical excitability.

We observed and reported significant effects on behavioural and electrophysiological parameters, and also on measures of cortical excitability. These results were often in agreement with the existing literature in the field of bio-electromagnetic interaction. But, as in the whole literature in this research field, also our effects resulted very subtle and, consequently, highly vulnerable to statistical errors. This problem was particularly relevant for performance measures, where a high variability is usually observed and a greater vulnerability to placebo effect is assumed.

Thus, taken together our studies suggest that: (a) the acute effects induced by GSM-like signals are reversible and transient, (b) the more sensitive measures seem to be the electrophysiological and metabolic/cortical functioning ones, and (c) the possible mechanisms of interaction between EMFs and biological tissue are likely non-thermal.

Nonetheless, it is well-known that many issues are still far to be clarified and well understood. Thus, on the basis of both current and planned studies of our group, it is proposed and discussed a research agenda for further investigations:

- to test more in depth the applicability of these results to real life (at work, driving a car, etc.);
- to test the relevance of these data to specific populations as elderly, often indicated, with children, as the most sensitive and/or vulnerable to EMFs exposure;
- to clarify the hot issue of the washing out period;
- to study what happen to the brain also during the exposure to the radiations;
- to turn the attention toward neuroimaging or cerebral functioning techniques (e.g., cortical excitability), that seem to confirm a small but clear effect of EMFs exposure;
- to dedicate particular care to both methodological and statistical control (blinding techniques, sample size, effect size).
-

Answering to these questions will help to definitively clarify the acute effects of MP exposure on users' brain functioning and, possibly, to suggest some of the long-term health effects not yet taken into consideration.

EXPOSURE TO MOBILE PHONES - STUDIES ON NERVOUS SYSTEM IN HUMANS

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Mobile phones expansion raised concerns about the eventual health risks from microwaves they emit. As the main worry about cancer has been widely addressed with most negative answers, some other claims such as headache, neurological diseases, or some kind of hyper sensitivity still remain. Laboratory in vitro and in vivo experiments can be helpful in orienting the answers, but are not always valid for humans. On the other hand, if long term effects are suspected, epidemiological studies will bring results only after some years. Furthermore, there must be an initial detectable effect before any actual pathology. Therefore studies were performed in parallel on human physiology with mid-term exposures. From the literature, research oriented on the nervous system, which started in 1994 at the University Hospital in Nîmes.

Research on the nervous system

EEG

Effects of exposure to radiofrequency (RF) electromagnetic fields of variable powers have been demonstrated in animals. Today’s spectacular rise in cellular telephone use stimulated research into the potential effects on human health. In this study, we specifically investigated the interaction of cellular telephone electromagnetic fields with cerebral electrical activity. Seventeen normal subjects were separated into two groups based on gender. Nine men and 8 women, aged 20 to 25 years, were exposed for one hour to global system mobile (GSM) telephones (Motorola D-460 model), transmitting at a frequency of 900 MHz. In addition, a sham exposure was carried out in a group of 6 male controls. Digital electroencephalograms (Q-EEGs) were recorded before and after the 1-hr exposure. In the 17 experimental volunteers, the post-exposure results showed an increase in the power of all frequency bands: □□□ı□□□ı□□ and □□ in the condition with eyes open, and □□□ı□ı□□ and □□ in the condition with eyes closed. The male group showed fewer modifications than the women and there was no significant modification in the control EEG patterns. It seems then that EEG is sensitive to mobile phone exposure, as it was already published by Mann and Röschke, and also by Thuroczy. Further work is needed to define : i) the parameters important for this effect ii) the potential health impact of this effect.

Cognitive

Up to now many papers have been published concerning the effects of acute radiocellular telephones (RCT) exposure on psychomotor performances. In a preliminary experiment, a slight but not statistically significant improvement of attentional functions could be hypothesised in view of an increase and a decrease of raw scores of forward digit span and reaction time in exposed subjects during EP. We looked in this study to check the effects of chronic exposure to RCT GSM 900 type on psychomotor performances including attentional functions.

55 subjects, 27 males and 28 females, aged from 18 to 40 years (mean age 24.25 ± 3.8 years) who previously used RCT less than 10 min a day, were selected and randomly divided into two groups: 28 subjects (14 male and 14 female) with emitting RCT and 27 subjects (13 male and 14 female) with non-emitting RCT. Subjects were paired by IQ.

Subjects underwent a first psychomotor test learning session on D-2 (pre-exposure period: PP). The psychomotor test battery was as the following: Auditory Verbal Learning Test (AVLT), Digit Span (forward and backward) and “digit-letters” sequences, visuospatial span (forward and backward), sustained attention and visuospatial availability (barrage de Toulouse-Piéron), stress test by Stroop, Visual reaction time and Choice reaction time (Hagfors), manual dexterity (Purdue Pegboard), visual memory (Benton), amorçage perceptif. Eight parallel series were made for the AVLT and the Digit spans. Three days later (D1), subjects began the exposure period (EP). They came to the lab and were "exposed" during 4 weeks (until Day 28), 2 hours/day, 5 days/week from 05:00 p.m. to 07:00 p.m. or 06:00 p.m. to 08:00 p.m.. During exposure, subjects were sitting on a chair, hanging a RCT and watching a movie on TV in order to sustain attention and initiate a correct holding of the phone. In order to appreciate the reversibility of possible effects of RCT on psychomotor performances, all subjects were sham-exposed for two more weeks (recovery period: RP). Psychomotor tests were performed three days before the EP (PP), then on the morning following the last day of every two-weeks intervals, i.e. twice during the EP (after two and four weeks of exposure) and once two weeks later at the end of the RP.

Psychomotor tests were not modified in human volunteers after chronic RCT exposure.

Alain Besset, Fabrice Espa, Yves Dauvilliers, Michel Billiard, René de Seze (2005) No effect on cognitive function from daily mobile phone use. Bioelectromagnetics 26:102-108

Sleep

The increasing use of radiocellular telephones (RCT) has raised the problem of its effects on human health. In an attempt to test the effects of exposure to RCT on sleep, a preliminary study was conducted in our sleep laboratory using GSM 900 type (Global System for Mobile at 900 MHz). Eight subjects (7 female and 1 male aged 25.7 ± 3.8 years) who never used RCT previously were selected and randomly divided into two groups: 5 with emitting RCT and 3 with non-emitting RCT.

The subjects underwent 3 selection and habituation nights of sleep recording (night polysomnography: NPSG) in order to be included in the study as good sleepers. 2 baseline NPSG (N0, N1) were performed 2 weeks later. At day 3 (D3) subjects began the exposure period (EP). Subjects came to the lab and were "exposed" (sitting on a chair, hanging a RCT and watching a movie on TV in order to sustain attention) during 4 weeks (until D28) 2 hours/day, 5 days/week from 06:00 p.m. to 08:00 p.m. In the middle (N14, N15) and at the end (N28, N29) of EP two new NPSG were performed. Finally two last NPSG were performed 2 weeks later in order to appreciate the reversibility of possible effects of RCT on sleep.

Classical methods were used for NPSG: 2 channels of electroencephalography, 2 channels of electrooculography, 1 channel of chin electromyography and 1 channel of electrocardiography. Sleep macrostructure was analysed according to Rechtschaffen and Kales criteria and sleep microstructure was assessed by means of spectral analysis (Embla recorder).

There was no difference between the 2 groups and between all of the different periods of the study on polysomnographic data (total sleep time, sleep stage latencies, percentage of occupation of each sleep stages, wake after sleep onset, sleep efficiency) and spectral analysis did not reveal any disturbance of power density in any frequency band (0.5-25 Hz). Finally, the exponential decay of slow wave activity (best homeostatic process marker) was similar in the 2 groups during all of the experiment periods.

No effect of RCT has been found in this study but the limited number of subjects does not allow such a conclusion. Complementary studies with more subjects are needed to confirm these preliminary results.

Effects of radiocellular telephones on human sleep : F. Espa, B. Ondze, A. Besset, M. Billiard, R. de Seze. Unité des Troubles du Sommeil et de l'Eveil, hôpital Gui de Chauliac 34295 Montpellier cedex 5, Laboratoire de Biophysique Médicale, CHU Nîmes 30907 Nîmes cedex 2. BEMS 2000, Munich

What about heating?

The thermal effect due to the absorption of the electromagnetic field (EMF) emitted by the mobile phone (MP) on the user's head is very small. Air insulation and thermal conduction due to the MP in contact with the user's head contribute more to heating. The thermal effect of the MP EMF emission could also be masked by activation of the thermoregulation mechanisms permitting control and stabilization of the body temperature.

Audition

In humans, as the auditory organ is the most exposed, we measured the auditory brainstem responses before and after 1hr exposure to mobile phones. No difference was observed. Chabert et de Seze, 1996.

E. Maby, R. Jeannès, G. Faucon, C. Liégeois-Chauvel, and R. De Seze (2005). Effects of GSM Signals on Auditory Evoked Responses. Bioelectromagnetics 26, 5, 341-350

+ Mondain, 2003

Up to now many papers have been published concerning the effects of acute RCT exposure on the auditory system. In a preliminary experiment, a sparse change on distortion products of otoemission (DPOE) has been observed after 30 min. exposure. We looked in this study to check the effects of chronic exposure to RCT GSM 900 type on the auditory system.

55 subjects, 27 males and 28 females, aged from 18to 40 years (mean age 24.25 ± 3.8 years) who previously used RCT less than 10 min a day, were selected and randomly divided into two groups: 28 subjects (14 male and 14 female) with emitting RCT and 27 subjects (13 male and 14 female) with non-emitting RCT.

Subjects underwent a first auditory examination on D-2 (pre-exposure period: PP). The auditory system was tested as follows: tone and voice audiometry, DPOE exploring the outer ciliated cells (OCC), and medial efferent system through controlateral stimulation. Three days later (D1), subjects began the exposure period (EP). They came to the lab and were "exposed" during 4 weeks (until Day 28), 2 hours/day, 5 days/week from 05:00 p.m. to 07:00 p.m. or 06:00 p.m. to 08:00 p.m.. During exposure, subjects were sitting on a chair, hanging a RCT and watching a movie on TV in order to sustain attention and initiate a correct holding of the phone. In order to appreciate the reversibility of possible effects of RCT on psychomotor performances, all subjects were sham-exposed for two more weeks (recovery period: RP). Auditory tests were performed before the EP (PP) and at the end of the EP (after four weeks of exposure).

No effect was seen on the tone or voice audiometry of the subjects. No effect was seen on DPOE but at one stimulation frequency: this isolated change with a p of 0.02 is of no physiological meaning, but could be further explored on a larger sample. Distortion products under controlateral stimulation at 60 dB were slightly modified after exposure at the higher stimulation frequencies. This effect is worth complementary studies for confirmation and relation to duration and dose of exposure, but does not support a toxicity on the medial efferent system.

EMF, COGNITION, BRAIN: EXPERIENCES FROM STUDIES ON ADULTS AND CHILDREN SINCE 1999

Heikki Hämälainen

SLEEP DISTURBANCES NEAR MOBILE PHONE BASE STATIONS

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In a double-blind crossover field study the potential role of radio frequency (RF) electromagnetic fields (EMF) in causing sleep disturbances was investigated in the sleeping rooms of 44 electrosensitive volunteers (one 10 year old girl, 26 women and 17 men). With a new approach potential sleep parameter changes were investigated associated with field reduction rather than provocation to elevated levels of RF-EMF exposures mimicked at laboratories. For exposure verification and quality control RF immissions were continuously recorded. Three test conditions (true-shield, shamshield and control) were selected in random order. In total, sleep quality of 475 nights could be assessed by morning questionnaires and polysomnographic recordings. Pooled analysis of all control nights did not exhibit a statistical significant dependence of sleep quality on RF-EMF immissions. Volunteer-specific results did not indicate adverse health effects, neither from total RF-EMF immissions nor from mobile telecommunication EMF. Most of the volunteers (73%) did not exhibit significant sleep quality changes. Several volunteers (16%) exhibited significant placebo effects. Three volunteers were identified having checked shielding and giving biased answers. However, 6 volunteers (14%) showed consistent statistical significant subtle effects of RF-EMF on their sleep quality, in particular an enlargement of sleep onset latencies. The results do not allow accepting the null hypothesis. Since the existing exposure limits prevent from health-relevant effects (only) rather than from any measurable response to RF-EMF exposure, the results do not challenge the limits. However, they are of particular interest in regard to potential interaction mechanisms of weak (non-thermal) radiofrequency electromagnetic fields.

Acknowledgement
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NO INFLUENCE OF 1970 MHZ UMTS-LIKE EXPOSURE ON SELECTED PARAMETERS OF HUMAN VISUAL PERCEPTION AND ATTENTION

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Objective: To date there is still a lack of studies that investigate possible effects of mobile phones of the UMTS-communication system on human perception and cognition. The results of two separate studies on effects of electromagnetic fields (EMF) emitted by mobile phones of the third generation on visual perception and attention are presented.

Methods: In the first study, possible effects of exposure to a generic 1.97 GHz UMTS-like signal on human visual perception were investigated in a double blinded, crossover study including 58 healthy volunteer subjects (29 male, 29 female), aged 29 +/- 5.1 years (mean +/- SD). Each subject underwent a battery of four different tests of visual perception (Critical Flicker and Fusion Frequency, Visual Pursuit Test, Tachistoscopic Traffic Test Mannheim, Contrast threshold) three times (two different exposure levels and sham exposure). In the second study, 40 healthy subjects (20 female, 20 male), aged 26.0 years (range 21-30 years) underwent four different tests on different aspects of attention (Vienna Reaction Test, Vigilance Test, Vienna Determination Test, Critical Flicker and Fusion Frequency) under three different UMTS-like exposure conditions (2 exposure levels plus sham exposure).

Exposure system and conditions were the same for both study groups: The generic signals applied to the subjects' head represented the RF emissions of an UMTS mobile phone under constant receiving conditions and the under condition of strongly varying transmit power, i.e., the signal envelope contained low frequency components. In the high exposure condition the resulting average exposure of the test subjects in the cortex of the left temporal lobe of the brain was 0.63 W/kg (1 g averaged SAR) and 0.37 W/kg (10 g averaged SAR). Low exposure condition was one tenth of high exposure and sham was at least 50 dB (corresponding to a factor of 100,000) below low exposure. Exposure condition (high, sham, low) was chosen randomly for each subject at the beginning of each session by the control software of the exposure system.

Results: Statistical evaluation revealed no statistically significant differences in the investigated parameters of visual perception and attention between the exposure conditions and sham exposure.

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HUMAN PROVOCATION STUDIES IN MOBILE PHONE USE

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We have studied effects of EMFs from mobile phones or mobile phone base station on the human central nervous system by provocation studies on humans. The auditory system, sensory cortex, motor cortex, saccade system and frontal cortices have been the targets of our study. In this communication, we summarize our works. In all these studies, we recorded the following responses before and after real and sham provocations and compared them.

Auditory system: The auditory system has been studied by recording auditory brainstem response (ABR), middle latency response (MLR) and their paired stimulation responses. Neither real nor sham provocations had any effects on those responses.

Sensori-motor cortices: The sensory cortex was studied with sensory evoked potentials (SEPs) and paired stimulation SEPs. The motor cortex was studied with transcranial magnetic stimulation (TMS) of the motor cortex and paired TMS technique.

Saccade system and hand reaction time: The visually guided saccade (VGS), gap saccade (GAP), and memory guided saccade (MGS) tasks and also a precued choice hand reaction time (RT) task were performed.
In these all studies, we did the experiments in normal volunteers. In all of them, neither real nor sham provocations affected any parameters. These results indicate that brainstem auditory pathways, temporal auditory cortex, primary sensory cortex, primary motor cortex were unaffected by the mobile phone use. Moreover, the paired stimulation results suggest that small inhibitory interneurons are also not influenced by EMFs from mobile phones.

Subjects with mobile phone related symptoms (MPRS)
Effects of EMF from the base station on psychological parameters, choice reaction times and cardiovascular parameters in subjects with MPRS and without it

Our questionnaire study from 5000 persons revealed that 1.2% (29/2472) of normal volunteers had some MPRS. Neither subjects with MPRS nor those without it correctly judge the presence of EMF. Some negative psychological parameters (fatigue, confusion and so on) increased after real and sham exposures in both groups of subjects. The reaction times and cardiovascular parameters were unaffected by EMFs from base station in both groups of subjects. We have shown no objective clues supporting that MPRSs have some correlation with actual EMF exposure.

EFFECTS OF ELECTROMAGNETIC FIELDS EMITTED BY COMMUNICATION SYSTEMS ON HUMAN COGNITION

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Three studies have been carried out to investigate whether RF EMF produced by occupational communication systems had robust effects on cognitive performance and self-reports of mood, anxiety and workload. Double-blind repeated measures design was used to investigate the following fields in comparison to sham: a high frequency (HF) 29MHz continuous wave (CW) signal, a very high frequency (VHF) 75MHz CW field, an Ultra High Frequency (UHF) frequency modulated 448MHz field, a UHF 1206MHz CW signal and a TETRA 381MHz field pulse modulated at 17.6Hz.

The first study investigating the effects of military communication system signals demonstrated no significant effects of the 75MHz signal on performance when compared to sham. The 29MHz signal appeared to reduce response time in two of the cognitive tasks and affect error rate on one of them. However, once error calculations were taken into account these results were non-significant. The second study again focussed on military signals, this time investigating 448MHz and 1206MHz signals. The results showed no significant differences between conditions. For the final study a TETRA signal was investigated, the results appeared to show reliable differences between TETRA exposure and sham conditions in two of the tasks. Only one of these remained significant following error correction; the TETRA signal appeared to significantly decrease the accuracy of response to the semantic recognition task. However, a more reliable measure of accuracy from the task demonstrated no significant differences between conditions.

Overall the results indicate that RF EMF signals at the frequencies and power levels used in these studies are well tolerated in healthy subjects. In general, the signals do not appear to have reliable and robust effects on human cognitive performance.

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SUMMARY AND UPDATE OF THE AUSTRALIAN CENTRE FOR RADIOFREQUENCY BIOEFFECTS RESEARCH (ACRBR) HUMAN NEUROPHYSIOLOGY RESEARCH

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Background:

The Australian Centre for Radiofrequency Bioeffects Research (ACRBR) was established in 2004 to conduct research into possible health-related consequences of using low-level radiofrequency (RF) emitting devices. In particular, one of the main focuses of the ACRBR research program is the potential effects of second and third generation mobile phone technologies on human neurophysiology, with a number of studies investigating the effects on human sleep, the electroencephalogram (EEG), and cognitive performance previously reported, and a number of neurophysiological studies currently ongoing.

This presentation will focus on the ACRBR's previous and ongoing research regarding the effects of mobile phone electromagnetic fields (EMF) on human sleep and the sleep EEG, and also provide a summary of the progress to date regarding the ACRBR's awake EEG and cognitive research.

Previous Sleep Results:

Fifty participants were exposed to pulsed high-frequency EMF emitted by a mobile phone handset, with continuous transmission and constant power output, for a period of 30 min prior to a full night-time sleep episode (Loughran et al., 2005). Exposure to mobile phone RF prior to sleep enhanced EEG spectral power in the 11.5-12.25 Hz frequency range, with the largest effect being seen at 11.5 Hz. This enhancement of EEG spectral power was seen in the first 30 minutes of the first NREM sleep period, however, there were no significant changes in EEG found for this frequency range or any other frequencies in any of the subsequent NREM periods. Furthermore, the results did not show any evidence of a change in EEG spectral power during REM sleep following mobile phone EMF exposure. In regards to conventional sleep parameters, the results suggested that exposure to RF prior to sleep decreases REM sleep latency.

Follow-Up Sleep Study (results expected 2007):

Results of a follow-up sleep study designed to replicate the original study reported by Loughran et al. (2005) are expected late 2007. The study specifically aims to test whether the changes in EEG found previously can be replicated and to investigate further the possibility of individual differences in response to mobile phone emissions. The latter will be achieved by grouping participants, based on whether their alpha increased with exposure in the original study, and determining whether they exhibit the same pattern of response.

Summary of Awake EEG and Cognitive Research:

Hamblin et al. (2006) investigated the effects of pulsed high-frequency EMF emitted by a mobile phone handset on N100 amplitude and latency, P300 latency and reaction time during an auditory task. Visual measures were also explored. No significant differences were found between exposure conditions for any auditory or visual event related potential (ERP) component or reaction times. As previous positive findings were not replicated, it was concluded that there is currently no evidence that acute mobile phone exposure affects these indices of brain activity. Additionally, the effect of exposure on the resting EEG was also investigated, with mobile phone exposure found to enhance EEG alpha band activity overall, but more so at ipsilateral sites ($p<0.05$) (Croft et al., 2007).

Currently the ACRBR is also completing a study to compare the effects of a 30-minute exposure to GSM, CDMA, and sham conditions on resting alpha and working memory. This study will be completed late 2007 and particularly aims to extend previous findings to both younger and older populations, and also provide a positive control (250mg caffeine).

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THE EFFECTS OF 900MHZ GSM WIRELESS COMMUNICATION SIGNALS ON SUBJECTIVE SYMPTOMS, PHYSIOLOGICAL REACTIONS, ALERTNESS, PERFORMANCE AND SLEEP; AN EXPERIMENTAL PROVOCATION STUDY

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Abstract
In the current study we assessed possible effects of prolonged (3 hours) exposure to 884MHz GSM wireless communication signals on cognitive function, electroencephalographically (EEG) recorded sleep, spatial memory, simple reaction time and physiological variables as heart rate variability and stress hormones and self-reported symptoms related to mobile phone use. The study design consisted of a double blind within-subjects provocation comparing effects during exposure to radiofrequency fields (RF) and sham exposure, and between-subjects comparisons of a 'symptomatic (SG)' and 'non-symptomatic' (NG) group. Subjects were defined as 'symptomatic' if they reported having experienced symptoms headache, vertigo or other kind of pain or discomfort in the head in relation to use of mobile phones. Heat sensation alone was not considered as an indication of symptom.

The participants were between age 18 and 45 (mean age 29+/-7) and were recruited through advertisements in a local newspapers between November 2004 and January 2006. Exclusion criteria were attribution of symptoms to other electrical equipment than mobile phones, medical or psychological illness where current symptoms could not be excluded; a history of brain injury; some present medication, sleeps disorders, hypertension and ongoing pregnancy.

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 psSAR10g of 1.95W/kg (average interval duration of 11 seconds) and DTX at psSAR10g of 0.23W/kg (average duration of 5s) resulting in time averaged psSAR10g of 1.4W/kg. The exposure was applied by a patch antenna on the left side of the head simultaneously exposing all possible exposure footprints of mobile phones as well as the deeper brain structures, i.e., 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, (Kuster 2004). The signal unit was computer-controlled allowing double blind exposure protocols (study group and Swedish research team). The exposure was monitored, controlled and recorded in an encoded file by the Swiss team at the IT'IS Foundation. The setup allowed continuous monitoring of the exposure by the Swiss team who were thus able to detect any degeneration or malfunction of the system. The system was also designed to prevent overexposure.

The exposure was conducted between 7.30 p.m. and 10.30 p.m. A habituation session, identical to the exposure sessions with the exception that the participants were informed that there would be no RF exposure and blood samples were only drawn at one time, preceded the exposure sessions. Equipment used for registration of outcome parameters

was applied. A medical examination including a medical history and physical examination was performed at the start of this session. Subjects were also screened for sleep disorders during the habituation session. The provocation sessions were performed in a specially designed laboratory at the Karolinska Institute in Stockholm, Sweden.

Overall Results

A total of 92 subjects who met the primary inclusion criteria were willing to participate according to the presented study protocol carried out the habituation. However, seven participants were excluded due to medical reasons after the habituation session. Another 14 subjects left the study after the habituation session. The final study population consisted after habituation session of 71 subjects, 33 males, (SG =14; NG =19) and 38 women, (SG =24, NG = 14). Additionally two subjects dropped out after first exposure session.

All subjects reported a daily use of mobile phone of at least 5 minutes (and up to 5 hours). The only scored symptom in the baseline assessment that was experienced significantly more often and more intensely in the symptom group was forgetfulness. The symptom group reported longer calling time per day than the non-symptom group. There was a significant difference in call times between the symptom and non-symptom groups ($p = 0.01$). In the non-symptom group 39% reported daily mobile call times > 40 min compared to the symptom group, where 58% reported call times > 40 minutes. Only 13% of the symptom group and 42% of the non- symptom group reported call times < 20 minutes. No association was found between call time and reported symptoms.

Neither group could no better than chances determine whether RF exposure had been active or not. Seven subjects were right both times, two in the symptom group and five in the nonsymptom group. Five subjects in the symptom group and six subjects in the non-symptom group reported RF exposure at both sessions (n.s.).

Acknowledgment

Funding for the study was provided by the Mobile Manufacturers Forum (MMF).

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EFFECTS ON SLEEP ARCHITECTURE OF AN EXTENDED EXPOSURE TO RADIO FREQUENCY FIELDS

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Introduction

Mobile phone use has increased in society and reports have been given on altered sleep from radiofrequency fields. Independent research teams have reported an increase in the EEG power spectrum for differential and narrow bands of the spectrum. But the results are not very consistent. In general, the traditional manual sleep score parameters are seldom affected. A drawback of earlier studies is the rather short exposure times of less than one hour preceding sleep.

Aim

To establish whether exposure to radiofrequency fields (RF) caused by mobile phone use during the day leads to a change in brain electric oscillations during subsequent sleep.

Method

The participants (N=55) consisted of men and females, accustomed daily mobile phone users, aged 18-45 years (mean age 29), with (symptomatic) and without (non-symptomatic) symptoms (headache, dizziness and concentration difficulties) they associated with mobile phone use.

A double blind, repeated measures crossover (separated by one week) provocation study comprising of a 3-hour long exposure (19.30-22.30) in the evening prior a 7-hour sleep (23.30-06.30) was carried out. Subjects were exposed to a GSM handset signal (timeaveraged psSAR of 1.4W/kg).

EEG, EOG, ECG and submental EMG were measured (EMBLATM system, 200 Hz sampling rate) and Ag/AgCl electrodes with eight referential EEG derivations were included. Sleep stages were visually scored in 20-second epochs according to a standard manual scoring procedure. Sleep data were subjected to a repeated 2-way ANOVA using the factors Group (symptom/non-symptom group) and Exposure (RF/Sham).

Results

Results from the manual scoring are presented in table 1. The results demonstrated that subjects after RF exposure obtained less stage 4 sleep (mean difference Sham/RF=9.6 minutes, $p=0.001$) and latency to stage 3 was increased by 0.11 hours ($p=0.003$). A second analysis using hour since sleep onset as a factor and summed stage 3 and 4 sleep (SWS) demonstrated that the main effect of exposure remained ($p<0.05$) and the interaction between exposure and hour of sleep showed a tendency ($p<0.10$) indicating the differences in SWS was somewhat stronger during the first three hours of sleep. Self-reported sleep did not show any effects of exposure. The results showed that two aspects of sleep recovery, SWS content and stage 3 latency were affected by prior RF exposure.

Table 1. EEG visual scores

Variable	RF	se	Sham	se	F-value	p-value
TST	6.22	0.09	6.28	0.08	0.75	
Wake (min)	20.70	3.22	21.53	3.59	0.00	
Stage 1 (min)	15.48	1.38	15.09	1.58	0.12	
Stage 2 (min)	204.93	4.01	199.51	4.09	**3.95**	0.052
Stage 3 (min)	34.32	1.68	32.45	1.62	0.40	
Stage 4 (min)	36.78	3.81	45.94	3.82	**12.28**	0.001

In Figure 1, the sum of Stages 3 and 4 has been plotted across seven hours of sleep. An ANOVA was performed using only data from the first five hours of sleep since many subjects had no slow wave sleep (SWS) (Stage 3 or 4 sleep) in the 5-7th hour of sleep. Huyhn-Feldt corrections were used to control for unequal variances of means being compared. The results demonstrated an effect of exposure (F=4.61, p<0.05, df=1,54) and the effect of hours of sleep became significant (F=124.8, p<0.001, df=4,46). The interaction between exposure and hour showed a tendency (F=2.10, p<0.10, df=4,46).

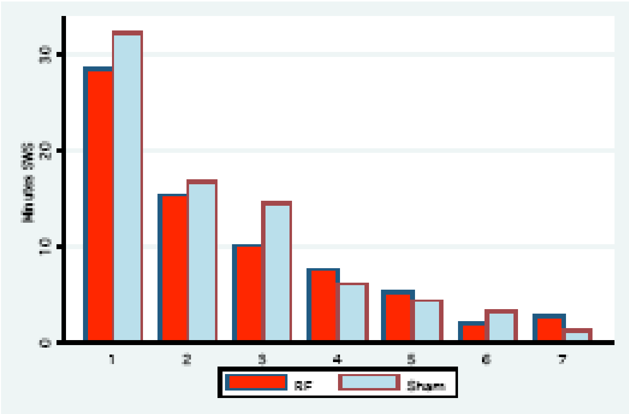

Fig. 1

Spectral analysis of the EEG was performed on frequencies 0.5-16 Hz and the means of the percent change in each quarter hertz band from RF exposure was obtained. When sham was used as reference no significant difference between conditions were obtained (Significant differences in single quarts bands was not considered due risk of mass significance).

However, see Figure 2, during periods scored as stage 3+4 (deep sleep), there was a 10% increase during sham.

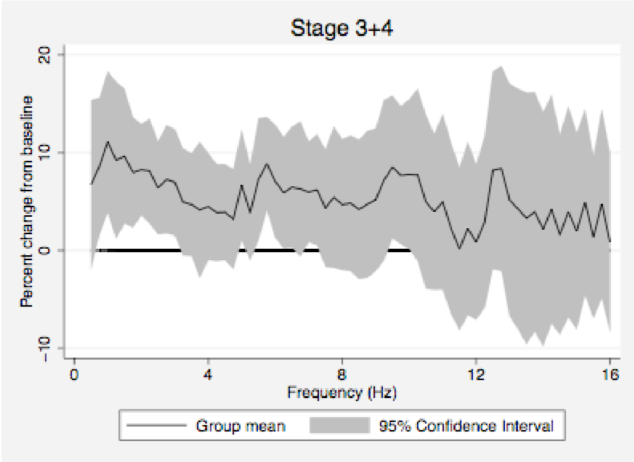

Fig. 2

Discussion

A possible result of a 3-hour RF exposure on sleep seems be a temporal altered distribution of slow wave sleep. Also, a sign of a more shallow sleep was observed during RF exposure with a decrease of slow wave sleep and increase of stage 2 sleep. Interestingly the reduction of SWS seemed to be compensated for by an increase in power density during SWS.

It is difficult to speculate whether the EEG changes due to RF and EMF exposure have any functional importance in the recovery processes during sleep. But it has been proposed that earlier presented EEG phenomena can be explained by non-thermal changes in neurons connected to the cortex and thalamus, particularly in the generation of EEG spindle activity being a sign of cortico-thalamo-cortical activation (Huber, 2003).

The reduction of slow wave sleep can be viewed as an increase of the ease of being aroused and might in connection with other sleep disturbing factors contribute to more awakenings and contribute to a reduced daytime function. The effect on total SWS in the present study may be due to the extended exposure (3 hours) compared to the shorter exposure periods that have been used before. The practical implications of a moderate reduction in SWS must be considered marginal, however.

Special methodological difficulties are present in spectral analysis when there is a lack of robust baseline sleep, individual variation is very large and many spectral differences from baseline can be attributed to differences in electrode placements. In the present material a mean difference in power levels of >30% for individuals was considered to be an accepted level.

Conclusions

An evening of long RF exposure delayed onset, shortened duration and changed the temporal pattern of SWS. The shorter duration was compensated for by an increased delta power during SWS.

Acknowledgement

Funding for the study was provided by the Mobile Manufacturers Forum (MMF).

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MOBILE PHONE 'TALK-MODE' SIGNAL SLOWS DOWN SLEEP ONSET

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Introduction: Mobile phone 'talk', 'listen' and 'standby' signals are pulse-modulated microwaves, which differ in their extremely-low-frequency (ELF) components, as do their respective specific absorption rates (SARs). Studies have shown ELF components are more important than microwave carriers for sleep/wake EEG effects, but no sleep study has differentiated these three modes.

Methods: We used a standard GSM 900 MHz mobile phone, operating at 12.5% (23dBm) of maximum power and controlled by a base-station simulator with a test SIM card. ELF components and SARs (for a 10g averaged tissue) of talk-mode are: 8, 217/1736 Hz with SAR=0.133 mW/g, for listen-mode: 2, 8, 217/1736 Hz with SAR=0.015 mW/g and for standby-mode: <2 Hz with SAR<0.001 mW/g. Ten right-handed healthy young men (mean age: 22±2.7y), sleep restricted to 6h, were exposed (blind) to talk, listen, standby and sham (nil signal) modes at weekly intervals. Ss lay in a sound-proof bedroom, with a thermally insulated phone attached beside the right ear and a silent signal generated for 30 min, starting at 13:30h. Ss remained silent and stared at a wall marker. Bipolar EEGs were recorded continuously, and subjective ratings of sleepiness obtained every 3 min (only during exposure). After exposure the phone and base-station were switched off, the bedroom darkened, and a 90-min sleep opportunity followed. Results are focused on sleep-onset using: i) visually scored latency to onset of stage 2 sleep, ii) EEG power spectral analysis.

Results: Post-exposure, sleep latency after talk-mode was markedly and significantly delayed beyond listen- and sham-modes. This condition effect was also evident in 1-4Hz EEG left frontal power across time. The SWS duration and sleep efficiency during the 90-min period was also significantly reduced from sham mode after talk-mode exposure. There was no condition effect for subjective sleepiness.

Conclusion: Talk mode shows an alerting effect. It is possible that 2, 8, 217 Hz modulation may differentially affect sleep-onset.

HUMAN SLEEP UNDER THE INFLUENCE OF A GSM 1800 ELECTROMAGNETIC FAR FIELD

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Summary

The ubiquitous availability of mobile phone networks has fuelled the public discussion about possible adverse side effects. Previous studies investigating potential sleep disturbances caused by electromagnetic fields (EMF) emitted by mobile phones yielded controversial results. Our study aimed at identifying such effects in the context of EMF emitted by base stations.

In a double blind design, we continuously applied a homogeneous, vertically polarized GSM 1800-type EMF (far field characteristic, 1736 Hz pulse frequency) during two of four consecutive nights randomly to thirteen healthy subjects. During sleep polysomnographic recordings including six EEG channels were acquired. The sleep pattern of each individual night was derived from hypnograms by two independent raters, and afterwards collapsed over the two nights per field condition (i.e. EMF on or off). In addition, the EEG power spectra were individually estimated for each recording and separately for each of the sleep stages.

The results failed to detect any statistically significant effect on human sleep in response to the EMF exposure.
Therefore, the hypothesis of sleep disturbances to be related to EMF emitted from GSM 1800 base stations could not be supported in these settings.

LABORATORY STUDY: STUDIES OF THE EFFECTS OF EXPOSURE TO ELECTROMAGNETIC FIELDS EMITTED FROM MOBILE PHONES ON VOLUNTEERS

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Background

Starting 11 years ago a number of different sleep laboratory studies were performed showing contradictory results. In their first study Mann and Röschke (1996) found some effect, which could not be reproduced in later studies. In different studies the group at the Zürich University (Borbély et al. 1999, Huber et al. 2000, 2002, 2003) consistently found an effect on the power of the NREM-EEG in the spindle frequency range. A study at the University of Magdeburg (Hinrichs et al. 2005) did not show any effects, while another study at the University of Swinburne (Loughran et al. 2005) did show some effects. The aim of the present study which started in 2003 was to contribute to a clarification of the situation.

Study design

In a very comprehensive selection procedure 30 healthy young men (age of 18 - 30) were selected out of 293 candidates, according to a long list of inclusion and exclusion criteria. This selection procedure, which comprised telephone interviews, written questionnaires and invited screening visits, aimed at excluding possible confounders and giving a homogeneous study sample.

During 20 consecutive weeks the subjects spent 10 days and 10 nights in the laboratory (one day or night per week alternating). The first visits served for adaptation. During the following 9 visits the subjects were exposed to sham, GSM (900 MHz, 217 Hz) and UMTS fields (three days and nights, respectively, for each exposure situation) in a double-blind, randomised, cross-over and placebo-controlled design. The radiation was applied continuously (8 hours during the night) by an antenna attached to the head in a way to simulate the spatial field distribution of a common dual band cell phone with SAR distribution being close to, but not exceeding, 2 W/kg. Uplink signals from UMTS and GSM (900 MHz, 217) were simulated. Exposure assessment was realised by IMST GmbH, Kamp Lintfort (Bahr et al. 2006, 2007).

During the day-visits, two test sessions were performed, the first starting at 11 am and the second starting at 4 pm. The following tests were performed in each session: pupillography, acoustic choice reaction test, contingent negative variation, oddball paradigm, sustained attention, alpha-attenuation-test, visual monitoring test, working memory test, divided attention and vigilance test. During all sessions EEG was recorded continuously. Evaluation of these data is still in progress.
Night-time assessment comprises an 8h polysomnographic recording. From these recordings a comprehensive number of parameters are derived: from visual expert scorings according to Rechtschaffen and Kales: 66 variables, from automatic scoring (Somnolyzer 24X7, Anderer et al. 2005): 175 variables, 810 variables describing slow (< 13 Hz), fast (≥ 13 Hz), possible, likely and certain spindles, number, density, duration, amplitude and frequency of all these types of spindles for the whole night as well as by sleep stages and by quarters of the night (automatic sleep spindle detection with the Somnolyzer 24x7, Anderer et al. 2005).

Results

The normal distribution hypothesis was tested by the Shapiro-Wilk test and Kolmogorov-Smirnov test, respectively. Depending on the results of this test, Student's-test or Wilcoxon's signed rank test for paired observations were used to test the null hypothesis that there was no difference between the pair-groups. For GSM exposure the number of statistically significant results observed for the macrostructure of sleep does not noteworthy exceed the number just expected by chance taking into account the multiple testing. Significant findings concerning the macrostructure of sleep from previous studies could not be confirmed. For UMTS this number of statistically significant results was even lower, e.g. below the number just expected by chance. The same holds true for the results of the detailed analysis of spindle activity. For GSM exposure as well as for UMTS exposure the number was far below the one expected when testing with a two-sided alpha < 0.05. No systematic changes in frequency, density, amplitude and/or duration of all types of spindles could be observed.

Conclusion

Neither GSM900- nor UMTS-exposure has a meaningful short term effect on sleep initiation, sleep maintenance, cyclicity and/or spindle characteristics during sleep.

ADVANTAGES AND LIMITATIONS OF EMF STUDIES CONDUCTED IN THE EVERYDAY ENVIRONMENT

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Background

Sleep disturbances and other symptoms are among the most often stated health problems attributed to radio frequency electromagnetic field exposure. Effects on sleep and other symptoms can either be investigated in a laboratory or in the everyday environment. Epidemiological and field studies are conducted in the latter. Epidemiological studies are often considered as purely observational whereas in field studies interventions are performed in the everyday environment. At the workshop an up to date overview about the studies conducted in the everyday environment will be given and their advantages and limitations will be discussed.

Advantages

One big advantage of studies taking place in the everyday environment is that they are well accepted by the study participants. In particular individuals claiming to be electromagnetic hypersensitive are afraid of being exposed in a laboratory and may refuse to participate in such a study. As a consequence the potentially most sensitive subjects could be left out in laboratory studies.

A further positive aspect of epidemiological studies is the fact that study participants are exposed in a familiar environment. Thus, it is more likely that subtle effects can be detected which may not be the case in a laboratory setting. Moreover, the burden for study participants is relatively low. This makes longer investigation periods more acceptable and allows investigating larger population samples yielding increased power to detect effects if present.

The exposure in epidemiological and field studies represents a common situation relevant for the whole population. Personal exposure assessment during the night is generally feasible, because the situation is clearly defined when study participants are in bed and the relevant sources can be determined. In contrast, exposure assessment during the day, when study participants are mobile are more challenging.

Limitations

The performance of objective outcome measurements in the everyday surroundings is often problematic. For instance good quality EEG measurements need a lot of devices and sensors have to be attached to the study participants by well trained study assistants. Thus, only simple objective measurements are feasible in that kind of research (e.g. actimeter) and more weight is usually given to subjective outcome measurements. Using standardized questionnaires allow a certain degree of objectivity for the determination of subjective outcomes such as sleep quality. Nevertheless, subjective outcome measurements are vulnerable to bias, in particular if participants are not blinded against exposure status. Blinding against exposure status is, however, often difficult to achieve in epidemiological and field studies.

Conclusions

The conduct of EMF studies on sleep and other symptoms in the everyday environment is warranted given the advantages of this approach. However, there are limitations, which have to be taken into account by study design and data analysis. Currently, a number of such studies are ongoing, having chosen different designs to tackle the limitations. It can be expected that from the research effort in this area further insights about potential effects of mobile phone radiation exposure will be obtained.

HEALTH RISK ASSESSEMENT IN WORKERS OCCUPATIONAL EXPOSED TO RADIOFREQUENCY ELECTROMAGNETIC FIELDS

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Aim

We tried to make a preliminary evaluation of health risk in workers occupationally exposed to electromagnetic fields (EMF): radiofrequency and microwaves, in RadioTV broadcasting stations .

Methods

The group taken into study consisted of 100 subjects occupationally exposed to EMF (workers in radiotv broadcasting stations) with the mean age = 41,7±7,5 years, and average – time of exposure =16,3±6,3 years.

We measured the level of RF EMF at work places . The measuring instruments were similar with those used in Western countries [EMR 300 Wandel & Goltermann, with probes for electric and magnetic flux density and power density]. The reference values are those used currently in European Union [ICNIRP 1998] .

A special individual questionnaire was used to appreciate the biological effects of the EMF occupational exposure. Biological monitoring by determination of the urine thioeteres (milimol thioether/mol. creatinine) in the occupationally exposed workers to EMF was performed. A clinical and paraclinical investigations were performed too.

Results

The measured values of radiofrequency and microwave levels in the work places were below the reference values(ICNIRP).

The results of the preliminary health study were compared with a control group not exposed to EMF. Our results revealed the following: 98% of the exposed workers had a neurasthenic syndrome (49% asthenia and fatigue, diurnal somnolence 28%, sleeping disorders 28%, headache 18%, irritability 15%, dizziness 8%), tensional oscillations 30%, anemia 23%, sexual dysfunctions 8%, paresthesia 8%, leucocytosis 8%, nonmalignant tumors 3%, psychical disorders 3% , etc. Urinary thioethers excretion in the occupationally exposed workers to EMF was increased (with ssd) in comparison with control group.

Conclusions

Preliminary conclusions suggest that the occupational exposure to radiofrequency and microwaves (even below the reference values) induce biological effects and further complex studies remain a necessity. The periodical medical examination and the protective measures must be improved.

FIELD STUDY: INVESTIGATION OF SLEEP QUALITY IN PERSONS LIVING NEAR A MOBILE BASE STATION – EXPERIMENTAL STUDY ON THE EVALUATION OF POSSIBLE PSYCHOLOGICAL AND PHYSIOLOGICAL EFFECTS UNDER RESIDENTIAL CONDITIONS

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History and background

The present study has its roots in a feasibility study that was conducted in 2002 in the small village Flachsmeer in the northeastern part of Germany (Ostfriesland). 47 men and 58 women participated in the study designed in a similar way as the present one. Apart from the fact, that the study attracted enormous media attention, it showed that such studies were feasible. Immediately after presentation of the results a proposal for the present study was submitted to the DMF. In 2005 a pilot study was conducted in order to: review the literature, get a vote of the Ethics Committee and achieve an agreement with the network providers. After all requirements had been fulfilled the main study could start in March 2006 and is planed to be finished by September 2007.

Design

The main focus of the study is the investigation of subjective and objective sleep quality and possible psychological effects on subjects living near mobile telecommunication basestations under residential conditions. In order to “disentangle” possible psychological effects from the investigated physiological effects study sites were selected where no mobile service is available, only weak fields from other RF sources (like TV) exist and where no emotional EMF discussion is going on during the study period. Nine study sites could already be determined and a tenth one was scheduled.

Selection of the study sites and construction and operation of the special transportable base station is done in close cooperation with the the network providers and the German Federal Network Agency. A container, originally used for disaster recovery, containing GSM900 and GSM1800 base stations (BS), was modified in order to meet the need of the study. The BS delivers generic GSM signals using a test mode without net service, so it is not displayed on mobile phones (enabling double blind design of the study). Additional 6/8 pulsed GSM signals simulate a BS transmission close to full capacity. Outdoor exposure measurements and single measurements of signals at the pillow of each participant’s bed are done by the IMST GmbH. Exposure from the test BS and external background exposure are assessed using frequency selective and isotropic methods. Signals of the various transmitting services are measured individually. DECT phones are replaced for the time of the study.

Selection of participants is done by inviting all inhabitants to an information meeting at the study site. Participating subjects have to be older than 17 years, able to give an informed consent and live closer than 500m to a site suitable for placing the experimental base station. At a second meeting with subjects who were willing to participate “entrance” questionnaires concerning sleep and well-being have to be filled in aiming at identifying possible psychological components. The experimental period lasts 2 weeks (12 nights). The type of exposure is randomly assigned to the study nights (sham and verum) allowing for double-blind, cross-over and sham-controlled design of the study. There is no exposure during days and no exposure during the weekend. During the experiment the quality of sleep at home is studied at subjective (questionnaires) and objective level. The questionnaire, recommended by the German Society for Sleep Research and Sleep Medicine, has to be filled in every morning and evening. Two questions were added to assess problems met with the handling of the EEG-devices and telephone use after 10 pm. Frontally recorded bipolar sleep EEG data were registered and automatically analysed as objective data.

Status of the project

Meanwhile the study was performed at 8 study sites in 4 provinces (Hesse: 4, Thuringia 2, Lower Saxony: 1 and Schleswig-Holstein: 1). The raw sample comprises 329 individuals (50.5% males), which on average is 17.4% of the eligible population of the respective study sites (range of number of eligible inhabitants: 116 to 511, average: 236). The age distribution of the participants corresponds very well to the overall age structure of the population of the study sites. The sample has to be adjusted for participants living in a distance of more than 500 m from the base station, and for recordings of bad quality. Two more study sites will be investigated.

ELECTROENCEPHALOGRAPHIC, PERSONALITY AND EXECUTIVE FUNCTION MEASURES ASSOCIATED WITH FREQUENT MOBILE PHONE USE

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Background*:* In previous studies the direct – or acute effects - of Mobile Phone (GSM) use on brain function have been investigated using neuropsychological and neurophysiological techniques. Previous studies suggests an association between acute GSM use and enhanced scores on cognitive tests. These results have been mostly interpreted as being due to small increases in brain temperature which lead to increased metabolic activity and thus faster reaction times. Electroencephalographic (EEG) studies show an increase in alpha EEG power, mainly in the parietal and occipital areas during exposure to a GSM-'like' field; during wakefulness (Croft et al., 2002; Schulze et al.; Mann & Röschke, 1996; Krause et al., 2000b) and sleep (Lebedeva et al., 2001; Borbely et al., 1999; Huber et al., 2000; 2002a; 2002b). Furthermore, increases in theta power (Lebedeva et al., 2001) and modulation of high frequency induced brain activity (Eulitz et al. 1998) have been reported during MP exposure. In contrast, other studies find no significant effects of MP exposure on spectral measures of the wake and sleep EEG (Röschke & Mann 1997; Wagner et al. 2000; Eulitz et al. 1998). In more controlled studies, Krause et al (2004) and Haarala et al (2003) failed to replicate previous findings. Thus, the acute effects of GSM-use on EEG, memory or reaction time may be small, variable and not easily replicable. Thus, results of the acute effects of an MP 'like' field on brain function are inconclusive and reasons for the above inconsistencies are unclear.

The relationship between the cumulative long-term and/or frequent use of GSM use on brain function and information processing has not been investigated yet. Therefore, this epidemiological study was designed to gather data and explore the association between long term and/or frequent GSM-use, brain function and personality.

Results: The results of our study show that Frequent mobile phone users showed improved performance on the Stroop test and showed a lower interference score. Furthermore, there was increased slow activity in the EEG (delta and theta) related to the frequency of mobile phone use. The alpha peak frequency was also lower for mobile phone users, and there was a significant correlation between mobile phone use and Eyes Open alpha peak frequency at central and right temporal sites. These results cannot be explained by the pre-existing differences in Personality and Stroop performance.

Conclusion: The results showed that frequent mobile phone (GSM) users were more extraverted and less open-minded (openness). Furthermore, frequent mobile phone users showed improved focused attention (less interference on the Stroop). This was explained by a learning effect due to making more often phone calls in busy environments, whereby people learn to better focus on the phone call and filtering out irrelevant environmental information. However, the brain activity from frequent mobile phone users showed more slow activity (increased Delta and Theta) and a slowed Alpha Peak Frequency. These effects could not be explained by the differences in personality and focused attention. Severely slowed brain activity has also been found in patients with Alzheimer's dementia.

However, the slowing found in this study (APF 0.6 Hz) can still be considered within 'normal' limits. The frequent mobile phone user group used their mobile phone at the time of data collection on average only 2.4 years, which can currently be considered short. Therefore, it could be expected that the observed effects in this study could be exaggerated with longer mobile phone use. Future, more controlled studies are required to investigate these effects further and investigate whether these effects have any implications for health.

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EVIDENCE BASE FOR CONCERNS STATED BY PHYSICIANS IN PUBLIC APPEALS ON MOBILE PHONE TECHNOLOGY

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In October 2002 German physicians appealed to persons in the field of health care, politicians and the public with „great concern" by way of the „Appeal of Freiburg". In this appeal "soaring incidences of symptoms and diseases in the general population" were causally related to the "commence of radio (wave) burden", i.e. due to mobile radio technology. Based on this example several further appeals have published nationally and Europe-wide up until today.
Aim of the presented work was an evaluation of scientific literature and databases concerning incidence and prevalence of symptoms and diseases stated to have "dramatically increased" or appeared in "greater frequency" in the appeals published by resident physicians.
Material and Method: The following health conditions were considered: Alzheimer's disease, dementia, sleep disturbances, tinnitus, headache, migraine. Data on the incidence of these conditions were assessed from 1993 thru 2005. For this, a systematic search by keywords was done in the online-database of the National Library of Medicine.
Outcome: For none of the considered symptoms or diseases a "dramatic increase" was found to have occurred since 1993.
Discussion: Because of the different diagnoses and terms used in the studies, direct comparability is somewhat difficult. Indeed, by means of the available data no time related increases and surely no "dramatic increase" can be identified, even if limited comparability is considered. The numerous public appeals from physicians, mostly general practitioners, cause massive anxiety and uncertainty about risk related to mobile radio technology which is not justified based in health data published to date.

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