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No increased sensitivity in brain activity of adolescents exposed to mobile phone-like emissions

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HIGHLIGHTS

- The current study examined the potential sensitivity of adolescents to mobile phone-like electromagnetic field exposures.
- Unlike previous studies conducted on adults, no significant effects of exposure were found.
- Results suggest that contrary to popular belief, adolescents are not more sensitive to mobile phone emissions.

ABSTRACT

Objective: To examine the potential sensitivity of adolescents to radiofrequency electromagnetic field (RF EMF) exposures, such as those emitted by mobile phones.
Methods: In a double-blind, randomized, crossover design, 22 adolescents aged 11–13 years (12 males) underwent three experimental sessions in which they were exposed to mobile phone-like RF EMF signals at two different intensities, and a sham session. During exposure cognitive tasks were performed and waking EEG was recorded at three time-points subsequent to exposure (0, 30 and 60 min).
Results: No clear significant effects of RF EMF exposure were found on the waking EEG or cognitive performance.
Conclusions: Overall, the current study was unable to demonstrate exposure-related effects previously observed on the waking EEG in adults, and also provides further support for a lack of an influence of mobile phone-like exposure on cognitive performance.
Significance: Adolescents do not appear to be more sensitive than adults to mobile phone RF EMF emissions.

1. Introduction

There has been increasing interest in recent years regarding whether radiofrequency electromagnetic fields (RF EMF), such as those emitted by mobile phones, have an influence on brain activity. Previous research has indeed shown that pulse-modulated RF EMFs characteristic of those emitted by mobile phones affect the electroencephalogram (EEG) during both sleep and waking in adults (e.g. Borbély et al., 1999; Croft et al., 2002; Curcio et al., 2005; Huber et al., 2000; Loughran et al., 2005; Regel et al., 2007a; Reiser et al., 1995; van Rongen et al., 2009). In particular, the alpha frequency range during waking and the alpha and spindle frequency ranges during sleep have been the most commonly reported areas influenced by such exposures to RF EMF. However, despite this increasing evidence of a repeatable mobile phone-induced effect on brain activity in adults, very little research exists regarding the presence and/or magnitude of this effect in children and adolescents.

Mobile phones are a dominant component of modern telecommunications technology and constitute the main source of RF EMF exposure for children and adolescents. In 2006 the World Health Organization (WHO) released a research agenda specifically relating to RF EMF in which investigations on potential effects on the EEG and cognition in children were identified as a high priority research need. A subsequent research agenda from the WHO stated that there have only been few such studies since this initial

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recommendation and therefore highlighted that further RF EMF provocation studies on children of different ages were still required (WHO, 2010). In addition, it was also suggested that neurobiological mechanisms and possible thresholds and dose–response relationships should also be investigated.

During normal mobile phone use, i.e., when operated at the head, some of the emitted RF EMF penetrates into the head tissues where it is absorbed. The distribution of the induced fields depends on the design of the phone, its position at the head and the brain anatomy (tissue distribution and dielectric parameters). Christ et al. (2010a) showed that local maximum averaged absorption is similar between children and adults but that the locally induced fields in certain subregions of the children's brain (specifically the cortex, hippocampus and hypothalamus) can be significantly higher (on average by about a factor of two) compared to adults due to anatomical reasons.

In general, the maximum specific absorption rate (SAR) of the brain tissues of adults and children is considerably below the basic restrictions of 2 W/kg (by more than a factor of two for children and a factor of four for adults). These restrictions were proposed by the International Commission on Non-Ionizing Radiation Protection (1998) as safety limits for the general population and have since been adopted by most countries. However, despite these restrictions it remains that effects on brain physiology still occur in adults at exposures well below the currently accepted safety guidelines (for review, see van Rongen et al., 2009). In regards to the possibility of effects on children and adolescents this becomes especially important for several reasons. Children start to use mobile phones extensively in early adolescence and they might be particularly sensitive to RF EMF as maturational cortical changes are ongoing throughout development (Segalowitz et al., 2010; Whitford et al., 2007).

In view of the higher brain exposure of children, it surprising that very few studies have investigated in younger cohorts the influence observed on the EEG in adults, or even the inconsistent effects reported on cognitive performance (for review, see van Rongen et al., 2009). Therefore, the current experiment aimed to determine whether RF EMF exposure also influences the waking EEG and/or cognitive performance in adolescents and to establish a possible dose–response relationship.

2. Materials and methods

2.1. Participants

Twenty-two young, healthy, right-handed adolescents (12 males) aged 11–13 years (mean age 12.3 ± 0.8 years) participated in this experiment. Pubertal status was assessed and determined as reported by the parents using the standardized Tanner staging system (adapted from Carskadon and Acebo, 1993), and only one female in the sample had reached menarche. Participants with a history of neurologic or psychiatric disorders were excluded from the study. Additionally, all subjects were medication and drug free at the time of participation. Participants were recruited mainly through schools, broadcasts on national television, and advertisements in local newspapers. All study protocols were approved by the Cantonal Ethical Committee for research on human participants and written informed consent was obtained from the participants' legal guardian prior to participation. The subjects received a cinema, book, or CD voucher and a t-shirt as compensation for their participation.

2.2. Study procedure

The study was carried out at the sleep laboratory of the Institute of Pharmacology and Toxicology, University of Zurich. In a double-blind, randomized, and counter-balanced crossover design, participants underwent three different exposure conditions at weekly intervals. Each session was performed at the same time of day within participants. During the study participants were required to abstain from caffeine and had to adhere to regular bed-times starting three days before each study day. Compliance for prior sleep activity was controlled by wrist-worn actimeters and sleep logs. Additionally, on all study days physical exercises had to be avoided and the use of mobile phones for calling was prohibited.

At each session, electrodes were first applied and then a baseline waking EEG (3 min eyes close, 3 min eyes open) was recorded prior to each of the three exposure conditions. During the exposure participants sat with their heads positioned between the two exposure antennas. Each exposure lasted 30 min, during which cognitive tasks were performed. The waking EEG (3 min of eyes closed followed by 3 min of eyes open) was then recorded in a different room (in the same manner and location as the baseline EEG recordings) immediately after exposure, and again at 30 min and 60 min after exposure in order to be comparable to a previous study conducted at our laboratory on adults (Regel et al., 2007a). At the conclusion of each experimental session participants were asked whether they were able to perceive the field. In addition, 100-mm visual analog scales were administered at each session prior to the EEG recording. Subjects were asked to rate themselves on the following items with the anchors indicated in parenthesis: tiredness (0 mm = tired; 100 mm = alert), general mood (0 mm = good mood; 100 mm = bad mood), energy (0 mm = lethargic; 100 mm = energetic), tension (0 mm = relaxed; 100 mm = stressed) and concentration (0 mm = concentrated; 100 mm = unable to concentrate).

2.3. Exposure conditions

The three exposure conditions were applied via a planar antenna at the left side of the participants head in order to be consistent with our previous studies (e.g. Huber et al., 2002; Schmid et al., 2012). Dosimetric assessment revealed a 9% assessment uncertainty and 15% inter-subject variation (both values denote one standard deviation, SD) for the guideline relevant psSAR values. To ensure compliance with the ICNIRP limit of 2 W/kg, the higher intensity condition was lowered by 30% (2 times SD of inter-subject variation). Therefore the 3 exposure conditions were: (1) GSM handset-like modulation, 900 MHz carrier frequency, peak spatial SAR (psSAR) 1.4 W/kg ('high SAR'); (2) GSM handset-like modulation, 900 MHz carrier frequency, psSAR 0.35 W/kg ('low SAR'); and (3) Sham (no field). A refined analysis with four different children models revealed actual mean exposure levels of 1.33 W/kg (±13%) for the targeted 1.4 W/kg. During exposure, the participant was seated comfortably between two planar antennas (left active only) in order to ensure a well-defined exposure and constant positioning (for details, see Boutry et al., 2008; Huber et al., 2002, 2005; Murbach et al., 2012; Schmid et al., 2012). Additionally, in order to eliminate or minimize any potential interference with the applied RF EMF signals, the attached electrode leads were oriented horizontally to the emitted field. Comparison of the exposure distribution between adults and children was also performed, and details shown in Table 1.

2.4. EEG data acquisition

At each time point waking EEG data (C3LM, C4LM, O1LM and O2LM derivations; LM = linked mastoid) were recorded, as well as electrooculogram (EOG) and electrocardiogram (ECG) using a polygraphic amplifier Artisan (Micromed, Mogliano Veneto, Italy). The analog signals were high-pass filtered (EEG: −3 dB at 0.15 Hz; ECG: 1 Hz) and low-pass filtered (−3 dB at 67.2 Hz), sampled at