Does chronic exposure to mobile phones affect cognition?

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Summary

Mobile phones form an integral part of our modern lifestyle. Following the drastic rise in mobile phone use in recent years, it has become important to study its potential public health impact. Amongst the various mobile phone health hazards, the most alarming is the possible effect on the brain. The aim of the present study was to explore whether chronic exposure to mobile phones affects cognition. Ninety subjects aged 17-25 years with normal hearing were recruited for the study and divided into three groups according to their duration of mobile phone use. No significant differences in N100, P200, N200, P300 latencies or N2-P300 amplitude were observed. Our results suggest that chronic mobile phone exposure does not have detrimental effects on cognition.

KEY WORDS: cognition, event-related potentials, mobile phones

Introduction

Mobile phones form an integral part of our modern lifestyle. While cell phones provide an efficient means to communicate with friends and family, their overuse may have deleterious effects on health. The drastic increase in the number of mobile phone connections in our country has resulted in a sharp increase in the intensity of electromagnetic radiations in the environment. The potential electromagnetic radiation-related health risks associated with mobile phone overuse are

a pressing environmental health issue and warrant investigation.

An emerging body of multidisciplinary studies has been carried out in recent years to investigate and monitor health risks due to electromagnetic emissions from mobile handsets. However, these studies yielded either inconclusive or contradictory results.

Numerous studies have focused on common health problems like headache, irritability, a burning sensation in the ears, and chronic pain and inflammation of joints – the latter due to responding to messages at a rapid speed on smart phones. Back pain is seen in cell phone users who hold their phone between their head and shoulders, especially when multi-tasking. Digital eye strain, eye redness, itching and dry eyes are also common. As the mobile phone antenna is in close proximity to the user's head, the brain is exposed to more electromagnetic fields (EMFs) than the rest of the body. A greater distance between head and handset is therefore essential to reduce radiofrequency exposure (Stefanics et al., 2008).

The effects of the electromagnetic radiation can be thermal (due to thermal interaction between radiation and tissues), producing skin burns, cataracts, seizures (Balbani and Montovani, 2008), or non-thermal (due to attraction between different types of cells in the presence of an electric field), producing changes in the electrophysiology of living cells (Kaprana et al., 2008).

Possible adverse effects of mobile phones on the central nervous system are of growing concern.

Various non-invasive methods are now used in quantitative evaluation of neurophysiological functions (Bastianello et al., 2008; Anjana et al., 2010; Vaney et al., 2011). Event-related potentials (ERPs) are the EEG potentials that are evoked by the perception of or the preparation for events and they include an early sensory evoked potential and a late cognitive response (P300 component) (Goodin, 1992). ERPs, which can be recorded through the scalp, are generated by neural activity associated with specific sensory, cognitive and motor processes. The N100 and P200 components are believed to reflect the activity occurring in neural areas that are activated by sensory stimuli and they are independent of the subject's attention (Picton and Hillyard, 1974). The N200 component is related to the degree of unexpectedness of the stimulus (Ritter et al., 1984), while the P300 wave is

believed to reflect cognitive processes underlying attention allocation and memory updating (Picton, 1992).

Whereas numerous studies have highlighted the effects of acute mobile phone exposure on ERPs of the human brain, there is little available evidence on how chronic exposure to mobile phones affects cognition. With this in mind, the primary aim of this work was to assess the effects on cognition of chronic exposure to electromagnetic radiation emitted by mobile phones.

Materials and methods

The present study was conducted at the Electrophysiology Laboratory in the Department of Physiology of UCMS, Delhi.

The study was carried out in 90 subjects aged between 17 and 25 years. Both males and females were included in the study. The subjects were divided into three groups according to the duration of their mobile phone use: 30 subjects who had used mobile phones for less than five years (Group 1); 30 subjects who had used mobile phones for more than five years (Group 2); 30 subjects who had never used a mobile phone (Group 3). Since this is a pilot study, a sample size of 30 subjects per group was required.

Selection of subjects

Students of UCMS college and neighboring colleges were invited to take part in this study. Only interested volunteers aged between 17 and 25 years were selected for the study. Subjects with a history of hearing impairment, use of ototoxic drugs and having previous ear infection or familial hearing disorder were excluded from the study. Among the college students there were just three who had never been exposed to mobile phones. Hence the subjects for Group 3 were selected from cleaners and other class IV employees of our college who had never been exposed to mobile phones. All the participants in Groups 1 and 2 filled in a questionnaire regarding their mobile phone use. These subjects were using mobile phones primarily to make phone calls, while text messaging and use of the internet constituted less than 20% of their total mobile phone use. The study was approved by the institutional ethics committee and informed consent was taken. The recording procedure was explained to the participants. All the subjects were tested under similar laboratory conditions having first been familiarized with the experimental and environmental (laboratory) conditions.

Recording of event-related potentials

The ERP recordings were done in a soundproofed room and the subjects underwent a trial session before the recording to familiarize them with the stimuli and the recording procedure. Recordings were

done from the scalp of the subjects using an Octopus 4 M/C NCV/EMG/EP system (Biostar Health Care, India). Silver-silver chloride disk electrodes were placed at standard scalp locations according to the 10-20 international system. The electrodes were placed at the vertex of the skull (reference electrode Cz), at the forehead (ground electrode FPz), and at the ear lobes (active electrodes A1 and A2), after cleaning the scalp or skin sites with alcohol and then applying skin preparation gel and Elefix™ EEG paste. The skin electrode impedance was kept below 5 k Ω . The auditory ERPs were recorded using an “oddball paradigm” wherein two stimuli (target and non-target) were presented in a random order through headphones. The target stimulus was a 2 kHz click sound with 20% occurrence and the non-target stimulus was a 1 kHz beep with 80% occurrence. The frequency of the auditory stimuli was 0.9 Hz (about 100 responses were collected and averaged), while their intensity was 90 dB SPL, with 60 dB SPL white noise masking of the contralateral ear.

Procedure

On hearing target stimuli delivered through headphones, the subject pressed a button on the response pad with the thumb of his/her dominant hand. During the recording session, the subject was instructed to close his/her eyes to avoid blink artifacts. Data for two trials were obtained, stored and averaged by computer. The peak latencies of the ERPs were measured from stimulus onset (stimulus artifact) to the peak point of the particular wave, i.e. the point of greatest amplitude. Amplitude was measured as the distance of the corresponding peak from the baseline. Peak latencies of N100, P200, N200 and P300 and amplitude of N2-P300 were recorded.

Statistical analysis

The statistical analysis was done using the SPSS 20 statistical package. The three groups were compared by one-way ANOVA and post-hoc Tukey HSD test at 5% level of significance. Data are presented as mean $\pm$ SD. A p-value <0.05 was considered significant.

Results

The latencies of the ERPs, i.e. N100, P200, N200, P300 were compared in the three groups. No significant differences in latencies were observed. Similarly, the N2-P300 amplitude did not differ significantly in the three groups (Table I). Representative ERP waves in the three groups are shown in figure 1.

Discussion

Mobile phone use is ubiquitous as it has become an integral part of modern telecommunications. About

half the population worldwide uses mobile phones, which constitute a rapidly growing market. It has thus become important to study the potential public health impact of mobile phone exposure. Previous ERP studies of mobile phone-related EMF exposure have given

Figure 1- representative ERP waves in Group 1 (<5 years of mobile phone use, A) Group 2 (>5 years of mobile phone use, B) and Group 3 (no previous mobile phone use, C).

varying results. The present research was conducted to study the effect on ERPs of chronic mobile phone exposure. The subjects were divided into three groups according to their duration of mobile phone use.

The results of present study revealed no significant changes in the latencies of N100, P200, N200 and P300 or in the amplitude of N2-P300 (Table I). ERPs, which can be recorded from the scalp, are generated by neural activity associated with specific sensory, cognitive and motor processes. The different waves of the auditory ERP have been found to reflect cognitive processes associated with different aspects of selective attention. The N100 component is thought to represent the initial extraction of information from the sensory analysis of the stimulus or the excitation associated with allocation of a channel for information processing in the primary cortex (Hansen and Hillyard, 1988). The P200 component may represent inhibition of further processing of the sensory input (Hegerl and Juckel, 1993), possibly via automatic stimulus identification and discrimination (Oades, 1998). As mentioned, it is thought to reflect the activity occurring in neural areas that are activated by sensory stimuli and it is independent of the subject's attention (Picton and Hillyard, 1974). The N200 component is thought to represent an endogenous mismatch detection process related to stimulus discrimination. This component has been associated with response identification (Snyder and Hillyard, 1976) and response selection. Our subjects showed no deficits in information processing as reflected in their ERP findings.

The P300 component of the ERP is associated with psychological processing. It is generated from various sites of the brain including the cortical and subcortical areas, particularly the auditory cortex, hippocampus, amygdala, brainstem and thalamic structures (Smith et al., 1990). The P300 wave is believed to reflect cognitive processes underlying attention allocation and memory updating (Picton, 1992), and its amplitude indicates the amount of difficulty encountered in differentiating target from non-target stimuli in the ERP oddball paradigm (Donchin and Coles, 1988). The lack of significant P300 latency and amplitude differences between the three groups in our study suggests that there were no deficits in the allocation of processing resources to task-relevant stimuli during the auditory oddball paradigm.

Table I - Mean latencies and amplitude of event-related potentials in subjects divided according to mobile phone use: <5 years (Group 1), >5 years (Group 2), none (Group 3).

		Group 1 (n=30)	Group 2 (n=30)	Group 3 (n=30)	p-value
Latency (ms)	N100	75.85 ± 17.21	90.27 ± 89.85	70.25 ± 25.65	0.350
	P200	136.65 ± 23.85	126.86 ± 27.69	124.76 ± 28.62	0.192
	N200	182.22 ± 23.32	186.40 ± 37.38	184.34 ± 27.56	0.865
	P300	239.73 ± 33.05	249.78 ± 37.75	240.68 ± 34.27	0.475
Amplitude (μV)	N2-P300	3.39 ± 2.20	3.09 ± 1.59	3.42 ± 1.54	0.736

Our results are consistent with those of Kleinogel et al. (2008) and Stefanics et al. (2008) who studied the effects of acute mobile phone exposure on ERPs. Kleinogel et al. tested the effects of EMFs on visually evoked occipital P100, the P300 of a continuous performance test, auditory evoked central N100 and the P300 during an auditory odd ball task, and on reaction time. They concluded that as the ERP and behavioral parameters were not changed, EMFs did not affect stimulus reception and processing. Stefanics et al. investigated the effect of 20 minutes of 3G mobile phone radiation on ERP components and early gamma synchronization in an auditory odd ball paradigm. They, too, observed no effect of mobile phone EMF exposure on above-mentioned parameters, however they underlined that since their results were obtained from young, healthy university students, further studies should be performed, focusing on other healthy subgroups, e.g. children, adolescents, elderly, and on groups of neurological patients who are more vulnerable due to specific deficits.

Hamblin et al. (2004) examined the effects of acute mobile phone exposure on human ERPs and performance during an auditory task. They observed decreased N100 amplitude, shortened N100 latency and delayed P300 latency during real as compared to sham exposure. They thus concluded that EMFs emitted by GSM mobile phones may alter human brain activity. In another study (Bak et al., 2010) of the effects on ERPs of acute exposure to GSM signals, no significant changes in the latencies of the N100, N200, P200, P300 waves were found but the P300 amplitude was significantly reduced. All these studies of acute exposure reported a high intensity of radiation.

An important point to consider when interpreting these data is that duration (in years) and frequency (number or duration of calls) of mobile phone use are imprecise measures of microwave exposure. The specific absorption rate (SAR) varies according to the make and model of the handset, the transmission system technology (analog or digital), the distance between the user's head and the handset antenna, and the distance between a mobile phone and its base station (Moulder et al., 2005). The maximum legally permitted levels of mobile phone radiation exposure in the United States and Europe are ~ 1.6 W/kg and 2.0 W/kg respectively. Generally, exposure due to the use of hand-held mobile phones falls below these limits (Kesari et al., 2013). In the present study about 47% of the subjects used their mobile phone for just 30 to 60 minutes per day. This may be one of the reasons for the non-significant changes in our study.

All the mobile phone users in the present study used GSM mobile sets of various models. The SAR values of all these were below 1.6 W/kg, i.e. within safe exposure limits (Kesari et al., 2013). Moreover, all these subjects were using handsets and none used Bluetooth. Our subjects were using mobile phones primarily to make phone calls, while text messaging or internet functions constituted less than 20% of their total mobile phone use. Thus it can be concluded that

emissions respecting the limits set for GSM mobile phones do not significantly impair cognition. Our study deals only with mild exposure. Further studies on a long-term exposure and in a larger sample size are recommended.

A limitation of our study is the fact that the exact radiation exposure/SAR could not be measured with precision. However, the radiation exposure/SAR values were below 1.6 W/kg, i.e. within safe exposure limits. On the basis of the findings of the present study (the electrophysiological parameters did not show significant changes), it can be concluded that chronic mobile phone exposure does not have detrimental effects on cognition. However, further studies in larger numbers of subjects and with a longer duration of exposure are needed to substantiate these results.

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