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ACUTE EFFECTS OF USING A MOBILE PHONE ON CNS FUNCTIONS

Hladký A., Musil J., Roth Z., Urban P., Blažková V.
National Institute of Public Health, Prague, Czech Republic

SUMMARY

Twenty volunteers participated in two experiments exploring the acute effects of using the mobile phone Motorola GSM 8700 on the functions of the CNS. When speaking (5 minutes reading a text from daily newspapers) the electromagnetic fields from the mobile apparatus did not affect the visual evoked potentials. Also a 6-min exposure did not reveal any effect of electromagnetic fields on the results in two tests (memory and attention) performed while speaking into the mobile. On the other hand the phone call itself strongly influenced the performance in a secondary task applying a test of switching attention which is a good model for driving a car. The response and decision speed were significantly worse. This is a proof that even a slight psychological stress involved in calling while driving can be a great risk.

Key words: mobile phone, electromagnetic fields, CNS functions

Address for correspondence: A. Hladký, M. Horákové 22, 170 00 Prague 7, Czech Republic

INTRODUCTION

The widespread use of mobile phones has given rise to the question of whether or not the electromagnetic fields created by these devices are detrimental to the health of their users. The effects of electromagnetic fields on living tissue have been widely documented. One of the problems associated with research into electromagnetic fields is posed by their physical characteristics. A number of factors are inherent: frequency, intensity, the composition of electrical and magnetic components and wave form. In view of the diversity of these conditions it is not surprising that research has often yielded conflicting results and that many facts have yet to be clarified. Another set of problems is presented in the determination of biological effects. Acute effects are monitored relatively easily but long-term effects of cumulative exposure are very difficult to demonstrate. Furthermore, in actual non-laboratory conditions electromagnetic fields are never encountered in isolation from other influences, which in combination may modify the effects observed.

Bearing in mind these circumstances we opted for experimental research into the acute effects of mobile phone use under model conditions which were to approach real-life situations. Because mobile phone use necessitates a close proximity of the antenna to areas of the brain in the region of the temple it is possible that the effects of electromagnetic fields can be detected in changes of bioelectrical brain activity. Visual evoked potentials (VEPs) are, in particular, regarded as highly sensitive electrophysiological markers of CNS dysfunction. It has also been recognised for some time that the effects of stress based on physical or chemical factors are particularly manifested in attention and memory functions. Markers of attention and memory are viewed as sensitive indicators of brain activity; we therefore supposed that it may be possible to detect the deleterious effects of electromagnetic field exposure in both of these areas.

METHODS

Subjects

A total of 20 subjects (10 men and 10 women) took part in the tests. The age group of the cohort was varied: the arithmetic mean was 42.7 years, standard deviation 15.8 years, ranging from 20–71 years of age.

Organisation of the Tests

Monitoring of bioelectrical brain activity and mental functions was carried out separately.

1. For the purposes of monitoring the potential negative effects of electromagnetic fields from a mobile phone on the CNS we used a Neuromatic 2000 Dantec apparatus, employing monocular checkerboard pattern reversal stimulation. Bioelectrical brain activity was registered on an Oz-Fz lead. The evaluated parameters comprised N1, P1 and N2 latencies and N1P1 and P1N2 amplitudes.

The tests were carried out on two separate occasions separated by a period of approximately 2 weeks. During each test VEP were tested on each eye – a total of 4 times – and a mobile phone was used between the first two and last two tests. The mobile phone was held to the right ear on each occasion. During one test the mobile was activated and during the other it was turned off: the order in which this was done was random. Each session with the mobile lasted 5 minutes during which the subject read a newspaper article out loud. In this way data on VEP were collected prior to and following exposure. For evaluation, only data collected from right eye stimulation were employed.

2. Attention and memory functions were monitored with two tests. The first was the subtraction test, in which the subject subtracts the number 7 from a given base digit. The measure of performance is given by the number of correct and incorrect replies within a 1 minute time limit. Subjects are informed when an incorrect reply has been given and continue only after they have replied correctly. This test challenges both memory and attention.

The second test comprised a modification of the well-known „test of switching attention" (1) and was performed on a PC. The person answers four different visual stimuli appearing on the screen at random for a short time of 200 ms by pressing one of four cursor keys. This constitutes a selective reaction in which the image flashed must be recognised, a correct selection made coupled with an appropriate movement. The following image is flashed only after the subject has responded,

either correctly or incorrectly. The limit was set at 3 minutes and the measure of performance defined by the number of right and wrong reactions.

The question of whether or not these mental functions are affected by the use of a mobile phone was tackled by testing the subjects under three different conditions: (1) without use of a mobile, (2) while phoning with a normal wireless telephone where electromagnetic field intensity is negligible and, (3) while using a mobile. Manipulation of cursor keys was one-handed, leaving the other hand free to hold the phone.

Because the tests were time-consuming they were carried out in two days with a hiatus of approximately 14 days. In order to curtail any systematic errors the sequence of telephone use was alternated: half of the subjects used a regular telephone on the first day and the mobile on the second. For the second half of the subjects this was reversed. The tests were organised in the following manner: following a brief introduction the subjects practised the test of switching attention for one minute and performed the actual 3 minute test without a telephone. Then the subjects were introduced to the subtraction test, given brief practice in subtracting from 3 numbers, followed by the actual 1 minute test.

In the next round of tests the subjects held an telephone apparatus in one hand and talked into it. For the first two minutes the subjects read out loud from a newspaper, and then performed the subtraction test for 1 minute. In order to avoid any systematic errors a different base number was selected each time. This was followed by the 3 minute test of switching attention. Because the level of electromagnetic fields emitted by a mobile depends on activation of the antenna during speech, the subjects were asked to count out loud from 1 upwards while performing the test of switching attention. The total time spent telephoning was 6 minutes.

The design of the experiment could not be double blind because identical conditions could not be achieved with a deactivated mobile.

Physical Characteristics of Equipment Used

The mobile phones employed were the MOTOROLA 8700 type, loaned by the Czech representatives of the manufacturer. This type of so-called cell phone is, as are other types, a transmitter and receiver of radio signals in the 900 MHz range. This range is exclusively used by the GSM system (Global System for Mobile Communications) using TDMA (Time Division Multiple Access) digital modulation. In use, the frequency and intensity of the signal (energy radiated) is automatically directed by the cell net of so-called base stations. The level of the pulse signal varies from 0.02–2 W, depending on the signal intensity of the base station in the given area and is indicated by the number of bars displayed on the telephone display. Adequate transmission quality requires a signal or field intensity equivalent to two bars on the display or a telephone pulse signal level of 1.5 W. In view of the TDMA modulation employed, the median level is 1/8 pulsed, equivalent to 187.5 mW. These levels were prioritised in the tests in which the phone was held to the ear in the normal manner and the antenna was extended. In terms of determining exposure, the data presented are only a qualitative description.

The equivalent level of absolute exposure given by SAR values in the head phantom (in W/kg) will be calculated subsequently following the completion of the experimental Department of EM Fields at the CVUT-FEL in Prague. A rough estimate based on experience would expect that average SAR, evaluated at 10 g of tissue volume, would not exceed 1/10 W/kg (for comparison, the originally recommended European population limit was 2 W/kg).

RESULTS

Visual Evoked Potentials

Evaluation of results was performed using analysis of variance tests. The effects of electromagnetic oscillation emitted by mobile phones on VEP parameters were tested as the influence of the mobile either turned on or off in contrast to VEP parameter values prior to and after telephoning.

Other potentially confounding factors were also tested: age, gender, telephoning as such, order of VEP examination. The effect of reading out loud on N1 wave latency was monitored – after phoning this was longer on average than before ($p<0.01$). No other confounding factors were significantly manifested. Detailed results of the VEP examinations have been published elsewhere (2).

Mental Functions

Performance in the tests which were carried out in three different ways (without a telephone, with a normal telephone, with a mobile phone) was statistically evaluated using analysis of variance tests. Results of four analyses are presented in Tab. 1. Only the statistical significance of test criterion F is presented, which expresses the influence of a given factor on overall variance.

If we accept a 0.05 level of significance for testing statistical hypotheses, it becomes apparent that differences between individual subjects are a highly marked source of variability for all variables. Another factor is the difference between both days which shows that an important role is played by practice in performing the tests. The difference between performance in the tests done with and without simultaneous telephoning manifested in errors during the subtraction test and the performance in the test of switching attention. The answer to the question of whether or not mobile-emitted electromagnetic fields adversely affect mental functions must be no: there was no significant difference in performance between tests conducted with a regular telephone and a mobile.

An interesting problem is the manner in which using a telephone affects performance in a simultaneously performed activity. In view of the statistical significance detected we present a comparison of arithmetic means of errors only in the subtraction test (Fig. 1) and performance markers in the test of switching attention (Fig. 2).

As shown above, the act of telephoning lead to an increased frequency of errors from 1.13 to 1.65 in the subtraction test and from 199.6 to 184.4 in the test of switching attention.

Table 1. Statistical significance of factors affecting test performance

Source of variability	Subtraction test		Test of switching attention	
Factor	Performance	Errors	Performance	Errors
Subjects (1 – 20)	< 0.001	< 0.001	< 0.001	< 0.001
Day (1,2)	< 0.001	0.387	< 0.001	0.018
Condition (with/without telephone)	0.293	0.011	< 0.001	0.070
Type (regular, mobile)	0.751	0.710	0.483	0.746

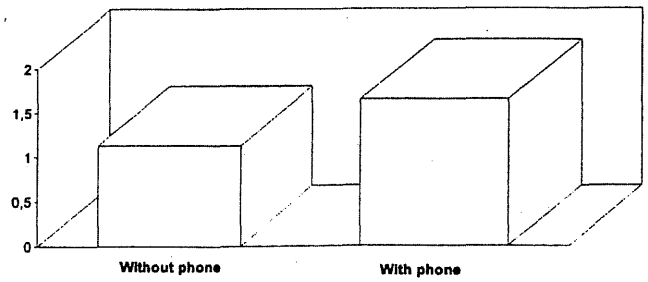

Fig. 1. Errors in the subtraction test.

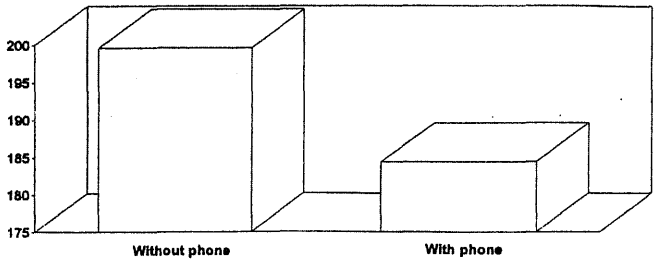

Fig. 2. Performance in the test of switching attention.

DISCUSSION

VEP examinations could not be performed during simultaneous telephoning because the electromagnetic emissions from the mobile would interfere with the bioelectrical signal of brain activity. The test was therefore based on a comparison of VEP parameters prior to and following exposure. Exposure was achieved by having the subjects talk into the mobile for 5 minutes without interruption. None of the five monitored VEP parameters were affected by this type of acute exposure to electromagnetic fields emitted by the given type of mobile phone. In contrast to VEP parameters, it was possible to monitor markers of performance tests directly during phone use. Comparison of performance during use of a regular phone and a mobile likewise showed that a six minute exposure to electromagnetic fields did not lead to any acute detrimental effects.

Repetition of the same activities lead to changes in the performance test markers. Comparison of arithmetic means revealed that repetition of activity in the tests manifested in a positive manner, apart from errors made during subtraction of the number seven. In order to avoid distortion of test results involving regular and mobile phone use by the factor of prior practice, the cohort was divided into two groups in which use of both types of phone was alternated.

We have already used the test of switching attention for monitoring the effects of electromagnetic fields elsewhere (3) and view it as a means of modelling load on car drivers. Although it may seem that the attention load on test subjects is far greater than during real driving, the activity is basically the same: situation evaluation, decision-making, appropriate movement – all involving fast reactions.

In terms of safety on the road, where many drivers use mobile phones during driving, it is worth asking whether or not this type of long-term load which forces drivers to divide their attention can affect their driving performance. In the model situation the activity in the attention test comprised a primary task, and the secondary task during telephoning was the mechanical counting of numbers from 1 upwards. Although this secondary activity did not represent an increased mental load, the distribution of attention lead to deterioration of performance in the primary task. Nonetheless, there was no significant increase in errors, although the decreased performance signifies that reaction time increased and decision-making slowed down. Our results conclude that use of a telephone during driving is hazardous, even in the event that the mobile is fixed in position inside the vehicle. This is supported by the fact that only one hand was necessary for manipulation in the test of switching attention. Furthermore, under real life conditions phoning is a frequent source of emotional stress which may lead to disturbance of the driver and a greater distraction of attention from the act of driving.

It is of interest that the actual process of telephoning – whether the phone was activated or not – had a statistically significant effect on resulting VEP latency. VEP markers were statistically compared prior to and following the reading of newspaper articles so it may be concluded that the increased latency was due to the act of reading out loud.

Conversely, it was found that phoning influenced the rate of mistakes in the subtraction test. This was not due to secondary load because the subjects were fully concentrated on performing the test and the fact that they held the telephone in one hand is negligible. The act of telephoning as such, in contrast to those actions performed without a telephone, influenced CNS functions. We may consider that the act of telephoning, without any secondary load, includes emotional elements and it is possible that during the tests the subjects experienced nervousness from the feeling that their test performance was controlled by someone else on the other end of the phone. In view of the fact that the rate of errors in the subtraction test was not influenced by practice but by actual performance, it may be assumed that the memory components contained in the test are, during a similar load, more open to errors whilst the speed of action remains the same.

CONCLUSION

Acute effects on Visual Evoked Potentials of a 5-minute period of exposure to electromagnetic fields generated by a mobile phone were not confirmed in a pilot study involving 20 healthy volunteers. A further 6-minute exposure had no influence on performance in two tests designed to load memory and attention functions.

In interpreting the negative results of this study it should be borne in mind that the number of subjects taking part was relatively small and the periods of exposure were short. It must be emphasised that the tests targeted the effects of acute exposure and that the results gained do not reveal anything about the potential consequences of chronic exposure.

It was found that even a slight mental load without marked emotional components during telephone use (counting numbers out loud) led to increased reaction times to stimuli and slower decision making. This demonstrates that use of telephones during driving is a hazardous activity.

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