Mobile Telecommunications and Health Research Programme

Mobile Cellular Communication and Cognitive Functioning

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RUM 9

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1. Executive Summary

Recent studies (e.g. Preece et al., 1999; Koivisto et al, 2000) have suggested that the use of mobile phones may affect cognitive functioning. However, a closer scrutiny of these studies suggests that, since the probability of wrongly rejecting a true null hypothesis was quite high (i.e. > 5%), these findings could simply reflect a statistical artefact. Therefore, the present research intended to overcome the limitations of previous studies providing a thorough evaluation of the impact of the use of GSM and analogue phones on attention and memory in adults. To this aim, a series of laboratory controlled experiments was conducted where different samples of about 160 volunteers per experiment performed a series of attention and memory tasks both while exposed and while not exposed to radiofrequency electromagnetic fields (REF) emitted by the antenna of mobile phones. REF were generated in the laboratory using a signal source device covering the standard frequency used by GSM and analogue mobile phones. Different groups were exposed to REF emitted by GSM and by analogue phones, respectively. The level of specific energy absorption rate (SAR) was the same for both unmodulated and GSM signals (with SAR always within the ICNIRP guidelines; i.e. those recommended by the Expert Group on Mobile Phones - Stewart Group). Overall, acute exposure to REF generated by mobile phones did not appear to have a significant effect on performance in attention and memory tasks.

2 Aims and Objectives

Given the limited number of studies on the effects of low-level level radiofrequency electromagnetic fields (REF) emitted by analogue and GSM mobile telephones on cognitive functioning and given their limitations, the present research intended to provide a thorough evaluation of the impact of the use of mobile communication devices on attention and memory. To this aim, a series of laboratory controlled experiments were conducted. Adult participants were given a series of tasks to assess their attention and memory both when exposed and when not exposed to low-level REF emitted by the antenna of a standard mobile telephone handset. Participants as well as the experimenter were blind to the conditions in which testing occurred (i.e. whether the mobile was ON or OFF). To evaluate lateralised effects of exposure to REF, subjects were assessed with the mobile phone positioned either on the right ear or on the left ear. Subjects were tested while exposure was occurring/not-occurring (i.e. in 2 sessions one week apart). Low-level REF were generated in the laboratory using a signal source device covering the frequencies used by mobile phone operators (i.e. 888 MHz).

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Two between-subjects conditions of exposure were used: one corresponding to the maximum level of power at which GSM phones are permitted to transmit by the present standards (i.e. 2 W, peak, and about 0.25 W, average); a second condition corresponding to the equivalent analogue unmodulated signal (the same SAR will be used in both modulated and unmodulated signal conditions).

2.1 Summary of the key research questions addressed by this research proposal:

a) Does exposure to low-level radiofrequency electromagnetic fields (900 MHz) generated by the antenna of standard mobile phones (GSM and analogue) affect adults' performance in attention and memory tasks?

b) Is there a lateralised effect (i.e. left vs. right) of low-level radiofrequency electromagnetic fields exposure?

3 Participants

Professor Riccardo Russo (Principal Investigator)
Professor Elaine Fox and Professor Dariush Mirshekar (Co-applicants)
Dr Caterina Cinel, Dr Angela Boldini and Mr Amith Mehta (Research Officers)

4 Achievements

4.1 Experimental tasks

In order to evaluate attention and memory the following tasks were used. In particular, in order to see if previous findings could be replicated, the same tasks that showed a significant effect of low-level REF exposure in Koivisto et al. (2000 a, 2000 b;see also Preece et al., 1999) were also used. However, in order to minimise the probability of a Type II error, a larger number of subjects than in the above studies were tested. The remaining new tasks were chosen because, being relatively demanding, they were considered more likely to discriminate between cognitive performance under different REF exposure conditions (administered in a double blind manner).

4.2 Attention

1) In the Simple reaction task participants were presented with the letter 'O' and asked to press the space bar on the computer keyboard as soon the letter appeared. The letter display lasted until the participant gave the response. The subsequent stimulus display was presented after a random interval ranging from 1 to 4 seconds. Each participant was presented with 40 trials.

2) In the 10-choice reaction time task (10CRT) participants had to read aloud into a microphone a one-digit number (any number from 0 to 9) randomly displayed. The number disappeared as soon as the response was given and the next number appeared 1 second after the verbal answer. After practice (i.e. 10 trials), a block of 80 trials was presented.

3) In the subtraction task (ST) participants were presented with subtractions (one for each display), in which a one-digit number had to be subtracted from the number 9 (e.g., 9-5=?). They had to say aloud the solution into a microphone. The display with the subtraction disappeared as soon as an answer was given and the next display appeared after 1 second. This task always followed the 10CRT task. 80 trials were randomly presented.

4) In the vigilance task (VT) a single capital letter (from a pool of 15 different letters) was presented for 200ms. Each participant had to press the space bar on the computer keyboard as soon as one of the target letters (L, M or Y) appeared, while no response had to be given when any other letter appeared. The inter-stimulus interval randomly varied from 500ms to 3000ms. Each participant was presented with 360 trials of which 72 (20%) were target trials.

This was the task where REF exposure induced a significant reduction in response time to target, $p < 0.001$, in Koivisto et al. (2000 a). A more difficult variant of this task consisted in having the participant

to select, at each trial, the target from an array of stimuli.

5) A Stroop task (e.g. MacLeod, 1991) was used to assess subjects' ability to cope with interference. In this task subjects are asked to name the colour in which each of a series of colour names is written. In the critical condition words will always be displayed in a different ink (interference condition; e.g. the word "black" is displayed in red ink). Since reading the colour name is a prepotent response, a relatively efficient performance in the interference condition compared to the baseline condition (where subjects have simply to name a colour patch presented on the screen) is an index of the ability to successfully cope with conflicting information.

6) A Visual search task was used to assess the ability to find a target among a varying number of distractors. For example, the task may be to find a brown X among distractors of brown T's and green X's. Extensive research has shown that this task gets progressively more difficult as the number of the distractors increases (e.g. Treisman & Gelade, 1980). This is a particularly appropriate task for the present purposes since we can assess performance when the difficulty of the task is manipulated in parametric way from relatively easy levels (e.g., 5 distractors) to relatively difficult levels (e.g., 20 distractors). If, as suggested by Koivisto et al. (2000 b), changes in performance due to low-level REF exposure will only be apparent when tasks are demanding, then the effect of exposure should be significant when there is a relatively large numbers of distractors.

4.3 Memory

A Short-term memory search paradigm (e.g. Sternberg, 1966) was used to assess the influence of low-level REF on retrieval reaction times. Each participant was presented with 68 sequences of pictures. A sequence was of 4 or 6 pictures. Each picture was presented for 1 second. After the presentation of a sequence, a sum or a subtraction was displayed. The task of participants was to say the solution to a microphone. The display disappeared when the response was given. After that, a further test picture was presented, and the task was to decide whether or not that picture was shown in the last presented sequence of pictures. The answer was given by pressing a "Yes" or "No" key on the computer keyboard, and RT was recorded. After an interval of 4 seconds a new sequence was then shown. Test pictures required a positive response half of times.

A N-back task (Jonides et al. 1997) consisted of the presentation of a series of items in succession. Subjects had to respond as quickly and as accurate as possible to each item presented. A yes answer was required if the same item was presented either two trials back (2-back condition) or three trials back (3-back condition). Target items were letters and unfamiliar faces. These were presented in different blocks. N-back conditions, target type and order of exposure were counterbalanced across subjects. If exposure to low-level REF has a lateralised effect, it is expected that positioning the phone on the left ear should affect performance for verbal material, while positioning the phone on the right ear should influence performance with non-verbal targets. The dependent variables will be retrieval accuracy and response reaction times.

4.4 Studies

In Study 1, 168 adults subjects were tested in two different sessions (1 week apart) using the following tasks administered in a counterbalanced order:

a) Simple reaction time task;

b) 10-choice and Subtraction tasks;

c) Vigilance task.

In Study 2 a new independent sample of 160 adults subjects was tested in two different sessions (1 week apart) using the following tasks administered in a counterbalanced order:

a) Vigilance task in 'easy' and 'difficult' formats;

b) N-back task.

In Study 3 a new independent sample of 168 adults subjects was tested in two different sessions(1 week apart) using the following tasks administered in a counterbalanced order:

a) Short-term memory search paradigm;

b) Visual search task and

c) Stroop task.

Notice that assuming a relatively small effect of REF on the task used (i.e. effect size of d=0.4) each experiment has a power of about 0.95 to reject a false null hypothesis.

4.5 Results Study 1

The results obtained in this study are fully reported in the paper by Russo, R., Fox, E., Cinel, C., Boldini, A., Defeyter, M.A., Mirshekar-Syahkal, D., and Mehta, A. (2006). Does acute exposure to mobile phones affect human attention? Bioelectromagnetics1033 , 27, 215-220.

Overall, we found that when a large sample of participants is tested and exposure to REF fields is administered in a double blind manner, then REF emitted by mobile phones does not appear to significantly affect performance in a series of attentional tasks. It is important to note that these are the same tasks that previous, less powered, studies have shown were affected by exposure to REF fields. Moreover, in this study whether REF exposure originated from the right or the left, or whether the REF signal was modulated or unmodulated, made little difference to any of the cognitive tests. Finally, REF exposure effects were not modulated by gender in any of the tasks.

4.6 Results Study 2 and 3

The results obtained in these studies are comparable to those obtained in Study 1 and they are reported in the paper by Cinel, Boldini, Fox and Russo (2008). Does the use of mobile phones affect human short-term memory or attention? Applied Cognitive Psychology, 22, 1113-1125.

Overall no significant effect of exposure emerged in the tasks used. Moreover, in our study whether REF exposure originated from the right or the left, or whether the REF signal was modulated or unmodulated, made little difference to any of the cognitive tests.

5 Analysis of objectives met

Overall we achieved the targets set at the beginning, i.e. to assess the extent to which exposure to low-level radiofrequency electromagnetic fields (900 MHz) generated by the antenna of standard mobile phones (GSM and analogue) affect adults' performance in attention and memory tasks. Moreover we examined the extent to which exposure to REF may have a lateralised effect (i.e. left vs. right).

We originally planned a series of 4 studies. Unfortunately, with post-hoc insight, 4 studies appeared to be a far demanding target within the set timeframe. Subject recruitment problems (it was not uncommon that subjects did not return for the second session, thus the need to test other extra unplanned subjects) as well as extensive piloting prevented the execution of 4 studies. On the positive side is to be noted that the 3 studies conducted included most of the planned experimental tasks we intended to use. Hence, the outcome of this project appears to be in line with what was proposed at its outset. Moreover, despite the above mentioned problems we were able to complete a further minor study on the effect of exposure to REF on an auditory order threshold task. The reason for this study is that Maier and colleagues (2004), in a pilot study with human participants, found that performance in an auditory discrimination task was impaired after REF exposure of 50 minutes.

Contrary to Mayer et al. we did not find any significant effect of REF exposure on the auditory discriminant task used by Mayer et al. (see Cinel, Boldini, Russo and Fox (2007) Effects of mobile phone

electromagnetic fields on an auditory order threshold task Bioelectromagnetics 28, 493-496).

Finally, in any study we measured subjective symptoms like headache, tiredness before and after exposure. It appeared that exposure did not affect the perception of subjective symptoms. These results are reported in the paper by Cinel, Russo, Boldini, and Fox (2008). "Exposure to Mobile Phone Electromagnetic Fields and Subjective Symptoms: A Double Blind Study" Psychosomatic Medicine, 70, 345-348.

6 Interpretation of the results obtained

In summary, while it appears that with the experimental tasks paradigm used we did not detect a significant effect of acute exposure to REF originated by mobile phones, the results we obtained do not, of course, preclude the possibility that exposure to REF fields generated by mobile phones may affect other aspects of cognitive functions that were not measured by our tasks. However, the present studies highlight the need for replicable patterns of results using adequately powered studies in order to provide a sound empirical foundation for any theoretical understanding of how REF fields might affect cognitive functioning.

7 Future priorities

In several occasions public recommendations have been made for limited or no use of mobile phone in the developmental age. While this is consistent with a precautionary approach, we think that more studies should be conducted to assess any effect that mobile phones may actually have on children. Within this context we think that the empirical tests we conducted on adults could, with appropriate modifications, be adapted to assess, in adequately powered studies, the extent to which acute exposure to REF emitted by mobile phones has any effect on both cognitive processes and EEG during development (i.e. on young people aged 16 at the most).

8 Publications

Russo R, Fox E, Cinel C, Boldini A, Defeyter MA, Mirshekar-Syahkal D, and Mehta A (2006). Does acute exposure to mobile phones affect human attention? *Bioelectromagnetics,* **27,** 215-220

(Note that the content of this study was also presented at the American Psychological Association Convention; Washington 18-21 August 2005)

Cinel, C, Boldini, A, Russo, R and Fox, E (2007). Effects of mobile phone electromagnetic fields on an auditory order threshold task. *Bioelectromagnetics,* **28,** 493-496.

Cinel, C, Boldini, A, Fox, E and Russo, R (2008). Does the use of mobile phones affect human short-term memory or attention? *Applied Cognitive Psychology,* **22,** 1113-1125

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9 Financial summary

The total sum awarded i.e. £278,747 was spent on the project. This sum was mainly used for salaries, overheads, equipment, subjects' expenses and consumables.

10 References

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