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Effects of thirty-minute mobile phone use on visuo-motor reaction time

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Abstract

Objective: To investigate whether exposure to pulsed high-frequency electromagnetic field (pulsed EMF) emitted by a mobile phone has short-term effects on the visuo-motor choice reaction time (RT) and movement time (MT).

Methods: A double blind, counterbalanced crossover design was employed. In 16 normal subjects, we studied the performance of a visuo-motor precued choice reaction time task (PCRT) before and after exposure to EMF emitted by a mobile phone for 30 minutes or sham exposure.

Results: The RTs and MTs under different conditions of precue information were not affected by exposure to pulsed EMF emitted by a mobile phone or by sham phone use.

Conclusions: Thirty minutes of mobile phone use has no significant short-term effect on the cortical visuo-motor processing as studied by the present PCRT task.

Significance: This is the first study to investigate visuo-motor behavior in relation to mobile phone exposure. No significant effect of mobile phone use was demonstrated on the performance of the visuo-motor reaction time task.

Keywords: Mobile phone; Safety; High-frequency electro-magnetic field; Reaction time; Movement time; Motor preparation

1. Introduction

The wide use of cellular phones has given rise to a diverse range of concerns about health issues such as increased rate of tumor induction, and depression to possible changes in brain function. Indeed, various studies have addressed adverse or sometimes beneficial effects of high-frequency electromagnetic field (EMF) emitted by the phones. Among them are studies addressing the possible influence of mobile phones on brain function in humans (Reiser et al., 1995; Freude et al., 1998; Eulitz et al., 1998; Preece et al., 1999, 2005; Borbely et al., 1999; Koivisto et al., 2000; Huber et al., 2000; Krause et al., 2004; Sandstrom et al., 2001; Croft et al., 2002; Arai et al., 2003; Lee et al., 2001; Hamblin et al., 2004, 2006), both positive and negative, which led to a controversy that has yet to be settled. Studies on the possible impact of EMF emitted by mobile phones on cognitive functioning is no exception to this controversy, where both inhibitory (Maier et al., 2004) and facilitatory effects of EMF are reported (Preece et al., 1999, 2005; Koivisto et al., 2000a,b; Edelstyn and Oldershaw, 2002; Lee et al., 2001; Smythe and Costall, 2003), although most of the studies give negative results (see Sienkiewicz et al., 2005 for review). Therefore, a serious concern still remains as to whether the observed effects are genuine. What makes the situation more complicated is the fact that the very groups who reported positive effects of mobile phone exposure completely failed to replicate their own original findings. For example, although Preece et al. (1999, 2005) presented evidence for an increase in responsiveness in a choice reaction time task, this was not replicated by the same authors (2005) in a study of children who performed similar cognitive tasks. Similarly,

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attempting to confirm and extend the effect of EMF on reaction times in 3 out of 12 different RT tests (Koivisto et al., 2000a, 2004), Haarala et al. (2004) administered a battery of nine cognitive tasks to 64 participants with and without EMF exposure using an improved experimental design. There were no significant differences in RT. Hamblin et al. (2006) were not able to replicate their own results of their pilot study (2004), namely a significant increase in RT in response to auditory stimuli under active relative to sham exposure to EMF, in a larger group of subjects. The unsettled controversy poses a great problem since any suggestion of potential EMF effect would lead to caution as to the use of mobile phones.

While the inconsistencies among studies may be ascribed to the specific details of the experimental setup, such as the ways of exposure or inadequate sample size, acceptance of the positive findings is problematic given the methodological limitations and inconclusive speculations on the data. Reviewing most of the reports, all the positive studies have resulted from single-blind studies, whereas the majority of null findings come from double blind studies in which neither the participant nor the investigator has been aware of the exposure condition (Hamblin et al., 2006). Low and variable power output of the phones used have also contributed to the inconsistent results. Furthermore, in some studies with double blind studies, the washout period between real and sham exposures was as short as 24 h (Koivisto et al., 2000a) and 48 h (Preece et al., 1999, 2005). Therefore, we adopted a double blind, cross-over design with a washout period of 7 days or more, and an experimental setup utilizing the PDC (Personal Digital Cellular) transmission that is a technology specifically used in Japan and is of the same generation as the global system for mobile communication (GSM), the world's most extensively used system. We also used a measurement system recommended by the International Electrotechnical Commission (IEC, 2005).

In this study, we set out to elucidate the specific effects of EMF on cognitive processing. If EMF has an effect on the cognitive process, it should vary with the cognitive load of the task. Although unreplicated, there are some reports indicating beneficial effects; pulsed EMFs speed up simple and choice reaction times in adult volunteers (Preece et al., 1999, 2005), or performances in tasks requiring attention and manipulation of information in working memory (Koivisto et al., 2000b). To extend these findings, we investigated the possible effect of a mobile phone on visuomotor behavior using a precued choice reaction time (RT) task. In this task, the subjects have to press one of two buttons with the left or right hand as quickly as possible after the go-signal. A precue preceding this conveyed full, partial or no advance information (hand and/or button), such that RT shortened with increasing amount of information (Terao et al., 2005). The precuing effect has been taken to reflect motor preparation or the "state of readiness of the brain to make a specific planned movement" (Henry and Rogers, 1960). Aside from attention that has frequently been investigated with respect to the effect of EMF (Freude et al., 1998; Preece et al., 1999, 2005; Lee et al., 2001; Huber et al., 2002; Edelstyn and Oldershaw, 2002; Russo et al., 2006), this state of readiness represents another of the important and fundamental functions of the brain.

Employing this paradigm, primate studies (Halsband and Passingham, 1982, 1985; Murray and Wise 1997; Murray et al., 2000; Petrides, 1982, 1987; Riehle et al., 1997) have delineated a network of cortical regions involved in motor preparation, including the bilateral parietal cortices, premotor cortex, primary motor cortex, supplementary motor cortex and the prefrontal cortex or even the frontal, lateral premotor, and superior parietal cortices of both hemispheres, all areas with rich interconnections among one another. Similarly, in humans, this task has been shown to involve a widespread network of cortical regions for its execution, including the parietal, premotor, primary motor and prefrontal cortices of both hemispheres (Deiber et al., 1996; Adam et al., 2003; Terao et al., 2005). On the other hand, Huber et al. (2002, 2005) observed an increase in relative regional cerebral blood flow in brain regions as far as the dorsolateral prefrontal cortex ipsilateral to 30 min pulse modulated EMF from a digital mobile phone. Given the relative closeness of the antenna of the mobile phone to the head and the documented EMF effect on EEG and physiological parameters of attention, such as changes in the EEG power or amplitudes of event-related potentials (Reiser et el., 1995; Freude et al., 1998; Huber et al., 2002; Lee et al., 2001), the effect of EMF emitted by mobile phones would also be expected to affect the function of this cortical network, resulting in disruption or facilitation of the task performance. To investigate the effect of EMF on the cortical processing for motor preparation, we administered this task to normal subjects before and after exposure to EMF from the mobile phone and sham exposure.

2. Methods

2.1. Subjects

Sixteen normal subjects (9 male, 7 female, age 34.9 ± 7.0 years [mean ± standard deviation], range 23–52 years), all right-handed, participated in the present study. The subjects gave their written informed consent to the study, which was approved by the ethics committee of the University of Tokyo according to the Declaration of Helsinki. None of the participants reported any psychological or neurological disorders, or serious head injury, and none of them used hands-free devices. A more detailed description of the subjects is given in Table 1.

2.2. Experimental setup and task procedure

The setup for mobile phone was the same as that described by Arai et al. (2003). Pulsed EMF was given with