

# Mobile Phones–Like Electromagnetic Fields Effects on Human Psychomotor Performance

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## INTRODUCTION

Over the last 20 years the exponential increase in mobile phone (MP) availability has given rise to questions about possible effects on users. Indeed, since a discrete amount of radiofrequency (RF) electromagnetic fields (EMFs) emitted by mobile phones is transmitted through the skull and reaches the brain, it is possible to hypothesize a physiological influence of these low level RF EMFs on human cerebral activity, and a consequent potential influence on cognitive performance. A number of studies have assessed several aspects of human cognitive and behavioural performance, such as: short-term and working memory, attention (divided, selective, and focused), spatial and verbal recognition, vigilance, learning, decision making or perception (for a recent metaanalysis see Valentini Ferrera, & Presaghi, 2010). The entry will focus on volunteer studies, that is experimental studies with volunteer human individuals. Most experimental studies with RF exposure were conducted as laboratory studies. Within each laboratory study, the entry will report only cognitive and psychomotor effects of MP-like EMFs. Each of these effects were tested by means of different tests and tasks, administered by a computer or in a paper-and-pencil fashion. Usually dependent variables were measures of speed (i.e., the time needed to accomplish the requested activity) or accuracy (i.e., the number of correct responses to the task or, conversely, the number of errors or absence of response to a task).

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## OVERVIEW

Whether there is an effect of MP-like EMFs exposure on human psychomotor performance is still matter of debate. Most of these studies entails MP-like signals or base station-like signals as well as other types of EM signals.

This entry will focus on experimental provocation studies with human volunteers. Most experimental studies with RF exposure have been conducted as laboratory studies. These laboratory studies will only be centred on cognitive and psychomotor effects of MP-like EMFs emissions. Here we will cover studies already reviewed and even recently metaanalysed, published in the last 15 years and focusing on MP-like emissions. To this respect, we will also provide a qualitative overview of the most recent studies published up to 2013. Pioneer attempt to study human psychomotor performance was undertaken by Koivisto et al. (2000) and Krause et al. (2000) at the University of Turku (Finland). Most current relevant contributions originate from several scholars distributed across different continents. Particular methodological improvements have been proposed by Curcio et al. (2004, 2008) at the Sapienza University of Rome (Italy) and by Regel et al. (2007 a,b) at the University of Zurich (Switzerland), while enlarged sample sizes were recently studied by Keetley et al. (2006) and Hamblin et al. (2006) at Swinburne University (Australia). In addition, important attempts of replications were performed by Russo et al. (2006)

at University of Essex (UK), and by Haaraala et al. (2007) at the University of Turku (Finland).

It should be stressed that several studies reported in this entry were primarily aimed at investigating brain neurophysiology (by means of electroencephalography - EEG, Event-Related Potentials, Event-Related Synchronization/Desynchronization, Transcranial Magnetic Stimulation, Magnetoencephalography) or metabolism (by means of Positron Emission Tomography, functional Magnetic Resonance Imaging, functional Near Infrared Spectroscopy); however, only concomitant cognitive and attentional measures will be presented and examined. In particular, we will discuss specifically those outcomes related to speed of motor responses (time needed to complete the trial). This choice is substantiated by the fact that most of studies reporting an effect of RF EMFs observed a significant reduction of reaction times during or after the active exposure, while only a few of them showed effects on accuracy, effects that disappeared when highly conservative post hoc statistical tests were applied. Moreover, the choice is also supported by the hypothesis that RF EMFs may act as modulators of cortical excitability (e.g., Ferreri et al., 2006), which in turn would influence the most sensitive psychomotor function, i.e. motor reaction times to external sensory stimuli.

### **CURRENT SCIENTIFIC KNOWLEDGE IN MOBILE PHONE LITERATURE AND HUMAN PSYCHOMOTOR PERFORMANCE**

Volunteer studies are experimental provocation studies with volunteer human individuals. Compared to observational studies, these allow controlling the exposure as well as other factors that may influence the outcome. However, ethical considerations restrict the use of experimental human studies to explore transient and relatively mild effects and commonly with exposures that do not exceed the maximal permissible levels.

Most experimental studies with RF exposure were laboratory studies. However, some observational studies exist where exposures were administered within a real life situation, usually at workplace or home place. Control of exposure and other potential confounding factors are usually a greater challenge in observational studies than in laboratory provocation studies. Here, we provide an outlook of current laboratory research (up to 2013). Literature selection criteria and studies endpoints are based on our recent metanalysis (Valentini et al., 2010). In particular, when more than one sensory modality was tested in a single study, we selected only results from the auditory modality (i.e., auditory reaction times), thus concentrating on the effects of MP-like EMFs on the auditory system. This criterion is justified by the rationale that the peri-auricular temporal area is the most exposed to the thermal effects of radiations, as also documented by dosimetric studies (Cardis et al., 2008). Most of studies on human cognitive performance can be included in three categories, two of which related to the study of attention (focused attention and speed of processing, divided and sustained attention) and then a third related to the study of memory. Here, we will also include studies published after year 2010 which were not covered in our previous publication (Valentini et al., 2010).

Finally it should be stressed that, in order to be included in this entry, studies had to mandatorily satisfy some qualitative criteria, i.e. blinding of the study participants (i.e., at least a single-blind procedure); task trials/conditions randomisation and/or counterbalancing of exposure sessions, and detailed exposure characterisation (e.g., main frequency and sub-frequencies of the EMFs, signal modulations, power density and Specific absorption rate estimation).

### **Attention and Speed of Processing**

In a single-blind, counterbalanced, cross-over design, Koivisto et al. (2000) investigated the effects of MP exposure on response times to

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