

# Chapter 67

## Human Psychomotor Performance Under the Exposure to Mobile Phones– Like Electromagnetic Fields

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### ABSTRACT

*The first studies on humans addressing cognitive functioning changes as a consequence of radiofrequency (RF) EMFs exposure date back to almost 20 years ago. The effects on human behavior showed in those pioneering works indicated an improvement of performance under the exposure to the signal, compared with sham exposure. These first and striking results were not fully replicated by subsequent studies that were characterized by a more methodological robustness and attention to exposure aspects. In accordance with this view, latest reviews and metanalyses have confirmed the paucity of evidence and the lack of reliability of psychomotor and cognitive effects of acute RF EMF exposure on human volunteers, particularly when assessed in well controlled laboratory settings. Thus, despite the public opinion about potential biologic effects of acute RF EMFs irradiation, it can be concluded that to date there is substantial lack of evidence about a negative influence of non-ionizing radiations on cognitive functioning in humans.*

### INTRODUCTION

At the present time the great majority of human beings on the planet are directly or indirectly exposed to the electromagnetic fields (EMFs) emitted by mobile phones, base stations, as well as other types of wireless communication technologies. Moreover, to date for the first time ever it can be affirmed that there are more mobile devices in the world than living people: if we look at GSMA's real-time tracker (June 2016), the number of mobile devices is assessed to be more than 7.75 billion, while the total world population is estimated to be around 7.3 billion (US Census Bureau, June 2016). Such repentine

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increase in number of mobile phones has induced a growing interest toward possible health effects in human beings, bringing also the World Health Organization (WHO) to open a health topic on this issue.

Since a discrete amount of radiofrequency (RF) electromagnetic fields (EMFs) emitted by mobile phones is transmitted through the skull and can reach the brain, it is possible to hypothesize a physiological influence of these low level RF EMFs on human cerebral activity, and, consequently, a potential influence on cognitive and behavioural performance. In the last 20 years a number of studies have assessed several aspects of human performance: vigilance and attention (divided, selective, and focused), perception, learning, short-term and working memory, spatial and verbal recognition, decision making. All these studies have been repeatedly reviewed (e.g. Kwon and Hämäläinen, 2011) and metaanalyzed (e.g., Valentini et al., 2010). And the scientific interest still continues, since that only in the last 5 years (2011-2015) several new papers have been published (Oftedal et al., 2016). Thus, the present entry will focus on volunteer studies (i.e. experimental studies with volunteer human individuals) and is intended as an updating of a previous critical review of literature (Valentini and Curcio, 2015). Most experimental studies with RF-EMFs exposure have been conducted as laboratory studies. Within each laboratory study, the entry will report only cognitive and psychomotor effects of mobile phone-like EMFs. In different studies, each of these effects have been tested through different tests and tasks, both administered by a computer and in a paper-and-pencil version. Usually in this kind of literature 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) have been considered as dependent variables.

## **BACKGROUND**

Most of the included studies entail mobile phone-like signals or base station-like signals as well as other types of EM signals. This review will focus on experimental provocation studies with human volunteers, most of them being carried out as laboratory studies. Only laboratory studies focused on cognitive and psychomotor effects of mobile phone-like EMFs emissions will be taken into consideration. Here, only studies published in the last 20 years and focusing on mobile phone-like emissions will be considered as relevant. To this respect, we will also provide a qualitative overview of the most recent studies published up to 2015.

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 have been 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).

As said in a previous review (Valentini and Curcio, 2015) also in this case it is due that several studies reported here were aimed at investigating also brain neurophysiology (with Electroencephalography-EEG, Event-Related Potentials-ERPs, Event-Related Synchronization/Desynchronization-ERS/ERD, Transcranial Magnetic Stimulation-TMS, Magnetoencephalography-MEG) or metabolism (by means of

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