

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

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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 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

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still continues, since that only in the last 5 years (2011-2015) several new papers have been published (Ofstedal 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 Positron Emission Tomography-PET, functional Magnetic Resonance Imaging-fMRI, functional Near Infrared Spectroscopy-fNIRS); 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 excit-

ability (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.

SCIENTIFIC KNOWLEDGE ABOUT MOBILE PHONE INFLUENCE ON HUMAN PSYCHOMOTOR PERFORMANCE

It is known that volunteer studies are experimental provocation studies with human volunteers; with respect to observational studies, they allow to accurately control some exposure factors that may influence the outcome (as, for example, the exposure characteristics). However, all experimental human studies aimed at exploring transient and relatively mild effects of MP exposure ever respect ethical aspects using exposures that do not exceed the maximal permissible levels defined by ICNIRP (1998) and currently under continuous revision. Considered these limitations, most experimental studies with RF exposure were laboratory studies, but some observational studies also do exist: in these limited cases exposures were administered within a real life situation (such as at work or home). Control of exposure and other potential confounding factors are usually a greater challenge in observational studies than in laboratory provocation studies.

Here, it is provided an updated outlook of laboratory research (up to year 2015). Literature selection criteria and studies endpoints are based on two recent scientific contributions (Valentini et al., 2010; Valentini and Curcio, 2015). 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 mobile phone-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 (see for example Curcio et al., 2004), as also documented

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