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Terrestrial Trunked Radio (TETRA) exposure and its impact on slow cortical potentials

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ABSTRACT

Background: Studies have shown that exposure to radiofrequency electromagnetic fields (RF-EMF) in the mobile communication frequency range may induce physiological modifications of both spontaneous as well as event-related human electroencephalogram. So far, there are very few peer-reviewed studies on effects of Terrestrial Trunked Radio (TETRA), which is a digital radio communication standard used by security authorities and organizations in several European countries, on the central nervous system.
Objectives: To analyze the impact of simulated TETRA handset signals at 385 MHz on slow cortical potentials (SCPs).
Methods: 30 young healthy males (25.2 ± 2.7 years) were exposed in a double-blind, counterbalanced, cross-over design to one of three exposure levels (TETRA with 10 g averaged peak spatial SAR: 1.5 W/kg, 6.0 W/kg and sham). Exposure was conducted with a body worn antenna (especially designed for this study), positioned at the left side of the head. Subjects had 9 test sessions (three per exposure condition) in which three SCPs were assessed: SCP related to a clock monitoring task (CMT), Contingent negative variation (CNV) and Bereitschaftspotential (BP).
Results: Neither behavioral measures nor the electrophysiological activity was significantly affected by exposure in the three investigated SCP paradigms. Independent of exposure, significant amplitude differences between scalp regions could be observed for the CMT-related SCP and for the CNV.
Conclusions: The present results reveal no evidence of RF-EMF exposure-dependent brain activity modifications investigated at the behavioral and the physiological level.

1. Introduction

Terrestrial Trunked Radio (TETRA) is a digital radio communication standard primarily designed for occupational use by security authorities and organizations (e.g. police forces, fire brigade and rescue services). The frequencies that have been allocated for the operation of the TETRA public safety systems in Europe vary between 380 and 400 MHz. Based on the Stewart report published in 2000, the TETRA-specific pulse modulation at 17.6 Hz has been viewed skeptically for the reason that it is adjacent to the 16 Hz amplitude modulation component which was seen to be associated with increased release of cellular calcium (IEGMP, 2000).

The steadily increasing use of digital mobile communication systems has also raised public concern about possible health effects from radiofrequency electromagnetic fields (RF-EMF; EC (2010)). Reviews of the literature by several national and international independent expert advisory boards concluded that there were no relevant health effects (e.g., AGNIR (2012), SCENIHR (2015) and WHO (2014)) provided that the exposure guidelines proposed by the International Commission of Non-Ionizing Radiation Protection (ICNIRP; ICNIRP (1998)) had been followed. There is some evidence that exposure to RF-EMF in the mobile communication frequency range may induce physiological modifications of both spontaneous (e.g., Croft et al. (2010) and Vecchio et al. (2010)) as well as event-related (e.g., Leung et al. (2011) and Maby et al. (2004)) human electroencephalogram (EEG). The biological significance of these effects, however, is not clear (SCENIHR, 2015).

Event-related EEG patterns or event-related potentials (ERP) are electrical waveforms embedded within the background activity which occur time-locked to an external or internal stimulus. They can be considered as neural responses to the perceptual,

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cognitive and action-related activities involved in stimulus processing (Luck, 2005). Since most movements are not just simple reflexes but pursue a certain goal, a plan how to react adequately is required. Knowing in advance the way to respond implies a preparation of the motor system for the action that is going to be executed in the very near future. Motor preparation is further under perceptual control in order to adapt to the expected upcoming changes in the environment which in turn presupposes attention. How precise and goal-oriented the behavior will be depends on perception as well as on action, and both are determined by anticipation (Brunia and Van Boxtel, 2000). Preparatory and/or anticipatory processes are expressed in the EEG as slowly increasing direct-current shifts, also referred to as slow cortical potentials (SCPs), with negative slopes that occur chronologically before the intended activity (Birbaumer et al., 1990).

Studies investigating effects of RF-EMF from digital mobile communication systems on SCPs are scarce. Freude and coworkers (Freude et al., 1998, 2000) revealed a significantly less pronounced negative deflection of a SCP that appeared during complex visual monitoring under Global System for Mobile Communications (GSM) exposure, whereas no exposure effects were found on the Bereitschaftspotential (BP), a SCP that can be observed prior to self-paced movements (Kornhuber and Deecke, 1965). With the same exposure-setup, Freude et al. (2000) stimulated participants during a forewarned reaction time task to elicit a Contingent Negative Variation (CNV), a SCP that has been shown to emerge between a warning signal and an upcoming imperative stimulus requiring a fast (motor) response (Walter et al., 1964). They observed a significant interaction between exposure and brain region with increased amplitudes at frontal electrodes when the subjects received GSM exposure compared to no exposure (Freude et al., 2000). In contrast, statistically significant amplitude reductions of the CNV following GSM exposure have been reported by de Tommaso et al. (2009).

Previous studies on TETRA exposure effects refer predominantly to behavioral aspects, symptoms or to physiological measurements restricted to the autonomic nervous system. Riddervold et al. (2010) conducted a study in which possible effects of a 45 min TETRA handset exposure on cognitive functions and subjective symptoms in 53 male adults were investigated, and yielded no statistically significant differences between the TETRA and sham conditions. Similar results were reported by Nieto-Hernandez et al. (2011) who investigated the impact of a 50 min TETRA-like, continuous wave or sham exposure on subjective symptoms and mood in 60 users reporting sensitivity to TETRA and 60 users not reporting sensitivity to TETRA. Blood pressure and related cardiovascular parameters were also not significantly affected by TETRA hand set signals (Barker et al., 2007). Studies on possible effects of TETRA base station EMFs on cognition and physiological responses in 51 individuals with self-reported electrosensitivity and 132 controls revealed no differences between sham and TETRA exposure, neither in the sensitive nor in the control group (Wallace et al., 2010, 2012). Possible health risks associated with the use of TETRA are currently being evaluated in a large-scale, prospective cohort study of police employees (Airwave Health Monitoring Study). This study has been launched in 2004 and aims at recruiting over 60,000 participants by 2018. The rationale, design and methods as well as first results of the study can be found in Elliott et al. (2014). Possible health outcomes related to TETRA are, however, not mentioned in this publication.

There are very few peer-reviewed studies on effects of TETRA on the central nervous system. Butler (2005) investigated whether an exposure to a TETRA signal or to an unmodulated carrier wave had an effect on electrophysiological activity compared to sham. Timing and amplitude of several evoked and event-related EEG patterns as well as the power spectrum of the EEG were not significantly affected by either exposure conditions.

In 2009, a comprehensive research project on open questions concerning possible risks of TETRA exposure and its health relevance for potential users was initiated by the Federal Agency for Public Safety Digital Radio (BDBOS) commissioned by the German Federal Office for Radiation Protection (BfS). Aim of this research project, which was carried out at the Competence Center for Sleep Medicine of the Charité – University Medicine Berlin, was to investigate possible effects of TETRA signals on brain functioning during sleep (overnight assessments) and wakefulness (daytime assessments) in healthy young male volunteers. The latter was investigated in a resting condition and while meeting several cognitive demands at various levels of information processing. Throughout daytime assessments subjects completed a set of psychometric tests while being exposed to one of three RF output power levels. First results of the daytime assessments dealing with a possible TETRA impact on cognitive function, symptoms and well-being have already been published (Sauter et al., 2015) and showed only sporadic exposure-dependent changes on cognition which are, however, not indicative of any adverse health effect. Psychometric testing throughout the daytime assessments comprised further several ERP experiments including paradigms to elicit SCPs related to motor preparation and anticipation for which results are presented in this paper. In the TETRA research project, three specific SCPs were considered in order to replicate previous observations by Freude et al. (1998, 2000) for GSM mobile phone frequencies. Referring to these two studies, it was hypothesized that (1) amplitudes of a SCP during visual monitoring decreased, (2) amplitudes of the CNV increased and (3) amplitudes of the BP remained unaffected following exposure. In addition, as three different exposure levels of increasing intensities were considered, more pronounced exposure effects were expected under the higher RF output power level condition.

2. Materials and methods

2.1. Subjects

32 healthy, right-handed young males attended the study, but only the results of 30 individuals could be analyzed [mean age $\pm$ standard deviation (SD): 25.2 ± 2.7 years; range: 20–30 years] due to initial technical problems with the test procedures. All of them were non-smokers and (potential) users of TETRA.

Information on sleep habits and sleep quality as well as on mood were assessed by a two week sleep diary (Liendl and Hoffmann, 1999), a general comprehensive sleep questionnaire (Zulley, 2002), the Pittsburgh Sleep Quality Index (PSQI; Buysse et al. (1989)), the Epworth Sleepiness Scale (ESS; Johns (1991)), the Landecker Inventory for sleep disturbances (LISST; Weeß et al. (2002)), the Morningness–Eveningness Questionnaire (MEQ; Horne and Östberg (1976)), the Zung Self-Rating Anxiety Scale (SAS; Zung (1971)), and the Zung Self-Rating Depression Scale (SDS; Zung (1965)). Participants had to pass a medical screening including a physical, psychiatric and neurological examination, a resting state waking EEG and an electrocardiogram. Participants were screened for sleep disorders by a home recording system followed by an adaptation and screening night in the lab.

Enrolled participants showed a regular sleep–wake cycle, alpha activity as the basic rhythm in the resting state waking EEG with eyes closed, and no evidence for a current or previous sleep disorder. Exclusion criteria were: (1) cognitive impairments, (2) present intake of CNS-active medication(s), (3) untreated medical condition, (4) any medical, neurological or psychiatric condition, which has a clinically significant effect on sleep and/or vigilance, (5) an electronic implant, (6) tattoos in the head or neck region