Summaries and assessments of selected studies

In the period from beginning of May to end of July 2021, 106 new publications have been identified, and six of these were discussed in depth by BERENIS. Based on the selection criteria, two of these publications were selected as the most relevant ones. Their summaries and assessments are provided below. In addition, a study on risk perception of 5G (Frey 2021) is discussed. This publication was initially identified as a preprint version at the end of 2020, and has been published as a peer-reviewed paper in September 2021.

1) Experimental animal and cell studies

Exposure to RF-EMF alters postsynaptic structure and hinders neurite outgrowth in developing hippocampal neurons of early postnatal mice (Kim et al. *2021)*

Effects of RF-EMF on learning behavior and memory performance in children are poorly understood. Therefore, Kim *et al.* (2021) investigated the memory performance of young mice after RF-EMF-exposure (1850 MHz, whole-body SAR: 4 W/kg) for 5 hours per day for 28 days. The length and morphology of the protrusion of neurons (neurites) and the number of branches (dendritic spines) were measured. Both are important for synaptic activity and signal transmission. In this study, experiments were performed in the hippocampus and in primary cell cultures from this brain region. The hippocampus is part of the limbic system and plays a role in emotion processing, learning and memory. The hippocampal cell cultures were exposed for 5 hours per day for a total of 9 days (SAR 4 W/kg). Proteins that are important for signal transduction, such as glutamate receptors, postsynaptic density protein (PSD95), and brain-derived neurotropic factor (BDNF) were analyzed at different time points. An important task of BDNF, a growth factor that occurs particularly in the forebrain, hippocampus and cerebral cortex, is the protection of existing neurons and synapses. Furthermore, BDNF stimulates the growth and further development of new neurons, neuronal pathways and synapses.

The *in vivo* results showed that the number of dendritic spines was decreased in neurons of the *dentate gyrus* but not of the *cornu ammonis* subregion of the hippocampus in RF-EMF-exposed animals. Glutamate receptors on the mushroom-type branches and BDNF expression were decreased in both regions. In line with the morphological findings, memory performance of RF-EMF-exposed animals was declined compared to sham-exposed control animals. In the experiments with cultured primary neurons, PSD95 levels increased over time, but this increase was significantly less pronounced in RF-EMF-exposed neurons during days 5-9 *in vitro*. In RF-EMF-exposed neuronal cultures, the neurites were also significantly shorter.

Although these results are in agreement with those of other studies that showed impaired neurogenesis after RF-EMF exposure *in vitro* (see also Chen *et al.* 2021 below), thermal effects cannot be completely excluded. A temperature increase of 0.6°C per hour was measured in a mouse phantom in saline water.

Changes in differentiation of neurons exposed to radiofrequency EMF (Chen et al. *2021).*

Chen *et al.* (2021) investigated the influence of a GSM-modulated RF-EMF on the development of neurons *in vitro*. To this end, the authors exposed neural stem cells from mouse embryos to a RF-EMF

(1.8 GHz, SAR: 4 W/kg, 5/10 minutes on/off) for 48 hours. The cells were exposed 1-2 days after initiation of the differentiation process, which resulted in differentiation to 55% neurons and 35% astrocytes under unperturbed conditions. Moreover, the main findings were also confirmed in a differentiating neuroblastoma cell line (Neuro-2a). First, the authors analyzed the global changes in gene expression caused by RF-EMF exposure during differentiation and found changes for about 240 genes. Many of these genes are involved in the neural outgrowth (dendrites, axons) and neuronal development, e.g., in the regulation of signaling cascades or the cytoskeleton (microtubule/actin filaments). The filaments of the cytoskeleton play an important role in the formation of nerve cell protrusions of cultured neurons, which are called neurites. The findings from the expression analysis were then followed up at the molecular and morphological levels. RF-EMF exposure reduced the length and number of neurite branching, which was accompanied by a reduction of related proteins, such as the microtubule-associated protein DCX and the ephrin ligand receptor Epha5. The authors used pharmacological inhibition and modulation of signaling pathways to investigate the mechanism that led to the changes in receptor activity.

The authors conclude that the ephrin ligand receptor Epha5 plays a central role in the reduction of neuronal development by GSM-modulated RF-EMF, and speculate on altered calcium signaling pathways as a cause for the reduction of Epha5. In addition to the well-documented role in neuronal development and function, an influence on calcium and other ion channels is frequently brought forward as a possible cause or mechanism of action for EMF effects. These are discussed in more detail in a recent review by Bertagna *et al.* (2021) (see below). The findings of Chen *et al.* (2021) together with similar observations in animal models and cultured cells with regard to neuronal development are quite coherent and should be explored more comprehensively.

2) Study on risk perception

Risk perception of 5G: A systematic case study (Frey 2021)

Frey (2021) conducted two surveys on risk perception regarding the new 5G technology in Switzerland. The first survey took place before the publication of an expert report on 5G by the Swiss Federal Department of the Environment, Transport, Energy and Communications (DETEC, November 2019)[1]. The survey results showed that 65% of the 2919 respondents associated 5G with a medium to high risk, and saw little to no personal benefit in the new mobile technology. On the other hand, 61% of the respondents rated the benefits for society and 76% those for the economy as high. Furthermore, a need for more regulation (74%) and more research (90%) became apparent. In the event of a national referendum, 52% would have voted against 5G. Subjective perception of a threat and electromagnetic hypersensitivity (EHS) were factors leading to higher risk ratings. Trust in authorities, male sex, and objective knowledge about 5G resulted in a lower rating. The findings of the second study (cross-sectional, 1013 different respondents) were in line with those of the first one. The publication of the expert report had no influence on the opinions. In addition, a longitudinal field experiment was conducted in which 839 participants from the first study were interviewed once again. Participants were randomly assigned to four groups that either received information material from the expert report (with varying degrees of detail) or received no material prior to the second survey. The risk perception of the respondents changed in both directions and it was found that mere information, as

[1] DETEC (2019): Report Mobile Radio and Radiation. Federal Department of the Environment, Transport, Energy and Communications (DETEC), working group on Mobile Radio and Radiation. 18th November 2019. https://www.newsd.admin.ch/newsd/message/attachments/59387.pdf

in this experiment, hardly seems to lead to a reduced risk perception overall. Trust in authorities, as well as the magnitude of the perceived threat, appear to be potentially important factors when it comes to changing risk perception. The study shows that the effect of this one-time information on risk perception is small. However, the study is not informative regarding changes of risk perception in the long term due to the communication of a wide variety of information, e.g., in the media.

3) Information on additional publications: Reviews

Effects of electromagnetic fields on ion channels

Based on studies published between 2005 and 2020, the systematic review by Bertagna *et al.* (2021) investigated the effects of EMF on ion channels in neuronal cells, and summarized 21 studies.

Health effects of WiFi

The review by Dongus *et al.* (2021) focused on biological and health effects of WiFi radiation. Studies published since 1997 were systematically identified, and 23 studies were synthesized.

References

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BERENIS - Swiss expert group on electromagnetic fields and non-ionising radiation

List of abbreviations (pdf)