Summaries and assessments of selected studies

In the period from beginning of May to mid of July 2020, 65 new publications have been identified, and seven of these were discussed in depth by BERENIS. Based on the selection criteria, three of these publications were selected as the most relevant ones. Their summaries and assessments are provided below.

1) Experimental animal and cell studies

Magnetoreception in the inner ear of pigeons (Nimpf et al. 2019)

Some animals can sense magnetic fields and use them for orientation. Various mechanisms have been discussed in this regard, yet little is known about whether and if so, where such sensory structures to detect static magnetic fields exist in these animals. The study by Nimpf *et al.* (2019) explored such structures in the inner ear of pigeons. The aim was to show that certain structures and cells in the inner ear detect magnetic fields independent of light. They found that magnetic stimuli (150 µT, rotating 360° in steps) activate neurons in the vestibular nucleus of pigeons exposed in Helmholtz coils. Neuronal activity markers such as the C-FOS protein, which responds very quickly to a variety of stimuli, were used as biomarkers. These stimuli induce a voltage in a semicircular canal, and magnetic fields are thereby detected by electroreceptive sensors through electromagnetic induction. The authors showed that magnetic field stimulation leads to voltage spikes (1.4 µV) in channel-like structures in cells of the inner ear, facilitating the perception of magnetic fields. A certain orientation of the magnetic field is necessary for detection. This voltage-dependent calcium channel (Cav1.3, long form) has already been described in sharks and skates. The study involved both experimental investigations and theoretical calculations. The detection of the magnetic field could be demonstrated independent of light stimuli.

These new findings are interesting because they corroborate previous studies and support the presence of structures in the inner ear, which can detect electrical activity independently of light. Subsequent experiments that could provide further evidence include: 1. pharmacological intervention in the calcium channels, 2. ablation (targeted destruction) of the hair cells[1] with antibiotics and/or 3. genetic manipulation of the calcium channel.

Promotion of cell ageing by radiofrequency electromagnetic fields (LTE signal)? (Choi et al. *2020)*

In this study, Choi *et al.* (2020) used a modulated RF-EMF, for which only few experimental data are available so far. The authors exposed cultured cells with a typical LTE signal (Long Term Evolution; 4G) on a 1.7 GHz carrier frequency, and investigated its effect on aspects of cell vitality and proliferation. Different types of cells from various tissue origins were exposed for 3 days, with calculated SAR values of 1 and 2 W/kg. First, the authors found that the three-day exposure led to a reduction in cell proliferation of about 10-90% compared to the control populations without exposure, depending on the dose. Overall, the anti-proliferative effect was more pronounced in cancer cells than, for example, in stem cells from adipose tissue or fibroblasts from the skin. Furthermore, the authors investigated the cause for the observed effects. As the effects could be attenuated by the addition of a ROS scavenger, a role of oxidative stress and the formation of ROS was postulated. According to the

[1] Hair cells are the sensory cells of the inner ear

authors, the reduction of cell proliferation by LTE exposure was caused neither by damage to the DNA nor the induction of programmed cell death (apoptosis), but by an enhancement of the cell ageing process (senescence). Accompanied by a slowing of the cell cycle progression, an increased proportion of cells with biomarkers for senescence was found in the exposed cultures.

The possibility that exposure to an RF-EMF could have an effect on the cell ageing process has been mentioned or investigated rarely in scientific studies so far. In this respect, the consistent effects found in different cell types in the methodologically and biologically elaborated study by Choi *et al.* (2020) are remarkable. It should be noted, however, that a new and hardly validated exposure device was used, which allows for a good temperature control, but might suffer from low field homogeneity, possibly leading to an underestimation of the calculated SAR values. Nevertheless, these observations should promote further investigation of cell ageing in relation to RF-EMF exposure.

3) Epidemiological studies

Radiofrequency electromagnetic fields and brain volume in preadolescents (Cabré-Riera et al. *2020)*

In a study conducted in the Netherlands ("Generation R study"), data from 2,592 children aged nine to twelve years were analysed to determine whether there is a connection between RF-EMF exposure and the volume of different brain areas. The brain volume of all study participants was assessed by magnetic resonance imaging (MRI) between 2013 and 2015. Data on use of wireless communication devices (mobile and cordless phones, as well as tablets and laptops used with WiFi) were collected via questionnaires filled by the parents. Exposure by broadcast transmitters and mobile phone base stations was modelled for the school and residential locations. Exposure at other locations was assessed based on personal RF-EMF measurements in a sample of 56 children. Based on all this information on exposure, the absorbed RF-EMF dose was calculated for different brain regions. The statistical analyses were corrected for a series of potential confounders (e.g. maternal education and smoking behavior, as well as body mass index and intelligence quotient of the child). The median daily brain RF-EMF dose was 84.3 mJ/kg. Of this, 62% were from mobile and cordless phone calls, 17% from screen activities with mobile devices and 21% from far-field sources (mobile and cordless phone base stations, broadcast transmitters, WiFi access points). The volume of all studied brain regions was not associated to the total absorbed RF-EMF dose nor to that from far-field sources. However, the RF-EMF dose from screen activities was associated to a smaller volume of the frontal lobe and the caudate nucleus. The authors conclude that not RF-EMF, but possibly other factors related to intensive screen use could have an effect on these brain regions. As alternative explanations, confounding, chance finding or reverse causality could not be excluded though.

Being part of the EU project Geronimo, this is a large study with accurate data on the volume of different brain regions. Furthermore, it is one of the few studies that has assessed the RF-EMF brain dose, which is more informative than merely analysing the use of RF-EMF emitting sources. Nevertheless, such estimates are inevitably subject to large uncertainties. The frontal lobe is important for impulse control. The basal ganglia, which include the caudate nucleus, initiate physiological and cognitive processes: they provide a filtering process in the loop of motor movements by allowing desirable and possible movements and preventing undesirable movements or movements that are not possible in the given situation. In this way, the spontaneous activity of the organism is modulated. The basal ganglia receive information from all regions of the cerebral cortex, and pass on information via the thalamus to the premotor and frontal cortex. This pathway facilitates the rapid and coordinated regulation of sequences of unconscious, automated, fine motor movements. A reduced volume of the

caudate nucleus was found to be related with ADHD in an earlier study[2] of preadolescents. Similar connection patterns as in tic disorders might be involved here. However, in ADHD, it is not a specific behaviour pattern that is processed incorrectly, but a general inadequate filter function in which redundant or "inappropriate" behaviour is stimulated (hyperactivity), while new behavioural plans are incorrectly inhibited (attention deficit). It might thus be plausible that the reduced brain regions are the cause and not the consequence of intensive screen use.

References

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Contact

Dr Stefan Dongus
BERENIS Secretariat
Swiss Tropical and Public Health Institute
Department of Epidemiology and Public Health
Environmental Exposures and Health Unit
Socinstr. 57, P.O. Box, CH-4002 Basel, Switzerland
Tel: +41 61 284 8111
Email: stefan.dongus@swisstph.ch

[2] Carrey N, Bernier D, Emms M, Gunde E, Sparkes S, Macmaster FP, Rusak B (2012): **Smaller volumes of caudate nuclei in prepubertal children with ADHD: impact of age.** J Psychiatr Res. 2012 Aug;46(8):1066-72. https://www.sciencedirect.com/science/article/pii/S0022395612001392
(„These novel findings suggest a different pattern of caudate volume abnormalities across narrow age clusters prior to puberty in boys with ADHD. Anatomical differences in brain structures related to ADHD in prepubertal children should be evaluated with respect to the changing developmental trajectory of brain regions within this period of rapid brain growth“)

Additional information:

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

List of abbreviations (pdf)