Summaries and assessments of selected studies

In the period from late April to early August 2018, 57 new publications have been identified, and eight 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

50 Hz magnetic fields impair cognitive and motor abilities of honey bees (Shepherd et al. *2018)*

In the study by Shepherd *et al.* (2018) honey bees were exposed to extremely low frequency magnetic fields (ELF-MF) (50 Hz) with intensities of 20-100 µT and 1000-7000 µT. Comparable magnetic fields can be found at ground level below high voltage power lines or in the immediate vicinity of the conductor cables. Learning and memory were tested by means of the proboscis extension response of the bees with respect to glucose (olfactory learning). Short-term exposure of one minute showed a dose-dependent impairment of the learning behaviour. This impairment was still visible one hour after the exposure. In order to investigate the effect of the ELF-MF on the flight behaviour, changes in the wing beat frequency during tethered flight were measured. An intensity-dependent increase in the wing beat frequency was observed, however, the difference to the unexposed control bees was only statistically significant at the highest intensity (7000 µT). The effects of 100 µT magnetic fields on foraging were studied in a flight tunnel, showing that while the number of successful outgoing flights was reduced, flights returning to the hive were not affected.

The results suggest that ELF-MF (50 Hz) emitted from power lines may be an environmental stressor for honey bees, with the potential to impact their cognitive and motor abilities, which could in turn affect pollination. The underlying mechanisms are unclear, although the magnetosensitive system of the bees could be involved. Further studies are needed to elucidate the mechanisms of action, and to gain a better understanding of the observations made here.

Magnetoreception: on the influence of weak static magnetic fields on biological processes (Zwang et al. *2018)*

The study by Zwang *et al.* (2018) investigates a possible concept of magnetoreception, the ability to perceive a magnetic field (MF). While it is widely accepted that some animal species such as migratory birds have the ability to detect the Earth's weak magnetic field and use it for navigation, the underlying sensing mechanism and organ has remained largely speculative. Proposed mechanisms include iron-containing nanoparticles and magnetically sensitive biochemical processes that involve radical pairing (i.e. reactive molecules with unpaired electrons). With regard to the latter mechanism, the current scientific focus is on the photoreceptor cryptochrome (see BERENIS Newsletter Nr. 13 - March 2018), while the biochemical processes and its integration into the regulatory mechanisms of the cells are still unclear. The publication by Zwang *et al.* (2018) addresses exactly this question by studying the influence of weak static magnetic fields on an enzymatic reaction by a well-controlled cell-free system using purified biomolecules. They used a short piece of DNA with a specific damage (a chemical modification of pyrimidine DNA bases - thymine and cytosine) resulting from UV-C irradiation, which is coupled to a microchip with electrodes. In bacteria, such thymine dimers are repaired in a light dependent reaction by so-called photolyases,

which are related to the cryptochromes of higher organisms. Both of them are able to absorb blue light and use the energy to transfer electrons from one molecule to another, involving the formation of radical pairs. In the case of the photolyases, an electron is transferred to the reduced flavin cofactor (FAD, flavin adenosine dinucleotide) then to the thymine dimer i in order to repair the damage before returning to the flavin while reverting the damaged base. In elaborated control experiments with their microchip, the authors showed that they can follow this repair process, and that the efficiency of this process is influenced by weak static magnetic fields. They observed that a 0.6 gauss magnetic field (60 µT), thus only 1.5 times stronger than the Earth's magnetic field at the site of the experiment, already reduced the repair efficiency of the thymine dimers. Stronger magnetic fields up to 30 gauss (3 mT) resulted in a further dose-dependent reduction of the reaction, whereas fields with higher magnetic flux densities did not yield any stronger enhancement of the effect. Furthermore, it was investigated whether this DNA repair reaction and its sensitivity to MF exposure applies for the related cryptochromes that are thought to be not effective in the repair of the thymine dimers, since they hardly bind to the DNA. For this purpose, the authors shortened a plant cryptochrome down to the conserved region in the photolyases, and again they observed a repair activity as well as an impact of the MF. Another interesting observation was that this reduction was not only dependent on the strength but also the direction of the MF, and that this reduction was effective only on the microchip where all DNA molecules are aligned but not when they were free-floating in solution. Another important conclusion of the authors was that the magnetosensitive radical pairing is not located on the photolyase-flavin complex as hypothesised, but in the thymine dimer itself. In the last step of the repair process, two radicals form on the two dimerized bases. Returning the electron back to the flavin, this either lead to the separation and thus repair or to falling back to the original thymine dimer. The authors conclude that the magnetic field shifts this balance to the disadvantage of the thymine dimer repair.

In summary, this innovative study provides conceptual insight on how a magnetic compass of living organisms may function at the molecular and biochemical level. For the first time, the direct influence of weak magnetic fields on biologically relevant enzymatic processes could be shown, in which the radical pairing mechanisms play a role. However, the search for the magnetic sensor or the magnetosensitive biological process is not conclusively resolved. It seems rather unlikely that a biological compass is based on the relatively dangerous UV-C induced damage of the genetic material. In addition, the fixed molecular structures required for such a mechanism are not known. In respect to the role of cryptochromes of higher organisms as magnetoreceptor, there is still a lot of space for further experimental studies regarding the mode of operation and the influence of manmade electromagnetic fields.

2) Epidemiological studies

Mobile phone radiation and adolescents' memory performance in Switzerland (Foerster et al. *2018)*

The study of Foerster *et al.* (2018) investigated the relationship between exposure to RF-EMF from wireless communication devices and memory performance in adolescents. The study follows up a report published by Schoeni *et al.* in 2015, with twice the sample size and more recent information on the absorption of RF-EMF in adolescents' brains. Almost 700 adolescents aged 12 to 17 years participated in the study over a period of one year. The participants were recruited from 7th to 9th public school grades in urban and rural areas of Swiss-German speaking Switzerland. Figural and verbal memory performance was measured twice with a one-year follow-up period using standardised computer tests. In addition, with the consent of the parents and the adolescents, the

analysis included objectively collected mobile phone usage data from the Swiss mobile service providers, covering the entire study period. Environmental RF-EMF exposure was individually modelled for the school and residence of the study participants. A subgroup of the adolescents also participated in a personal RF-EMF measurement study. Based on these usage and exposure data, the cumulative RF-EMF dose from mobile phones and other wireless communication devices was calculated both for the brain and for the whole body. The study found that cumulative RF-EMF brain exposure from mobile phone use over one year may have a negative effect on the development of figural memory performance in adolescents, confirming prior results published in 2015. Figural memory is mainly located in the right brain hemisphere, and association with RF-EMF was more pronounced in adolescents using the mobile phone on the right side of the head (80% of study participants). Verbal memory is mainly located in the left brain hemisphere. With regard to usage data from mobile service providers, adolescents using their mobile phone also on the left side of the head tended to show a negative effect on the development of their verbal memory. Other aspects of wireless communication use, such as sending text messages, playing games or browsing the internet cause only marginal RF-EMF exposure to the brain and were not associated with the development of memory performance over one year.

The dependence of the results on the laterality and the absence of associations in the negative exposure control variables texting, gaming and browsing the internet may suggest that RF-EMF absorbed by the brain is responsible for the observed associations. Most of the cumulative brain dose was from own mobile phone calls, while the contribution of mobile phone base stations and Wi-Fi was low. This is the world's first epidemiological study that has made dose calculations for the adolescent brain, using objectively collected usage data from mobile service providers. The effects were relatively small and the underlying mechanism is unclear. An influence of other factors thus cannot be ruled out. For instance, the study results could have been affected by puberty, which affects both mobile phone use and the participant's behaviour as well as cognitive abilities.

A German / French summary of the complete HERMES study has recently been published in a Swiss periodical (Roser *et al.*, 2018). In addition to the memory effects described here, the HERMES study also investigated possible influences on behaviour, nonspecific symptoms and the ability to concentrate.

References

Foerster M, Thielens A, Joseph W, Eeftens M, Röösli M (2018**): A Prospective Cohort Study of Adolescents' Memory Performance and Individual Brain Dose of Microwave Radiation from Wireless Communication.** Environ Health Perspect. 2018 Jul 23;126(7):077007. https://www.ncbi.nlm.nih.gov/pubmed/30044230

Roser K, Schoeni A, Foerster M, Röösli M (2018): **Wie wirkt die Nutzung und die Strahlung von Mobiltelefonen auf Jugendliche? [Quels sont les effets de l'utilisation et du rayonnement des téléphones mobiles sur les jeunes?]** Primary and Hospital Care – Allgemeine Innere Medizin, 2018: 18(21): 386–388. https://primary-hospital-care.ch/de/article/doi/phc-d.2018.01852/

Schoeni A, Roser K, Röösli M (2015): **Memory performance, wireless communication and exposure to radiofrequency electromagnetic fields: a prospective cohort study in adolescents.** Environ Int. 2015 Dec;85:343-51. Epub 2015 Oct 30. https://www.ncbi.nlm.nih.gov/pubmed/26474271

Shepherd S, Lima MAP, Oliveira EE, Sharkh SM, Jackson CW, Newland PL (2018): **Extremely Low Frequency Electromagnetic Fields impair the Cognitive and Motor Abilities of Honey Bees.** Sci Rep. 2018 May 21;8(1):7932. https://www.ncbi.nlm.nih.gov/pubmed/29785039

Zwang TJ, Tse ECM, Zhong D, Barton JK (2018): **A Compass at Weak Magnetic Fields Using Thymine Dimer Repair.** ACS Cent Sci. 2018 Mar 28;4(3):405-412. Epub 2018 Mar 7. https://www.ncbi.nlm.nih.gov/pubmed/29632887

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

Additional information:

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

List of abbreviations (pdf)