Spotlight on EMF Research

Spotlight on "The effect of exposure to radiofrequency electromagnetic fields on cognitive performance in human experimental studies: Systematic review and meta-analyses" by Pophof et al. in Environment International (2024)

Category [radiofrequency, review]

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Competence Centre Electromagnetic Fields (KEMF)

1   Putting the paper into context by the BfS

The World Health Organization (WHO) has initiated an ongoing project to systematically assess the potential health effects of exposure to radiofrequency electromagnetic fields (RF-EMF) in the general and occupational populations. To this end, in 2018, the WHO conducted a comprehensive international survey among RF-EMF experts to prioritize the potential health effects according to their importance [2]. Key topics were identified for which the WHO has commissioned systematic reviews. More information on the WHO systematic reviews in general can be found in another Spotlight on EMF Research article (Apr/2024 no.2 [3]).

Possible effects of RF-EMF on various aspects of cognitive functions have been discussed for many years because the human brain is potentially exposed to a relevant extent when a mobile phone is operated close to the head during phone calls. The systematic review at hand [1] assesses findings on the effects of RF-EMF exposure on cognitive performance, as reported in human experimental studies. Another systematic review that assesses the effects of RF-EMF on cognition in human observational studies [4] will be addressed in a separate Spotlight on EMF Research article.

2   Results and conclusions from the perspective of Pophof et al.

This systematic review focuses on experimental studies examining the effects of short-term exposure to RF-EMF on human cognitive performance (e.g. Memory, Attention, etc.) [1]. Pophof et al. followed the Cochrane recommendations for the conduct of systematic reviews in toxicology and environmental health research [5] and described the methods, including literature search strategy, eligibility criteria, and the procedures of data extraction, synthesis, and analysis in a study protocol that was published prior to conducting the review [6]. The PECO (population, exposure, comparator, outcome) that formulates the research question was: "*what are the immediate effects of exposure to RF-EMF in the frequency range 100*

kHz – 300 GHz (E) on the cognitive performance (O) in humans (P) as compared to no exposure or a lower level of exposure (C)?". The quality of included studies was assessed taking into account predefined risk of bias (RoB) criteria [7]. A three-tier stratification system was employed to classify studies according to their susceptibility to bias. Studies classified within tier 1 exhibited a low overall RoB, indicating high study quality, whereas those assigned to tier 3 demonstrated a high overall RoB, reflecting low study quality. Blinding and outcome assessment were considered the most critical factors for overall study quality and were therefore used as key criteria for tier classification.

Cognitive performance was categorized into seven different domains [8]. For five of these domains, suitable data from at least two studies were available for a meta-analysis: 1) Attention and Orientation, 2) Perception, 3) Memory, 4) Construction and Motor Performance, 5) Concept Formation and Reasoning. The cognitive performance was being measured in terms of speed and/or accuracy, and effect sizes (Hedges's g) were calculated using a random effects meta-analyses of separately for accuracy- and speed-related performance measures. If the study results were inconsistent to a relevant extent, subgroup analyses were performed to explore possible sources of heterogeneity. The assessment of the certainty of the evidence for the overall effect size of each exposure-outcome combination was performed according to the GRADE "Grading of Recommendations Assessment, Development and Evaluation" approach [9].

In total, 57,543 publications were identified, and 76 studies met the inclusion criteria. The included 76 studies were published between 1989 and 2021 and included 3,846 human participants of different age, sex and health status from 19 countries. Fifty of the 76 studies provided quantitative data, enabling a meta-analysis based on 2,433 participants. In the majority of the included studies, head exposure to RF-EMF with global systems for mobile communications (GSM) and uplink-like modulation at 900 MHz was applied. The quality of the studies was mixed, 50% of included studies were classified as 2nd tier, 28% as 3rd tier, and only 22% as 1st tier. The main reasons for a high RoB were selection bias, lack of double-blinding, and insufficient description of exposure generation and assessment.

A total of 35 meta-analyses were performed for accuracy- and speed-related performance measures of subclasses of five cognitive domains (Table 1).

Table 1: Summary of results
Effect size: Hedges's g - a positive value suggests improved cognitive performance; CI: Confidence interval; Study quality - tier 1: low RoB; tier 2: medium RoB; tier 3: high RoB

Outcome		No. of studies	Study quality (no. of studies per tier)	Effect size [95% CI]	Certainty of the evidence
Domain: Attention and Orientation					
Attentional Capacity	Accuracy	5	1st tier: 1 2nd tier: 3 3rd tier: 1	0.024 [-0.10; 0.149]	high for no effect
Focused Attention	Speed	3	1st tier: 1 2nd tier: 2 3rd tier: 0	0.005 [-0.171; 0.180]	high for no effect
	Accuracy	4	1st tier: 1 2nd tier: 3 3rd tier: 0	0.097 [-0.049; 0.244]	moderate for no effect / high for no negative effect

Vigilance	Speed	7	1st tier: 4 2nd tier: 2 3rd tier: 1	0.118 [-0.044; 0.279]	moderate for no effect / high for no negative effect
	Accuracy	6	1st tier: 4 2nd tier: 2 3rd tier: 0	0.042 [-0.094; 0.178]	high for no effect6
Selective Attention	Speed	13	1st tier: 4 2nd tier: 8 3rd tier: 1	0.080 [-0.089; 0.250]	moderate for no effect / high for no negative effect
	Accuracy	10	1st tier: 2 2nd tier: 6 3rd tier: 2	0.178 [-0.022; 0.378]	low for no effect / moderate for no negative effect
Divided Attention	Speed	6	1st tier: 2 2nd tier: 3 3rd tier: 1	-0.010 [-0.142; 0.122]	high for no effect
	Accuracy	4	1st tier: 2 2nd tier: 1 3rd tier: 1	-0.089 [-0.354; 0.176]	low for no effect
Simple Reaction Time Task	Speed	14	1st tier: 5 2nd tier: 5 3rd tier: 4	0.069 [-0.020; 0.159]	high for no effect
2-Choice Reaction Time Task	Speed	9	1st tier: 5 2nd tier: 3 3rd tier: 1	-0.023 [-0.125; 0.079]	high for no effect
	Accuracy	3	1st tier: 3 2nd tier: 0 3rd tier: 0	-0.063 [-0.376; 0.250]	low for no effect
More than 2-Choice Reaction Time Task	Speed	7	1st tier: 2 2nd tier: 3 3rd tier: 2	-0.054 [-0.140; 0.033]	high for no effect
	Accuracy	3	1st tier: 2 2nd tier: 1 3rd tier: 0	-0.129 [-0.298; 0.041]	moderate for no effect
Other Tasks	Speed	6	1st tier: 1 2nd tier: 5 3rd tier: 0	0.067 [-0.121; 0.256]	moderate for no effect / high for no negative effect
	Accuracy	5	1st tier: 2 2nd tier: 2 3rd tier: 1	0.036 [-0.080; 0.152]	high for no effect
Working Memory: 0-back Task	Speed	8	1st tier: 4 2nd tier: 2 3rd tier: 2	-0.032 [-0.149; 0.086]	high for no effect
	Accuracy	8	1st tier: 4 2nd tier: 2 3rd tier: 2	0.060 [-0.057; 0.178]	high for no effect
Working Memory: 1-back Task	Speed	11	1st tier: 6 2nd tier: 3 3rd tier: 2	-0.090 [-0.184; 0.004]	high for no effect
	Accuracy	9	1st tier: 5	0.005 [-0.109; 0.119]	high for no effect

			2nd tier: 2 3rd tier: 2		
Working Memory: 2-back Task	Speed	13	1st tier: 8 2nd tier: 3 3rd tier: 2	-0.044 [-0.132; 0.044]	high for no effect
	Accuracy	10	1st tier: 6 2nd tier: 2 3rd tier: 2	-0.054 [-0.163; 0.054]	high for no effect
Working Memory: 3-back Task	Speed	10	1st tier: 6 2nd tier: 3 3rd tier: 1	-0.018 [-0.114; 0.079]	high for no effect
	Accuracy	7	1st tier: 4 2nd tier: 2 3rd tier: 1	0.027 [-0.097; 0.152]	high for no effect
Working memory: Mental Tracking	Accuracy	7	1st tier: 2 2nd tier: 3 3rd tier: 2	-0.047 [-0.146; 0.052]	high for no effect
Domain: Perception					
Visual and Auditory Perception	Speed	2	1st tier: 1 2nd tier: 0 3rd tier: 1	-0.015 [-0.225; 0.195]	low for no effect
	Accuracy	4	1st tier: 1 2nd tier: 1 3rd tier: 2	0.035 [-0.129; 0.199]	moderate for no effect
Domain: Memory					
Verbal and Visual Memory	Speed	3	1st tier: 1 2nd tier: 1 3rd tier: 1	0.042 [-0.148; 0.231]	moderate for no effect / high for no negative effect
	Accuracy	10	1st tier: 1 2nd tier: 6 3rd tier: 3	-0.087 [-0.376; 0.203]	low for no effect
Domain: Construction and Motor Performance					
Motor Skills	Speed	2	1st tier: 1 2nd tier: 1 3rd tier: 0	-0.919 [-3.093; 1.256]	very low for a large negative effect
	Accuracy	3	1st tier: 1 2nd tier: 2 3rd tier: 0	0.228 [-0.007; 0.463]	moderate for a small positive effect / high for no negative effect
Domain: Concept Formation and Reasoning					
Reasoning	Speed	4	1st tier: 1 2nd tier: 2 3rd tier: 1	0.010 [-0.110; 0.129]	high for no effect

	Accuracy	2	1st tier: 1 2nd tier: 1 3rd tier: 0	0.051 [-0.142; 0.245]	moderate for no effect / high for no negative effect
Mathematical Procedures	Speed	4	1st tier: 1 2nd tier: 2 3rd tier: 1	0.033 [-0.116; 0.181]	high for no effect
	Accuracy	5	1st tier: 2 2nd tier: 2 3rd tier: 1	0.232 [-0.121; 0.586]	low for a small positive effect / moderate certainty for no negative effect

No statistically significant effect of RF-EMF exposure on performance was observed in the meta-analyses for any of the investigated domains and subclasses of cognitive function. In 20 out of 35 meta-analyses, the values of the effect size estimate as well as the corresponding 95% confidence interval indicate that RF-EMF exposure results in little to no difference in the outcome. The certainty of evidence for no effect of RF-EMF exposure on cognitive performance was high in 19 meta-analyses, moderate in nine, low in six and very low in one meta-analysis. The reasons for downgrading the certainty of evidence in the meta-analyses were study limitations (characterized by a large proportion of RoB tier 3 studies), imprecision (wide confidence interval), and inconsistency (high heterogeneity between studies). In some cases, subgroup analyses could explain the source of heterogeneity. In particular, excluding small studies with less than 30 participants and excluding RoB tier 3 studies reduced heterogeneity.

Overall, the results from all domains and subclasses provide consistent evidence that short-term RF-EMF exposure is not associated with a negative effect on cognitive performance in human experimental studies. The present systematic review provides mostly moderate to high certainty of evidence that short-term RF-EMF exposure at SAR levels within the recommended limits [10] does not negatively affect the investigated domains of cognitive function.

3 Comments by the BfS

For the publication presented here, BfS employees have participated as authors. As a result, we are refraining from providing a detailed evaluation and commentary on the content and significance of this publication.

References

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