Interview with neurobiologist Dr. Keren Grafen about study results on the effects of RF-EMF on children's brain development

„It is high time that the negative effects of radiofrequency EMF on the brain development of children and adolescents were taken seriously!“

Dr. Keren Grafen, PhD in Natural Sciences, is a neurobiologist and alternative practitioner. She studied biology, conducted research, and earned her doctorate at the University of Bielefeld, where she focused on neuroanatomy and cognitive neuroscience. Since 2013, she has been working independently in her own practice. Her scientific areas of interest include the influence of early childhood experiences on brain maturation, as well as the effects of drugs and stress on emotionally and cognitively processing brain structures. She is a lecturer in neurology and sensory physiology and has authored numerous scientific publications. She spent her childhood in the Himalayas, where she was early on exposed to a healing system heavily influenced by Tibetan practices, which shaped her deep affection for nature and natural healing.

In her lecture in Neckartenzlingen, neurobiologist Prof. Gertraud Teuchert-Noodt explained that brain metabolism is largely controlled by electromagnetic frequencies between 4 Hz and 30 Hz and that homeostasis in the brain is based on the sensitive interaction of these frequencies. Her institute has research results on this. It is therefore logical that external radiation, such as that generated by mobile phone radiation (RF-EMF), has an effect on this. Dr. Keren Grafen worked at Prof. G. Teuchert-Noodt's institute and is very familiar with the neurobiological research carried out there.

Neurobiology has shown how digital media overstimulation affects brain metabolism, inhibits the development of the frontal brain (prefrontal cortex) and can also lead to addiction. The study by Kim et al. (2024) „Radiofrequency exposure induces synaptic dysfunction in cortical neurons causing learning and memory alterations in early postnatal mice", now also demonstrates pathological effects of radiofrequency radiation on brain development at the molecular level. Mobile phone radiation inhibits the development of the synaptic structure and its density as well as neurite growth with negative consequences for behavior, spatial learning and memory.

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Negative effects of cell phone radiation on memory have not only been demonstrated in animal experiments. A study entitled „A prospective cohort study on the memory performance of adolescents and the individual brain dose of microwave fields from wireless communication" involving 670 adolescents in Switzerland found that radiofrequency electromagnetic fields from cell phones have a detrimental effect on the development of memory performance in figural and verbal memory. It was conducted by the Swiss Tropical and Public Health Institute (Förster et al. 2018). The cell phone use of twelve to seventeen-year-olds was evaluated for one year. Frequent phone users showed an increased contamination of the brain with radiation. The exciting finding: the more phone calls are made, the poorer the performance in the figural memory test. Verbal memory also showed poorer results.

Have Kim et al. now provided a neurobiological explanation for the results of Förster et al? What relevance do these study results have? We asked neurobiologist Dr. Keren Grafen about this. A glossary of technical terms can be found at the end of the interview.

Hippocampus - center for effective learning

DIAGNOSE:FUNK: **Dr. Grafen, we would like to ask you to evaluate the results of the two studies by Kim and Förster, both of which investigated the effects of cell phone radiation on the brain. First of all, the question for our readers who are not biologists, what is the function of the hippocampus? What role do synapses and neurites play in the brain?**

KEREN GRAFEN: With pleasure! The hippocampus is a fascinating structure of the brain that plays a crucial role in short-term memory, the transfer of information into long-term memory, as well as emotions, motivation and spatial orientation. The name „hippocampus" is derived from its shape, which is reminiscent of a seahorse.

A remarkable feature of the hippocampus is its ability to generate new nerve cells throughout life. This takes place in an embryonic germinal store, which is located in the hippocampus and enables continuous neurogenesis. This process contributes significantly to neuronal plasticity by maintaining the adaptability of the neuronal network and preventing the development of rigid structures. As the hippocampus must continuously store new information, the system is forced to remain receptive to environmental stimuli. This phenomenon, known as hippocampal neurogenesis, is a central area of research that I have been working on intensively for many years. It is important to know that the formation of new nerve cells in the hippocampus continues into adulthood as an essential prerequisite for learning processes, emotional regulation and cognitive flexibility.

Another central function of the hippocampus is its involvement in the creation of cognitive maps. The discovery of place cells in the hippocampus and grid cells

in the adjacent entorhinal cortex was awarded the Nobel Prize in Physiology and Medicine in 2014. These specialized nerve cells are essential for encoding spatial information and enable the calculation of internal maps for navigation.

The neuroanatomical basis of all these processes is formed by neurites, i.e. axons and dendrites, which ensure comprehensive synaptic connectivity between the nerve cells. Synapses play a crucial role in signal transmission and enable the exchange of information within neuronal networks.

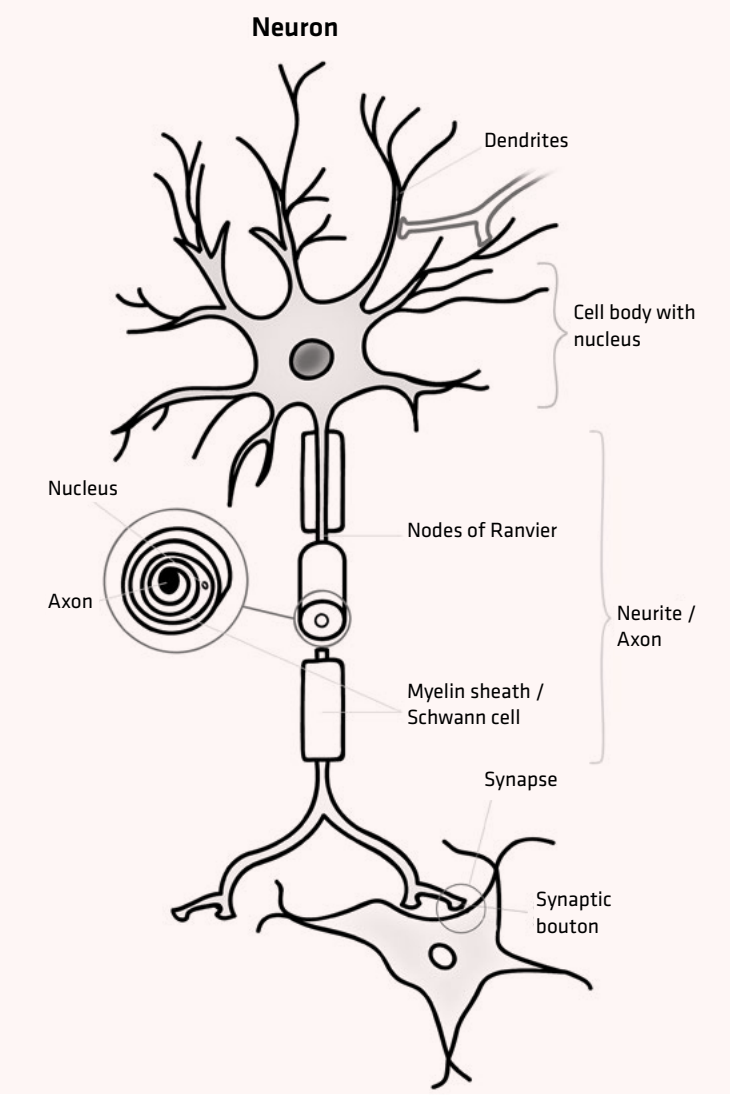
Damage to the hippocampus has far-reaching consequences for cognitive and spatial processes. Experimental studies on rodents show that effective learning is no longer possible without this structure - a finding that has also been confirmed in humans. The case of the patient H. M., whose hippocampus was removed on both sides in the 1950s, impressively illustrates the central importance of this region: after the operation, he was neither able to form new memories nor could he orient himself spatially.

DIAGNOSE:FUNK: **One result of the study by Kim et al.: RF-EMF exposure led to a reduction in neurite length and the number of branches. What consequences can this have?**

KEREN GRAFEN: A neuronal network can be compared to a forest: Each nerve cell resembles a tree whose branches branch out widely and are in contact with other trees. However, if individual branches or even entire trees die, gaps appear in the dense forest - the once vital connection between the trees is interrupted. The study by Kim et al. impressively demonstrated precisely this phenomenon: Exposure to radiofrequency electromagnetic fields (RF-EMF) has a negative effect on the axons and dendrites of nerve cells in the hippocampus. The branches of the neuronal trees atrophy, their number decreases and the network loses stability.

The possible effects on spatial orientation are even more profound: EMF exposure can impair both the formation and function of cognitive maps. This would not only have consequences for our memory, but also for more complex thought processes - such as the ability to distinguish between past and future, or social interaction with other people. Just as a damaged forest not only changes its ecosystem but also affects the lives of countless animals, a disrupted neuronal network could have far-reaching consequences for our thinking and behavior.

RF-EMF (radiofrequency electromagnetic) fields cause branches of neuronal trees to waste away



Radiofrequency electromagnetic fields cause the branches of neuronal trees to atrophy. Cellular processes in neurons are regulated electrochemically: "Neurons that fire together, wire together" (Donald Hebb). According to K. Grafen: "Exposure to radiofrequency electromagnetic fields has a detrimental effect on the axons and dendrites of neurons in the hippocampus. The branches of the neuronal trees atrophy, their number decreases, and the network loses stability ... The anatomical correlate of all learning is impaired."

Hebbian learning synapse: „Neurons that fire together, wire together."

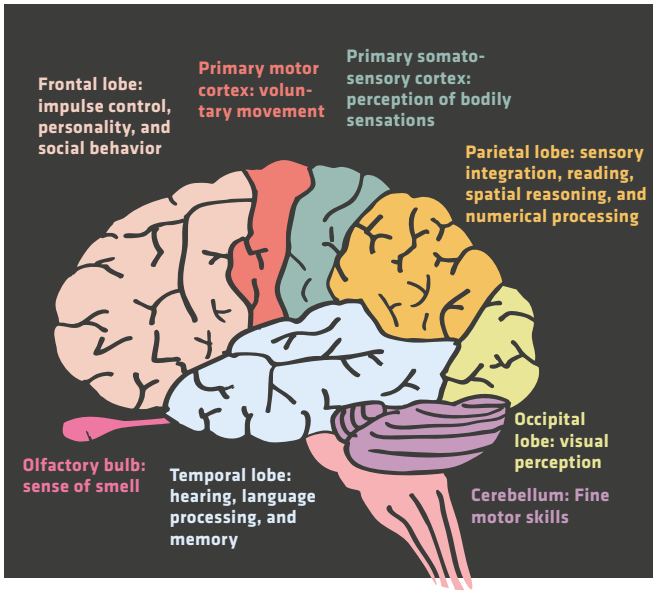
DIAGNOSE:FUNK: **Kim's team found that EMF significantly reduced the expression of AMPA and NMDA glutamate receptors (Hebbian learning synapse) in the hippocampal neurons studied. What does this mean? Can the consequences for neuroplasticity be deduced from this? What role does neuroplasticity play?**

KEREN GRAFEN: We should first explain Hebb's learning synapse, which is a fundamental principle of neuronal plasticity and was formulated by the Canadian researcher Donald Hebb in 1949: „Neurons that fire together, wire together." This means that the synaptic connection between two nerve cells is strengthened when they are repeatedly active at the same time. More precisely: if a presynaptic nerve cell (transmitter) is active at the same time as a postsynaptic nerve cell (receiver), the synaptic connection is strengthened. This phenomenon is known as long-term potentiation (LTP). The NMDA receptor plays a central role here.

The process works as follows: an incoming signal first activates the AMPA receptor, which immediately transmits the excitation. Only when the nerve cell remains active over a longer period of time - as is the case with learning processes through repeated stimulation - is the NMDA receptor activated. A special feature of the NMDA receptor is that it is blocked by a magnesium ion in the resting state. Only when the input to the receptor cell is large enough is this blockade removed. This leads to structural changes in the synapse via various chemical processes: it grows, becomes more stable and increases in size. These changes facilitate signal transmission at this synapse, which increases the efficiency of learning. This is what Hebb meant in 1949 when he postulated that the synaptic connection between two nerve cells is strengthened when they are repeatedly active at the same time.

The significantly reduced expression of AMPA and NMDA glutamate receptors in hippocampal neurons - as Kim was able to show in the above-mentioned study - means that learning processes are impaired at a physiological level. This in turn means that the brain's ability to adapt structurally and functionally to experience and environmental factors - a process known as neuroplasticity - is inadequate. The consequences are far-reaching: the anatomical correlate for all learning is impaired.

RF-EMF influence the homeostasis of the brain



Radiofrequency electromagnetic fields (RF-EMF) disrupt the homeostasis of the brain's oscillatory activity. The human brain – the most highly evolved organ in the course of evolution. The hippocampus is located in the temporal lobe.

DIAGNOSE:FUNK: **At the Teuchert-Noodt Institute, where you worked, an electrophysiological connection was discovered in the study by Hoffmann et al. in 2001: metabolic processes in the brain are controlled by EMF, in the frequencies from 4 Hz to 30 Hz. Could you explain this mechanism to us, and could the damage discovered by Kim et al., including reduced BDNF expression, also be related to this?**

KEREN GRAFEN: The electrophysiological correlation discovered by Hoffmann et al. (2001) at the Teuchert-Noodt Institute shows that electromagnetic fields (EMF) in the frequency range from 4 Hz to 30 Hz influence the hippocampal neurogenesis. It is particularly striking that EMF exposures in the frequency range of 1, 29 and 50 Hz significantly reduce neurogenesis, while other frequencies such as 8 and 12 Hz have no effect. The study interprets that only certain frequencies activate the release of neurotransmitters and hormones, which in turn control the changes in the hippocampus.

This finding opens the way to an interesting hypothesis: there is a common mechanism that can be found in both the study by Hoffmann et al. and the study by Kim et al. The EMF-controlled regulation of neurotransmitters and hormones could be the trigger

for reduced BDNF expression and thus reduced synaptic density - an extremely interesting assumption that will certainly also occupy future research. BDNF, or Brain-Derived Neurotrophic Factor, is a protein that plays a central role in the formation of new synapses in the brain. A lack of BDNF is associated with cognitive deficits and neurodegenerative diseases.

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Emotional safety, contact, and attachment: The baby listens to the mother reading aloud and, in doing so, develops language and imagination.

The brain learns in particular through movement, through grasping – in both the physical and cognitive sense – and in three dimensions

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The brain learns especially through movement – through grasping in the literal sense – and in three dimensions. „Man only plays when he is in the fullest sense of the word a human being, and he is only fully a human being when he plays." – Friedrich Schiller

DIAGNOSE:FUNK: **What role does all this play in learning and healthy brain development? What do you think, based on your neurobiological knowledge, when you see children and young people who are constantly on the phone?**

KEREN GRAFEN: That's a very important question: from a neurobiological perspective, healthy brain development plays a central role in learning, because the brains of children and young people are particularly plastic and trainable. This means that it is particularly open on the one hand, but also particularly vulnerable to damaging influences on the other. To use the metaphor of the forest, every new experience, every learning and every interaction is integrated into this neuronal network as new „branches". Harmful or inadequate stimuli cause this forest to wither. It is not only damaging influences, as described above with the damaging effects of EMF radiation, that play a role here, but also the way in which learning takes place. The brain learns in particular through movement, through grasping – in both the physical and cognitive sense – and in three dimensions. This means that we not only absorb information passively, but also integrate it through active, physical engagement with the environment and anchor it in our brain.

The increasing dependence on digital devices and the associated 24/7 EMF exposure could therefore have a negative impact on neuronal growth and cognitive abilities, particularly in the highly vulnerable brains of our children and young people. In neurobiology, such cases are referred to as „emergency maturation", as occurs in the Kasper-Hauser effect, for example. Therefore, from a neurobiological point of view, it is critically urgent to take the experimental studies seriously, reduce EMF exposure and use alternative means that support learning and brain development by promoting movement and interaction with the real world.

DIAGNOSIS:FUNK: **All this means that brain development would be massively damaged by cell phone radiation. The study was carried out on mice. Can we draw conclusions from this that our children's brain development is at risk?**

KEREN GRAFEN: Yes, I would do that. The studies cited above were conducted on mice, but the basic neurobiological mechanisms that primarily affect the important relay station hippocampus - including neurogenesis, synaptic plasticity and spatial coordination - are completely comparable in mammals, including us humans. If these findings are ignored by an industry-infested and interest-driven policy, they should at least serve as a warning signal to parents, teachers and educators. It is high time that the negative effects of radiofrequency EMF on the brain development of children and adolescents are finally taken seriously. Precautionary measures such as reduced mobile phone use in children, the use of wired alternatives and minimizing exposure to radiation in the sleeping area are the least that can be done to avoid potential long-term damage.

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Who talks to me about my questions? Who matters to Mama?

Swiss study: Smartphone use damages figural memory

DIAGNOSE:FUNK: **Kim et al. have researched biological processes in mice. Could this subsequently explain the results of the study by Förster et al. (2018) from Switzerland? The study investigated the influence of RF-EMF on memory performance in around 670 adolescents. The main results: An increase in cumulative RF-EMF exposure was associated with a deterioration in figural memory performance. The effect was particularly pronounced in participants who preferred to use their cell phone on the right side of their head. The effect was significant when RF-EMF doses were estimated based on operator data.**

KEREN GRAFEN: Yes, figural memory refers to the ability to store and remember visual impressions such as images, shapes, patterns or spatial structures. It is an essential part of visual memory and enables us to remember the appearance of objects, faces, places and situations without having to rely on verbal descriptions. It plays a key role in spatial orientation and the reconstruction of perceptions. And this is exactly where the hippocampus comes into play - THE central control centre for spatial mapping and orientation, remember the Place-Cells? A clear connection can therefore be established.

The study by Kim et al. therefore fits in with the findings of Förster et al. (2018), who discovered a connection between cumulative RF-EMF exposure and a deterioration in figural memory performance in adolescents. The changes in the hippocampus disrupt the complex neuronal three-dimensional network in the long term.

At this point, however, I would like to make a critical comment: The hypothesis that certain brain regions - such as the right hippocampus - are responsible for specific functions such as figural memory is a simplistic view. I personally consider this „left-right hypothesis" to be problematic, as we should increasingly move from a strictly anatomical view to a systemic and networked way of thinking about the brain. The brain does not function in isolation in individual areas, but in dynamic, interactive networks. This perspective shows us that the effects of EMFs are much more complex and go far beyond the isolated consideration of brain regions.

Salford - Studies confirm: RF-EMF opens the blood-brain-barrier

Salford studies confirm: Radiofrequency electromagnetic fields (RF-EMF) open the blood-brain barrier. In 2024, Professor Gertraud Teuchert-Noodt gave a lecture on neurobiological findings regarding the effects of digital media on brain development. The video with english subtitles is available at: www.diagnose-funk.org/2159

DIAGNOSE:FUNK: **In 2022, you yourself published the article „Albumin as a key marker. How the permeability of the BLOOD-BRAIN BARRIER (BBB) changes after exposure to mobile phone radiation“ published by Thieme, in which you write: „Professor Salford‘s findings on albumin extravasation by electromagnetic fields may provide an indication of pathogenic mechanisms for a broad spectrum of neurological diseases associated with blood-brain barrier dysfunction.“ What role could this mechanism, when seen in interaction with the findings of Kim et al., play in brain development, especially when young children are already using a smartphone?**

KEREN GRAFEN: Prof. Salford‘s extremely revealing findings, which I have included in my article „Albumin as a key marker“ and combined with current data, illustrate the immensely complex and potentially dangerous effects of EMFs on the brain - in a completely new way: via the blood-brain barrier. It is now well documented that the extravasation (leakage) of albumin is associated with hyperpermeability of the blood-brain barrier (BBB).

When these results are combined with the results of the previously mentioned studies, the seriousness of the potential effects of EMF on children‘s brain development becomes even clearer. The hyperpermeability of the blood-brain barrier caused by EMF opens the brain to harmful substances that place additional stress on the brain, particularly at the immunological level. The neuronal network, which is still developing and particularly susceptible, is additionally and massively disrupted as a result.

Now imagine what the future holds for our children as younger and younger children come into contact with smartphones and other wireless devices! The mechanism of BBB dysfunction combined with the findings of Kim et al. shows that chronic EMF exposure leads to significant impairment of brain function. I see this every day in my practice, how desperate parents watch powerlessly as their children act like remote-controlled beings. It is about time that at least parents, teachers and educators develop an awareness of the ever-increasing danger of EMF exposure to the brains of our children and young people. There are alternatives, even in an increasingly digital world. Switching to wired devices, a drastic reduction in cell phone use, especially among young children, and, above all, the urgent need for education about the risks of EMFs are essential to protect healthy brain development. We can no longer stand back and watch our children‘s health being put at risk!

It is high time to address the dramatic consequences

DIAGNOSIS:FUNK: **In his book „The Anxious Generation“, Jonathan Haidt argues that the mental health of young people has fallen off a cliff since 2012 as a result of smartphone use. The PISA studies show that skills in arithmetic, writing, reading and speaking are in decline. Mental illness among children and young people is on the rise. Does the study by Kim et al. not provide a plausible explanation for this? What consequences do you see for day-care centres, schools and parents as a result of these findings?**

KEREN GRAFEN: The study by Kim et al. not only provides a plausible biological explanation for Jonathan Haidt‘s theses in „The Anxious Generation“ but also allows us to see the full extent of the impact of EMFs on young people‘s mental health. Haidt notes that the ever-increasing use of smartphones since 2012 has led to a dramatic decline in adolescent mental health, reflected in rising mental illness and declining academic performance. The numerous neurobiological changes, as I have described above, could be the cause of young people‘s increasing difficulties in basic cognitive areas such as arithmetic, reading, writing and speaking.

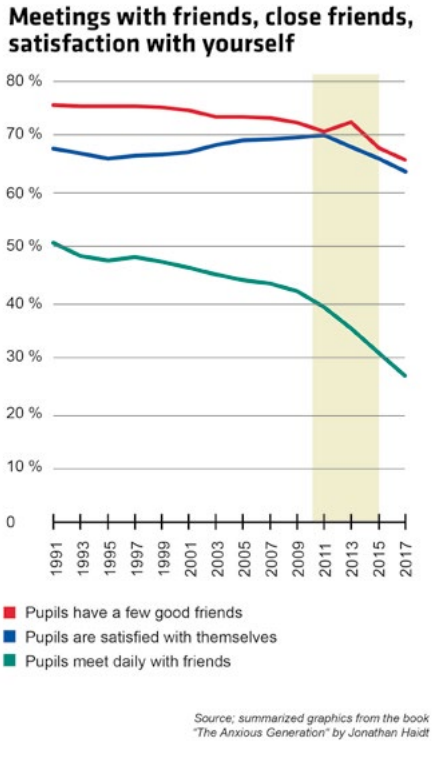
On a neuroanatomical level, the hippocampus in

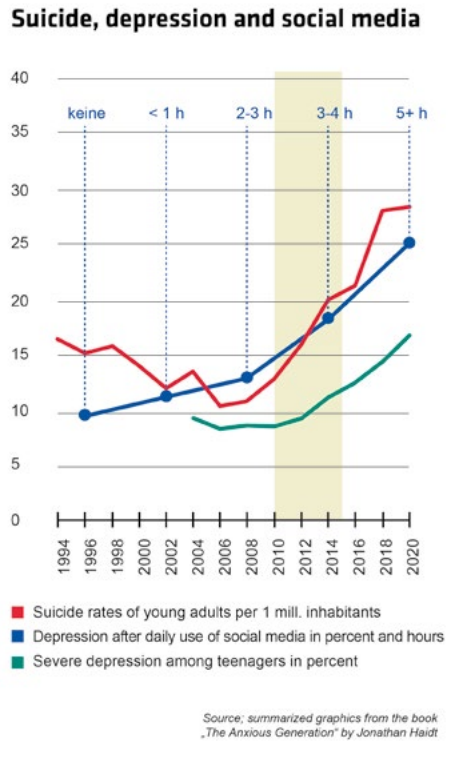
conjunction with the amygdala is crucially responsible for the perception of fear. Fear can be meaningfully contextualized by higher-level structures such as the prefrontal cortex so that we can assess whether the fear is real or fictitious. As explained in the lecture by Prof. Dr. Teuchert-Noodt in Neckartenzlingen, the meso-limbo-cortical dopaminergic stress pathway plays a decisive role here. This stress pathway is responsible for how we deal with stress and anxiety, and its impairment dramatically reduces the emotional resilience of young people.

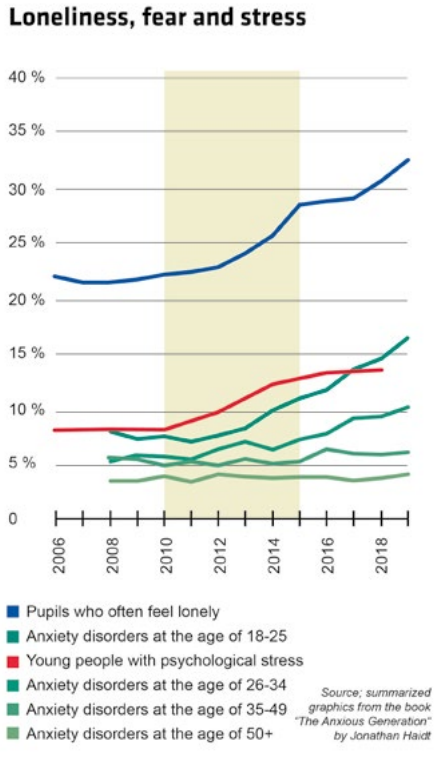
It is high time we addressed the dramatic consequences of these findings! Schools, day-care centres and parents must act now to reduce the unchecked EMF exposure of children and young people. Urgent action is needed to protect the welfare of our children: We need to drastically reduce screen time, promote analogue learning methods and social interactions, educate and make digital devices healthier to use. If we fail to act, we risk permanently damaging the mental health and cognitive development of the next generation.

DIAGNOSE:FUNK: **Dr. Grafen, thank you very much for explaining these highly explosive contexts. These findings from your research must become known. We will distribute this interview to as many parents, educators and doctors as possible.**

The questions were asked by Peter Hensinger, CEO of diagnose:funk.







Glossary for the interview

AMPA glutamate receptor: receptor that serves as the main mediator of rapid excitatory signal transmission in the central nervous system through the influx of sodium (Na^+) and occasionally calcium ions (Ca^{2+}) after binding of glutamate (AMPA: α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid).

BDNF: Brain-Derived Neurotrophic Factor, growth factor – A protein that belongs to the family of nerve growth factors (neurotrophins). BDNF is mainly present in the central nervous system and promotes the growth of sensory and motor nerve cells.

Blood-brain barrier: The blood-brain barrier protects the nerve cells in the brain from harmful substances. It is a selectively permeable barrier between the blood and brain substance, through which the exchange of substances with the central nervous system is subject to active control.

Dendrite: Branched offshoot of a nerve cell (neuron) that conducts impulses to the cell body.

Hebbian learning synapse: The Hebbian learning synapse is a neurophysiological principle in which the synaptic connection between two neurons is strengthened by repeated simultaneous activation („cells that fire together, wire together"), which is considered the basis for synaptic plasticity and learning.

RF-EMF: Radiofrequency electromagnetic field is the term used to describe the part of the electromagnetic spectrum comprising the frequency range from 100 kHz to 300 GHz.

Hippocampus: Part of the brain that is primarily important for memory.

Neurite / axon: The extension of a nerve cell that transmits the signals.

Neurogenesis: The formation of nerve cells through differentiation and division of stem cells.

NMDA glutamate receptor: NMDA (N-methyl-D-aspartate) receptors are important for neuronal plasticity and learning processes in the brain. Place-Cells are a kind of pyramidal neuron in the hippocampus that becomes active when an animal enters a particular place in its environment, which is known as the place field.

Synapse: Transmission site for an excitation from one nerve cell to another nerve cell or a muscle cell.

Literature

Foerster M, Thielens A, Joseph W, Eeftens M and Röösli M (2018): A Prospective Cohort Study of Adolescents' Memory Performance and Individual Brain Dose of Microwave Radiation from Wireless Communication. Environmental Health Perspectives, Vol. 126, No. 7, ResearchOpen Access,https://www.emf-portal.org/de/article/35641; Video with Prof. Michael Kundi (Medical University of Vienna) on the significance of the study: www.youtube.com/watch?v=07G65fE0xEM, https://kurzlinks.de/xmtd

Grafen, K (2022): Albumin as a key marker - How the permeability of the BLOOD-BRAIN-SCHRANGE changes after exposure to mobile phone radiation, Deutsche Heilpraktiker-Zeitschrift 2022; 17(06): 56-59. DOI: 10.1055/a-1870-2580; https://www.emf-portal.org/de/article/58608 , Download: https://www.emfdata.org/de/studien/detail?id=785

Hoffmann K, Bagorda F, Stevenson AF, Teuchert-Noodt G (2001): Electromagnetic exposure effects the hippocampal dentate cell proliferation in gerbils (meriones unguiculatus), Indian J Exp Biol 39(12): 1220-1226.

Kim JH, Seok JY, Kim YH, Kim HJ, Lee JK, Kim HR (2024): Exposure to radiofrequency Induces Synaptic Dysfunction in Cortical Neurons Causing Learning and Memory Alteration in Early Postnatal Mice. International Journal of Molecular Sciences, 25(16). Review of the study at: https://www.emfdata.org/de/studien/detail&id=860

Lehmann K, Grund T, Bagorda A, Bagorda F, Grafen K, Winter Y, Teuchert-Noodt G (2009): Developmental effects on dopamine projections and hippocampal cell proliferation in the rodent model of postweaning social and physical deprivation can be triggered by brief changes of environmental context. Behav Brain Res 205(1): 26-31.

Neufeld J, Teuchert-Noodt G, Grafen K, Winter Y, Witte AV (2009): Synapse plasticity in motor, sensory, and limbo-prefrontal cortex areas as measured by degrading axon terminals in an environment model of gerbils (meriones unguiculatus). Neural Plast 2009: 1-15.

Teuchert-Noodt G, Hensinger P (2025): No way out of the smartphone epidemic without taking into account the findings of brain research, J Neurol Neurosci, 16 (01) 2025 : 001-011