Effects of electromagnetic fields from wireless technologies on brain metabolism

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We are currently witnessing a profound change in how children and young people grow up. The introduction of the smartphone in 2007 was the tipping point. Childhoods based on play and face-to-face social interaction have given way to smartphone-based ones. According to a 2025 Postbank study, young people today spend on average over 70 hours per week on smartphones and tablets.[1] Where is the time for anything else?

Since about 2010, the rapid proliferation of smartphones has led to significant increases in attention disorders, sleep disturbances, speech development issues, depression, and suicidal thoughts among young people. There has also been an annual decline in school performance.[2] Every new PISA and education standards study documents a steady decline. A press release (2025) from the Standing Conference of the Ministers of Education (KMK) on the 2024 IQB Trends in Student Achievement study briefly touches on the causes of the decline in STEM (science, technology, engineering, and mathematics) performance. The release states that this decline is due to *"excessive media consumption, such as social media, which impairs the development of young people,"* resulting in *"declines in motivation, self-confidence, and basic skills."*[3] However, beyond this, there is not much information. To analyze this educational crisis and devise a turnaround, one must consider societal factors, primarily the commercialization of education and the departure from Humboldt's educational ideal.[4]

These developments are the subject of numerous debates, and rightfully so. The psychosocial impact of digital media is finally being recognized. This includes sensory overload, the addictive potential of digital media, and the resulting lack of exercise that leads to obesity and cardiovascular disease. The 2023 German national guideline on the prevention of dysregulated screen media use addresses these dramatic developments in depth.[5]

One key aspect that is rarely discussed publicly, even though it should have raised alarm bells long ago, is the effect of radiofrequency (RF) radiation emitted by mobile devices.[6] While the risk of brain tumors caused by cell phones is widely debated, little discussion has focused on their effect on brain metabolism, which plays a key role in learning and memory. This is the main topic of this article. What if electromagnetic fields from wireless technologies – the infrastructure of the digital world – deeply interfere with neurobiological development, in addition to the effects of psychosocial stress and violent content?[7] Dealing with radiation is not esoteric; we have a Federal Office for Radiation Protection. The risks associated with X-rays and other forms of ionizing radiation are well documented. However, the risks of non-ionizing radiation from wireless technologies are often dismissed for economic reasons. There is also cognitive dissonance among users. They love their smartphones and don't want to hear bad news about potential risks. Nevertheless, the studies speak for themselves.

Results of epidemiological studies

The human brain is an electrochemical organ. It functions based on finely tuned electrical rhythms and the transmission of electrochemical signals at synapses. Long-term potentiation (LTP) plays a key role in this process by strengthening and stabilizing synaptic connections over time. This is how we store what we learn in our memory.

However, radiofrequency electromagnetic fields (RF-EMFs), such as those emitted by smartphones, tablets, and Wi-Fi devices, can interfere with this system. RF-EMFs disrupt neural rhythms, inhibit synapse formation, and hinder central processes, such as memory formation and emotion regulation. Numerous studies demonstrate that these disruptions are real and occur via understandable mechanisms.

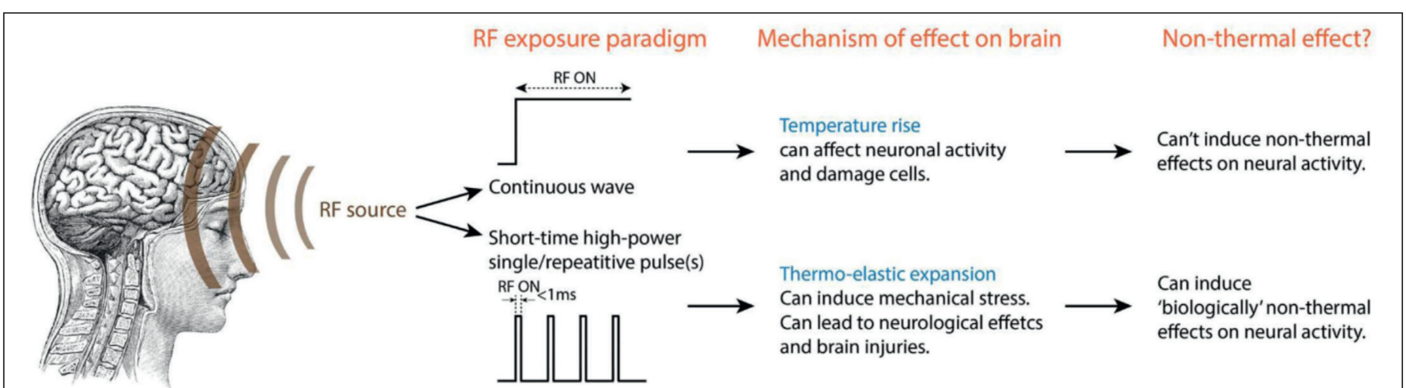

Figure 1: Researchers are investigating the thermal and non-thermal effects of non-ionizing radiation on the brain. Studies with proven biological effects are documented in the diagnose:funk database EMF Data. Graphic from: Yaghmazadeh O (2024). Pulsed high-power radio frequency energy can cause non-thermal harmful effects on the brain. IEEE Open J Eng Med Biol, p. 52.

First, I will review four epidemiological studies, and then I will analyze the extent to which these results are caused by RF-EMFs.

Study 1: As early as 2008 and 2012, Divan et al. conducted two studies in Denmark entitled "Prenatal and Postnatal Exposure to Mobile Phone Use and Behavioral Problems in Children." These studies were conducted in collaboration with US health authorities, including the National Institute of Environmental Health Sciences (NIEHS) and the National Institutes of Health (NIH). The first study examined 13,159 seven-year-old children and found that exposure to cell phones before and after birth was associated with general behavioral problems, including symptoms of ADHD, emotional issues, and difficulties with peers (OR 1.80; CI 1.45–2.23).[8] A new group of 28,745 children was studied in 2012, and the results were confirmed. The highest odds ratios (relative risk) for behavioral problems were observed in children exposed to cell phone radiation before and after birth, compared to unexposed children (OR 1.5; CI 1.4–1.7).

Study 2: In a study of over 800 young people in Switzerland, Förster et al. (2018) discovered a correlation. Those exposed to more RF radiation from cell phone use performed worse on figural memory tests, which assess the ability to recognize and remember visual information.[9]

Study 3: A recent study from India (Setia et al., 2025) raises concerns. The study observed infants in households with varying levels of RF radiation exposure. Those with high exposure exhibited significant delays in the development of language, communication, and motor skills, as well as problem solving.[10]

Study 4: Neurobiologist Professor Gertraud Teuchert-Noodt and psychologist Angelika Supper (2021) set out to determine the effects of smartphone use on the frontal lobe function and spatial-temporal reasoning skills.[11] The task: Third-grade elementary school students were asked to write the phrase "snowball fight" in the provided boxes (Figure 2). Children who did not use smartphones were able to complete the task, but those who frequently played with smartphones could not. They wrote outside the borders and could not finish. Results: Children who heavily use smartphones have underdeveloped spatial-temporal reasoning skills. Thus, the authors proved that these skills are underdeveloped due to fixation on one-dimensional screens and insufficient whole-body movement. One might ask whether this could also be related to RF exposure.

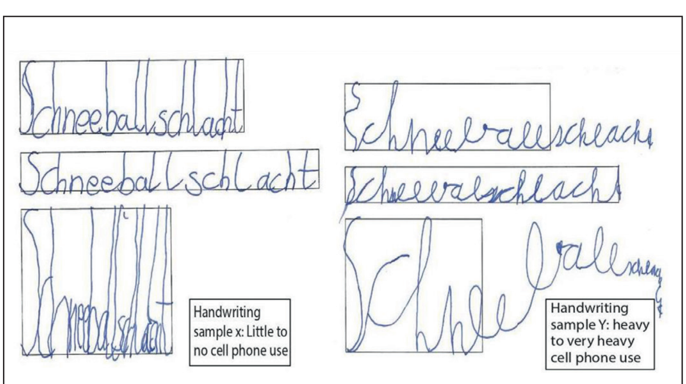

Figure 2: Writing the word "Schneeballschlacht" [snowball fight] within the given boxes requires spatial-temporal reasoning skills. Graphic from: Supper A & Teuchert-Noodt G (2021), see endnote 11.

While these four studies demonstrate correlations, are there plausible causal mechanisms with supporting evidence? What causes these developmental disorders?

Brain functions are controlled by electrochemical couplings and, at the highest functional level, synchronized by electromagnetic frequencies.
Electromagnetic fields (EMFs) play an important role in transmitting signals between neurons and synapses. In the brain, information is transmitted between neurons in two ways: electrically and chemically.[12]

Brain functions are controlled by electrochemical couplings and, at the highest functional level, synchronized by electromagnetic frequencies.[13] In the frontal lobe, a coherent electromagnetic spectrum is formed when different frequency ranges from the brainstem, thalamus, and hippocampus converge. This phasic synchronization then spreads across the cortex, enabling concentration, thinking, memory formation, and emotional regulation. However, chronic and significant disruption of the interaction between the hippocampus and frontal lobe caused by external electromagnetic fields can lead to pathological changes and even psychosis. There is substantial research on the effects of RF radiation that penetrates the body and brain when using a cell phone.[14]

The impact of electromagnetic fields on neurogenesis in the hippocampus
Twenty-five years ago, Hoffmann et al. (2001) demonstrated the biological effects of EMFs on the brain. The researchers at the University of Bielefeld achieved this by applying EMFs to gerbils' brains from outside the animals' bodies.[15] They investigated the effects of 30 minutes of daily EMF exposure on the hippocampus, which is the brain area responsible for memory formation and learning. The test animals were exposed to various extremely low frequency (ELF) modulations between 1 and 50 Hz for 14 days. The key finding:

At 50 Hz, cell regeneration – neurogenesis – in the hippocampus decreased by nearly 30%.
This proves that EMFs can significantly hinder the formation of new neurons. Interestingly, a so-called "frequency window" was observed. Chronic exposure at 8 or 12 Hz had no effect; however, chronic exposure at 29 or 50 Hz significantly decreased neuron formation. This suggests that not all frequencies are harmful and that only certain frequencies lead to biologically relevant changes.

Further studies by the authors revealed that the NMDA receptor plays a key neurochemical role. This glutamate receptor is central to learning and memory processes and regulates neurogenesis in the dentate gyrus, where new neurons form in the hippocampus. EMFs can influence NMDA receptor activity by altering dopamine and melatonin levels. Disrupting its calcium signaling directly impairs the formation and interconnection of neurons. The mechanism of action is therefore as follows: →

Exposure to EMF → altered regulation of dopamine and melatonin → modulation of the NMDA system → reduced neurogenesis and plasticity in the hippocampus.

Since the hippocampus plays a crucial role in memory formation, alterations to this region can result in learning and memory deficits.

Hoffmann et al. warned of the possible subtle yet lasting effects of chronic EMF exposure on cognitive and emotional functions, especially given our growing reliance on Wi-Fi and cellular networks.

Conclusion: Electromagnetic fields (EMFs) can influence neural development in a frequency-dependent manner. EMFs directly impact learning, memory, and mental stability through the NMDA system – a particularly relevant finding given our widespread use of RF-emitting devices today. Therefore, Hoffmann et al. called for further research into the neurobiological effects of chronic EMF exposure. Two episodes illustrate how this research is linked to vested interests. At the time, the head of the institute encouraged a colleague from another institute who was a member of the author group to study the effects of Wi-Fi radiation. The response was that this was not possible due to conflicts of interests. Professor Lebrecht von Klitzing participated in Hoffmann et al.'s work in an advisory capacity. At the time, he was the head of research at the University Medical Center in Lübeck. He conducted experiments with Wi-Fi radiation and demonstrated its effects on the EEG, among other things. In an interview with diagnose:funk, von Klitzing reported massive interventions by Telekom to stop this research, but they were unsuccessful. The Federal Office for Radiation Protection questioned his results. To date, the office has not responded to von Klitzing's offer and repeated requests to replicate his studies.

The hippocampus control center under RF-EMF stress

The hippocampus is at the center of research into the effects of radiofrequency electromagnetic fields (RF-EMFs). This region of the brain is responsible for spatial thinking and memory, as well as controlling other regions, especially the frontal lobe. I will begin with a typical study result that questions the use of Wi-Fi in learning environments, such as daycare centers and schools. Two studies by Shahin et al. (2015, 2018) revealed the following about Wi-Fi radiation:

(1) *"Male adult mice exposed to 2.45 GHz microwaves (Wi-Fi) exhibit impaired learning and memory. (2) Increased stress levels in the hippocampus. (3) Impaired synaptic plasticity. (4) Reduced expression of signaling pathway components that are important for learning and memory processes. All of these effects depend on exposure duration; the longer the exposure, the more drastic the effect. According to the authors, the fundamental mechanism by which 2.45 GHz microwaves negatively impact the learning and memory abilities of mice has been identified."* Review quote (translated from German) from: ElektrosmogReport (April 2018).[17]

Therefore, RF-EMFs affect **the** brain's signaling pathways that are responsible for memory formation. Two key terms appear in almost all studies: the hippocampus and brain plasticity. These two structures play a vital role in learning and controlling brain functions, especially in the following areas:

- Learning and memory formation, which occur through communication via synapses and long-term potentiation (Hebb's learning mechanism).

- Spatial-temporal orientation: The hippocampus contains place and time cells that enable memory of experiences in terms of both content and temporal sequences and spatial contexts. These discoveries earned the 2014 Nobel Prize in Physiology or Medicine.

The hippocampus is a central control center that is responsible for memory, learning, and orientation. It oscillates at a theta frequency of 4–7 Hz. As the brain's "secretary," the hippocampus controls the frontal lobe, which regulates impulse control and other functions. Errors in this control can have serious consequences, not only for a person's intelligence but also their mental health.

The inhibition of the brain fertilizer BDNF

Studies by Kim et al. in South Korea demonstrate that brief exposure to cell phone radiation can alter metabolic processes in the brain, including those in the hippocampus.[18] The titles of these studies reveal their explosive nature: "Exposure to RF-EMF Alters Postsynaptic Structure and Hinders Neurite Outgrowth in Developing Hippocampal Neurons of Early Postnatal Mice" (Kim et al., 2021) and "Exposure to Radiofrequency Radiation Induces Synaptic Dysfunction in Cortical Neurons Causing Learning and Memory Alterations in Early Postnatal Mice" (Kim et al., 2024). In both studies, newborn mice were exposed to 1850 MHz, a typical cell phone frequency, for four weeks. The results of the exposure are serious:

- Reduced expression of BDNF (brain-derived neurotrophic factor), a growth factor that acts like a fertilizer for neuron growth, for example.

- A significant decrease in NMDA and AMPA glutamate receptors, which are responsible for the plasticity of neuronal signal transmission.

- A reduced number of dendritic spines, which are contact points for synaptic transmission.

The findings regarding BDNF and glutamate receptors (NMDA and AMPA) are significant because: BDNF promotes the formation and strengthening of synaptic connections, forming the basis for learning and memory. It also promotes neurogenesis, or the formation of new neurons, in the hippocampus (even in adulthood!) and is essential for long-term potentiation (LTP) there. Together with the NMDA and AMPA glutamate receptors, BDNF triggers the Hebbian learning mechanism at synapses. This mechanism is based on a principle formulated by Canadian psychologist Donald Hebb in 1949: "Neurons that fire together, wire together." According to Hebb's learning rule, a synapse is strengthened when the presynaptic (sending) and postsynaptic (receiving) neurons are active simultaneously and repeatedly, like a self-reinforcing echo. This strengthens the connection between the two neurons, allowing them to transmit information more efficiently. This process is known as long-term potentiation (LTP). *"Neurons that fire together, wire together."*

In combination with NMDA and AMPA, BDNF serves as the "ammunition" for this process. RF-EMFs hinder the formation of this ammunition and "defuse" existing ammunition. Exposure to RF-EMFs can result in a shortage of ammunition or a jammed loading mechanism.

Similar to the studies by Kim et al., the study by Bodin et al. (2025) also observed that: *"In vivo results showed a decrease in BDNF level."* Overall, the French working group concludes that *"during prenatal development, continuous wave RF-EMF exposures at regulatory thresholds decrease … synaptogenesis in the immature brain of rodents"* and warns that *"these data support the hypothesis of a* *vulnerability of developing organisms towards RF-EMF exposures and to maintain caution regarding RF-EMF exposures of pregnant women and young children during telecommunication use."*[20]

Another prenatal effect of RF-EMFs is their impact on the production and plasticity of new neurons in the dentate gyrus, which is important for hippocampal function. In a 2008 study of rat embryos, Odaci et al. demonstrated that exposure to electromagnetic fields during pregnancy decreased the number of granule cells in the dentate gyrus. These cells mediate synaptic connections, among other functions.[21]

In summary, exposure to RF-EMFs impairs the brain's ability to develop, form networks, and learn, even during the prenatal and early childhood stages.

From symptoms to mechanisms of action

In ÜBERBLICK No. 4, diagnose:funk compiled over 50 studies proving that RF-EMFs alter brain metabolism. The title of this review report: "Does Mobile Phone Radiation Affect the Brain? Are the Individual Mechanisms of Action Known?" A peer-reviewed narrative review by the Chinese working group of Hu et al. (2021) is also available on this topic.[22] Hu et al. describe how electromagnetic fields within the frequency range of wireless technologies, including Wi-Fi, influence neurotransmitter systems in the brain, particularly those involving glutamate/NMDA, dopamine, serotonin, GABA, and acetylcholine.[23] These systems control our thinking and learning processes. A key finding of the study:

- *"In summary, these studies suggest that radiofrequency electromagnetic fields (RF-EMF) can lead to metabolic disturbances of monoamine neurotransmitters in the brain depending on the intensity of radiation exposure and can theoretically result in abnormal emotional behavior."* (p. 4)

The authors arrived at four key findings. RF-EMFs lead to:

1. Neurotransmitter imbalance, which is equivalent to biochemical dysregulation.
2. Oxidative stress and apoptosis, which are equivalent to cellular damage.
3. Behavioral and memory changes, which are equivalent to functional consequences.
4. The brains of fetuses and children are particularly sensitive because their neural networks and neurotransmitter systems are still developing. This can result in irreversible developmental disorders.

These changes are frequency- and dose-dependent. Together, these factors demonstrate the pathophysiological impairment of the brain caused by RF-EMFs. This disrupts the delicate balance of neurotransmitters.

Dopamine is an example of this disruption. Studies on cell phone addiction, which is triggered by sensory overload, among other things, show that frontal lobe maturation is delayed due to a dopamine deficiency. This occurs because the reward system consumes dopamine disproportionately, thereby depriving the frontal lobe. The aforementioned snowball fight study shows that an undersupply of dopamine to the frontal lobe is related to underdeveloped spatial-temporal memory. Hu et al. report that RF exposure significantly decreases dopamine in the hippocampus, which could lead to *"decreased learning and memory ability"* (p. 2). Studies on Wi-Fi radiation show that RF-EMFs affect neurotransmitters, leading to *"a deficit in spatial working memory function"* (p. 8). As early as 1992, Henry Lai, a pioneer in EMF research, demonstrated these consequences, which were also found in the aforementioned snowball fight study and the Swiss study on figural memory.

Oxidative cell stress: a mechanism of action and the basis of inflammatory diseases

In their review, Hu et al. highlight the mechanisms of nitrosative and oxidative stress that are responsible for many inflammatory diseases. These mechanisms involve the overproduction of free radicals, resulting in oxidative cell stress.[24] The authors explain:

"The energy of non-ionizing radiation is not enough to directly break chemical bonds, and therefore the occurrence of DNA damage with non-ionizing EMR exposures is primarily a consequence of generation of ROS, followed by oxidative stress." (p.10)

A 2021 review study by Schürmann and Mevissen for the Swiss Federal Office for the Environment (FOEN) confirms this mechanism of oxidative cell stress. The study found that more than half of the 150 evaluated EMF studies showed oxidative stress. Consistent evidence of oxidative cell stress was found in the brain, testicles, heart, liver, and kidneys, as well as in the initiation of cancer.[25]

Hu et al. discuss another mechanism of action. EMFs can increase the activity of voltage-gated calcium channels (VGCCs) in cell membranes. As a result, *"changes of intracellular calcium levels can trigger unusual synaptic action or cause neuronal apoptosis. This in turn can exert an influence on the neurotransmission of learning and memory process (93)."* (p. 9)

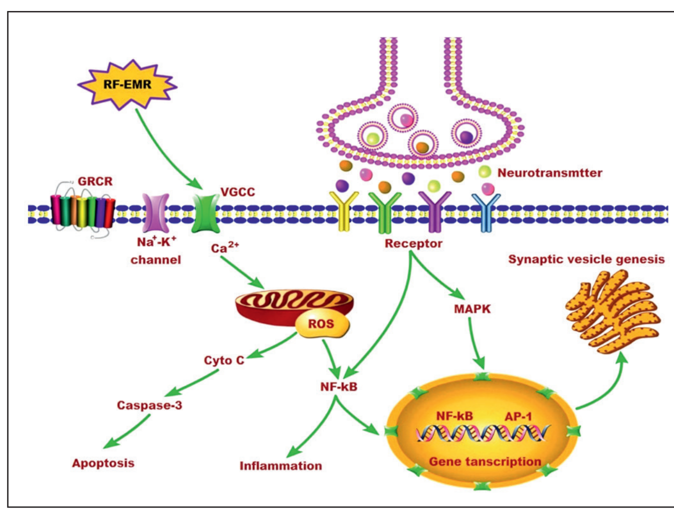

Figure 3: The Effects of RF-EMR exposure on neurotransmitters in the brain and the possible underlying mechanism.

The discovery process is not yet finished.

The review by Hu et al. documents numerous findings regarding the effects of EMFs on brain metabolism. However, the authors note that heterogeneity leaves many questions unanswered. In particular, conclusions drawn at the cellular level and regarding cell interactions have not yet been definitively clarified. The authors hope that advances in neuroscience will clarify these issues: *"studying the effects of EMR on neurotransmitter metabolism and the transport of neurotransmitters at the neural circuit level is expected to overcome the challenges inherent in investigating the neurobiological effect of EMR and its mechanisms and open novel pathways for the exploration of preventive targets and interventions."* (p.12) The current state of research reviewed in this paper requires not only the application of the precautionary principle, but also the prevention of hazards.

There are other effects of RF-EMFs on the brain.[26] As early as 2003, Salford's studies demonstrated that RF-EMFs open the blood–brain barrier, allowing toxins to enter the brain.[27] RF-EMFs can also trigger epileptic seizures. In a 2022 review entitled "Albumin as a Key Marker," neurobiologist Dr. Keren Grafen addresses the relevance of these effects.[28] Epileptic seizures can also be triggered by RF-EMFs. A compilation of these studies can be found in diagnose:-funk's review report (ÜBERBLICK No. 4). Finally, 30 years ago, Professor Lebrecht von Klitzing, who was then the head of research at the University Medical Center Lübeck, demonstrated the effects of Wi-Fi radiation on the brain.[29] Two large-scale studies, the NTP study in the USA and the Ramazzini study in Italy, demonstrated an increased risk of cancer and brain tumors.[30]

Interestingly, these results were observed at RF-EMF levels below the current regulatory limits, which calls into question the effectiveness of these limits as a protective measure.

Establish alternatives!

Studies reveal one clear conclusion: radiofrequency electromagnetic fields (RF-EMFs) alter central metabolic processes in the brain. Of particular concern is the resulting desynchronization of endogenous rhythms, which disrupts neural interaction by throwing central processes out of sync. These changes can affect learning, memory, and behavior, potentially leading to neurological and neurodegenerative disorders. Neurobiologist Teuchert-Noodt refers to this phenomenon as a "cyberattack on the brain." These interactions lead to the previously described pathological consequences.

- For example, addiction triggered by sensory overload and an undersupply of dopamine to the frontal lobe can result in impaired spatial-temporal memory.
- Declines in physical play and exercise result in BDNF deficiency, motor disorders, and obesity.
- An increase in speech disorders is due to isolation in front of a screen and a decline in social contact.
- The consequences of RF radiation on brain metabolism are also evident.

This toxic mixture is evident in the education crisis and the continuous decline in learning performance. A digital childhood is proving to be a neurobiological dead end. When memory fades due to disrupted hippocampal function and children stop learning, neural plasticity and our future as a society are lost.

A Swedish study (Figures 4) reveals an alarming surge in memory problems among children and adolescents in Sweden and Norway (Nilsson M & Hardell L, 2025).[31]

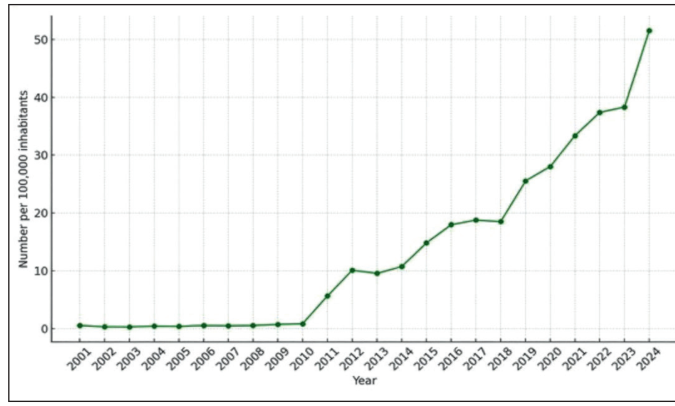

Figure 4: Number of patients aged 5 to 19 per 100,000 inhabitants per year with the main diagnosis of R41.8, "mild cognitive impairment, subjective," in Sweden from 2001 to 2024 (Nilsson M & Hardell L, 2025).

In his meta-study, Professor Klaus Zierer, an educator, came to the following conclusion: *"The more time children and young adults spend on their smartphones and social media in their free time, the worse they perform academically."*[32]

Many studies document this decline in learning performance, which has been accelerated by digitization.[33] Despite the lack of pedagogical and medical evidence, Germany's federal government coalition agreement states that digitization should be expanded further. A student ID will be introduced to store educational records and transition seamlessly into a citizen ID. To this end, every student will receive a tablet, and those in need will receive one free of charge from the federal government. However, this online data collection is pure surveillance.[34] In March 2025, 75 experts appealed to the federal government to halt this digitization. Finally, the risks of digital media are being addressed.[35]

Smartphone and social media bans are popular topics in the mainstream media. The German National Academy of Sciences Leopoldina weighed in with an expert opinion containing the following key message:

"We recommend prohibiting the use of smartphones in daycare centers and schools up to and including 10th grade."

This recommendation can be built upon. It must be implemented. It should also be accompanied by steps that reduce RF-EMF exposure. There are many ways to minimize RF-EMF exposure, such as using cable connections, Li-Fi technology (which uses light for data transmission), low-EMF devices, and a single network for all. Most importantly, education is essential. Physicians have a key role to play here. During consultations, they should inform parents about the risks and low-EMF alternatives. Help ensure that the IT industry cannot continue operating unregulated at the expense of our health and help protect our children.

This article was presented as a lecture at the 23rd Annual Conference on Environmental Medicine of the European Society for Clinical Environmental Medicine (EGKU).

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Glossary

AMPA glutamate receptor: A receptor that facilitates rapid excitatory signal transmission in the central nervous system by allowing sodium (Ca^{2+}) and, occasionally, calcium (Na^{+}) ions to enter the cell after binding to glutamate (AMPA: α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid).

BDNF, brain-derived neurotrophic factor: A protein belonging to the family of nerve growth factors (neurotrophins). It is primarily found in the central nervous system where it promotes the growth of sensory and motor neurons.

Blood–brain barrier: This barrier protects neurons in the brain from harmful substances. It is a selective, semipermeable barrier that actively controls the exchange of substances with the central nervous system.

Electromagnetic field: A field that contains both electrical and magnetic components/forces that are physically inseparable.

Dendrite: A branched extension of a neuron that conducts nerve impulses to the cell body.

Dentate gyrus: A part of the hippocampus. The dentate gyrus is one of the few structures in the brain where new neurons form in adult humans (neurogenesis).

Hebbian learning synapse: This neurophysiological principle states that the synaptic connection between two neurons is strengthened by repeated, simultaneous activation (“neurons that fire together, wire together”), which is considered the basis for synaptic plasticity and learning.

Hippocampus: A part of the brain that is particularly important for memory.

Ionizing radiation: Radiation with a wavelength of less than 200 nm that causes ionization when passing through matter. In other words, it can remove an electron from an atom or molecule, producing an ion and a free electron (e.g. alpha particles, X-rays, and gamma radiation).

Granule cells in the dentate gyrus primarily receive input signals from the entorhinal cortex and transmit them to the pyramidal cells in the CA3 region of the hippocampus via their axons (mossy fibers). These cells filter and transmit information in the hippocampal memory loop.

Non-ionizing radiation: NIR includes all fields and radiation in the electromagnetic spectrum that lack the energy to cause ionization. Examples include radio waves, microwaves, infrared radiation, and visible light.

NMDA glutamate receptor: NMDA (N-methyl-D-aspartate) receptors are important for neural plasticity and learning processes in the brain.

Neurite/axon: An extension of a neuron that transmits signals.

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

Oxidative stress: It occurs when oxidative processes caused by free radicals (e.g. hydrogen peroxide) exceed the capacity of antioxidant processes to neutralize them, thereby shifting the balance in favor of oxidation. This can cause various types of cell damage, such as the oxidation of unsaturated fatty acids, proteins, and DNA.

Radical: A molecule or molecular region in which single electrons occur in addition to electrons that normally occur in pairs. These additional electrons make the molecules chemically aggressive and capable of damaging cells, such as their DNA (oxidative stress). A well-known example is hydrogen peroxide. However, radicals are also important components in enzyme reactions. They can be produced by metabolic processes or external influences and are quickly broken down by radical scavengers.

ROS (reactive oxygen species): Oxygen-containing molecules that are highly unstable and reactive.

This high reactivity is caused by the radicals’ unstable electron configuration. ROS quickly extract electrons from other molecules, which then become free radicals themselves. This triggers a chain reaction that causes cell damage through oxidative stress. ROS include superoxides, peroxides, and hydroxyl radicals.

Synapse: The point at which an impulse is transmitted from one neuron to another neuron or a muscle cell.

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Peter Hensinger: How did you reach the conclusion that mobile devices and radiofrequency radiation could affect EEG readings? How did the scientific community and your employer react to your findings?

Lebrecht von Klitzing: Since mobile phone technology uses pulsed RF fields, the next research topic was obvious. No sooner had this project been announced than Telekom questioned my scientific expertise once again by presenting a 10-point program against my further activities. However, the university saw no reason to comment on the matter. This cleared the way for me to proceed.

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"The energy of non-ionizing radiation is not enough to directly break chemical bonds, and therefore the occurrence of DNA damage with non-ionizing EMR exposures is primarily a consequence of generation of ROS, followed by oxidative stress. Numerous animal experiments have clearly demonstrated that non-thermal EMR can cause oxidative stress (115, 116), particularly in the brain (3, 117–119). It has been documented that non-thermal EMR exposure of 900 MHz or 2.45 GHz in rats, either short-term or long-term, can trigger neuronal dysfunction and apoptosis of hippocampal pyramidal cells (117, 120) and cerebellum Purkinje cells (121) through induction of oxidative stress." (p. 10)

"Lushchak et al. reported that EMR exposure may firstly produce the free radicals in the brain and later they are converted to ROS (126). The elevation of ROS level can attack various biomolecules in the cell. The raised ROS can also in turn trigger calcium release, and then activate the genetic factors leading to DNA damage (110)." (p. 10)

"It is also possible that the various neurotransmission effects following EMR exposure in animals might be due to combined effects in various brain regions, such as neurophysiological changes, increase of calcium and ROS, and thereby cell membrane damage and the downstream signaling changes." (p.11)

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Appendix: Illustrations on

Effects of electromagnetic fields from wireless technologies on brain metabolism

Peter Hensinger

Naturheilkunde 6 / 2025

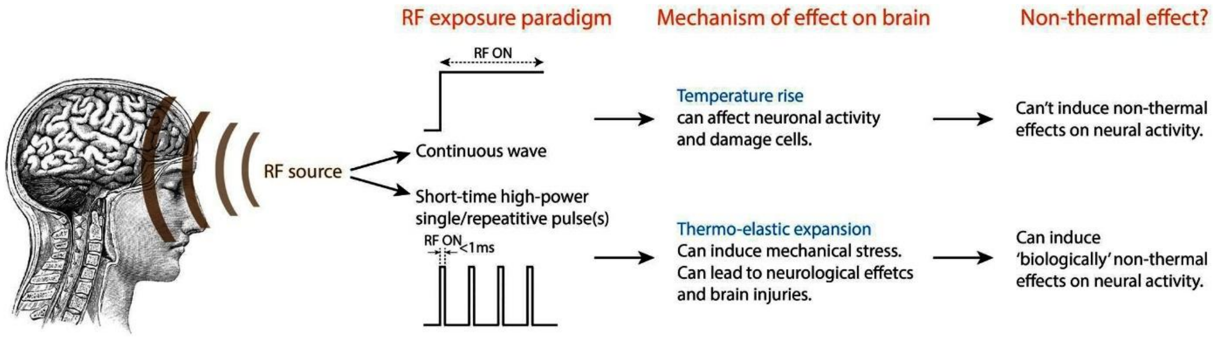

Figure 1: Researchers are investigating the thermal and non-thermal effects of non-ionizing radiation on the brain. Studies with proven biological effects are documented in the diagnose:funk database EMF Data. Graphic from: Yaghmazadeh O (2024). Pulsed high-power radio frequency energy can cause non-thermal harmful effects on the brain. IEEE Open J Eng Med Biol, p. 52.

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Figure. 1a. *In this handwriting sample, both students try to fit the word "Schneeballschlacht" [snowball fight] into the assigned rectangle.*

Figure 2: Writing the word "Schneeballschlacht" [snowball fight] within the given boxes requires spatial-temporal reasoning skills. Graphic from: Supper A & Teuchert-Noodt G (2021), see endnote 11.

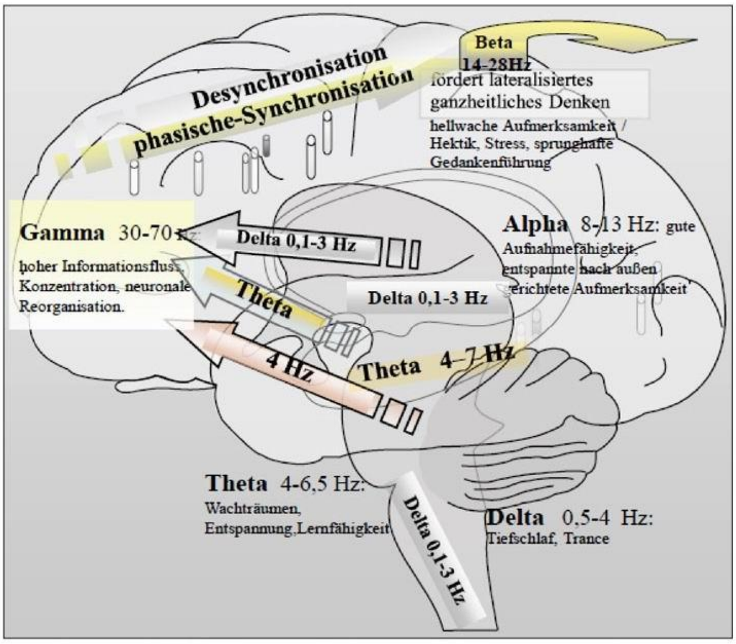

Figure 3: "Activity lies at the heart of all neural maturation processes. Sensory pathways supply environmental activity, which the brain's oscillators transmit by synchronizing brain rhythms. These rhythms form the basis for thinking and learning. Both sources influence each other through the brain's chemistry, that is, via specific neurotransmitters that inscribe electrical signal currents into neural network structures. This coupling of electrical and chemical signals is a core component of the relationship between neural structure and function." Quote (translated from German) and graphic from: Teuchert-Noodt G (2019), see endnote 13.

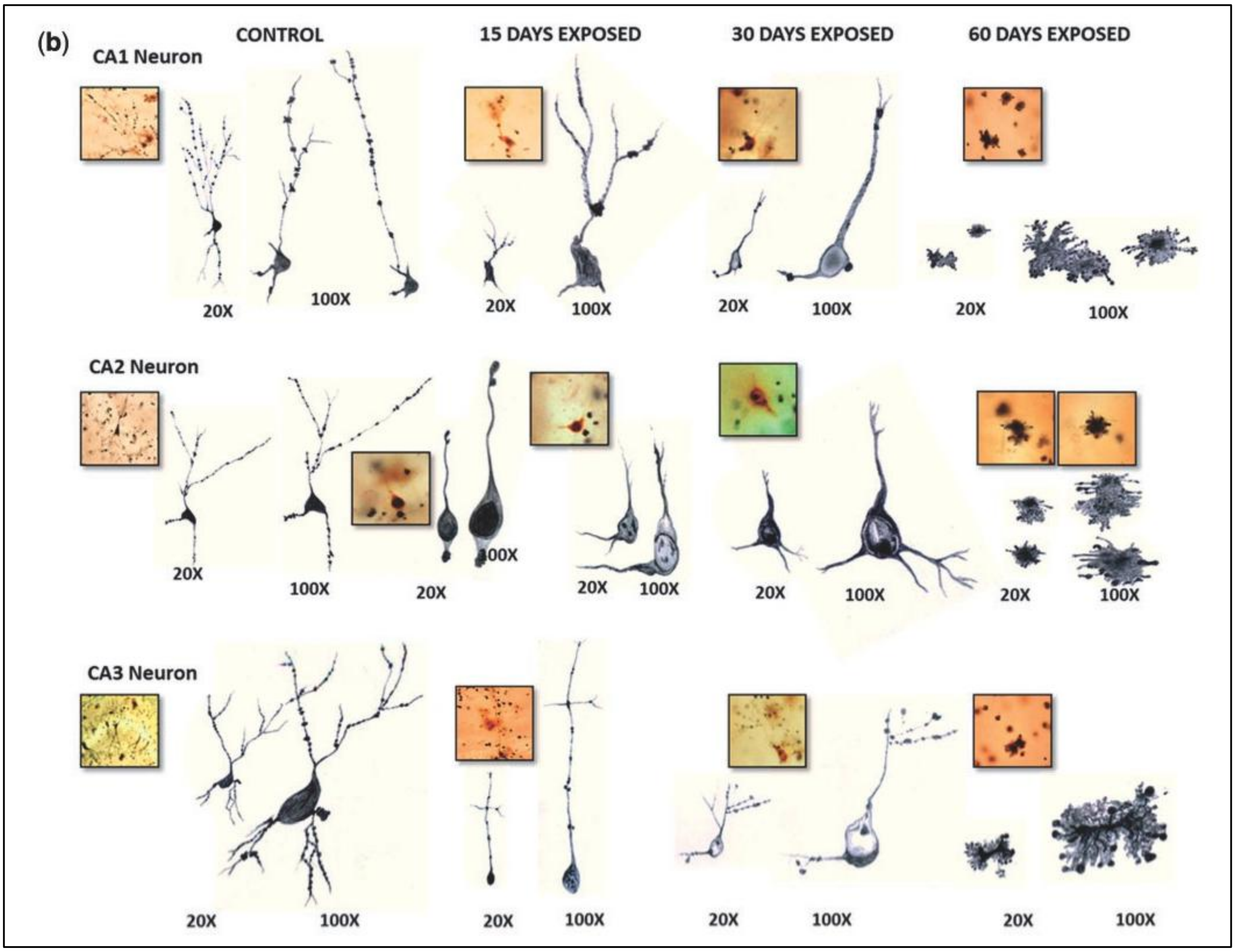

Figure 4: "The number of pyramidal neurons which is very important for memory formation decrease significantly in all the 2.45 GHz (CW) MW irradiated groups of mice compared to control. Moreover, in 60 days exposed group of mice no pyramidal neuron was observed in the different regions of hippocampus. The diameter of neuronal soma (pyramidal as well as other types of 23 neurons) increased significantly while the axonal length decreased significantly in all the exposed group of mice compared to control (Table 1). These changes were more prominent in the hippocampal region of 30- and 60-days MW irradiated mice compared to 15 days exposed mice. This indicates a decreased in synaptic plasticity due to neuronal loss and reduced dendritic arborization in different region of hippocampus. Neuronal clogging was observed in 30- and 60-days MW irradiated group (Fig. 3 b). Next, we examine the effect of 2.45 GHz MW radiation on spine number. MW irradiated mice revealed a significant reduction in number of spine per 10 µm segment of dendrite for both primary and secondary branches compared to sham control (p<0.001; Fig. 3 c)." (Shahin et al. 2015)

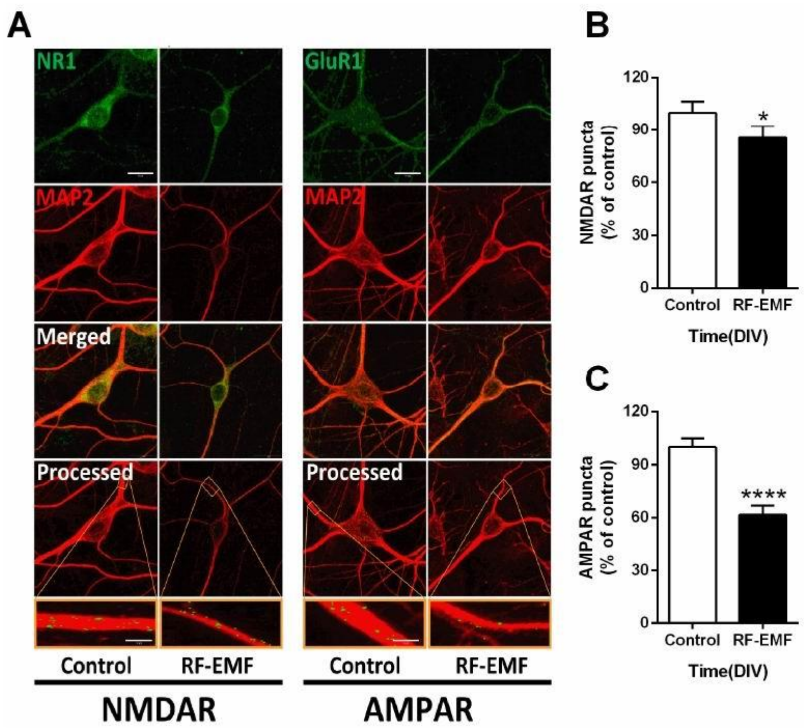

Figure 5. Exposure to RF-EMF decreased the expression of NMDAR and AMPAR. (**A**). Confocal images display hippocampal neurons expressing AMPAR (GluR1, green) or NMDAR (NR1, green) with MAP2 (red). Images of GluR1 and NR1 with MAP2 were analyzed using ImageJ. (**B**,**C**). Summary of changes in the number of GluR1 and NR1 punctae. Data are expressed as means ± SD. Statistical significance was evaluated using the Student's *t*-test. * $p < 0.05$, **** $p < 0.0001$ vs. control (control $n = 18$ mice, RF-EMF $n = 18$ mice). Scale bars = 15 μm.

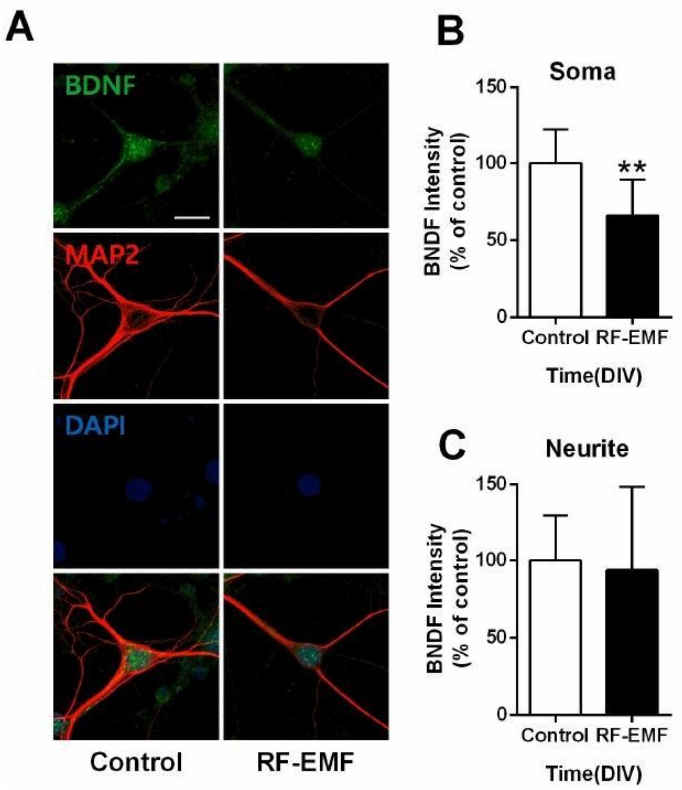

Figure 6. Exposure to RF-EMF decreased somatic BDNF expression in primary cultured hippocampal neurons. (**A**). Confocal images display hippocampal neurons expressing BDNF (green), MAP2 (red), and nuclei (DAPI, blue). Expression of BDNF in hippocampal neurons was analyzed on DIV 9. (**B**,**C**). Summary of changes in BDNF expression in the soma and neurites of cultured hippocampal neurons. Data are expressed as means ± SD. Statistical significance was evaluated using the Student's *t*-test. ** $p < 0.01$ vs. control (control $n = 18$ mice, RF-EMF $n = 18$ mice). Scale bar = 15 μm.

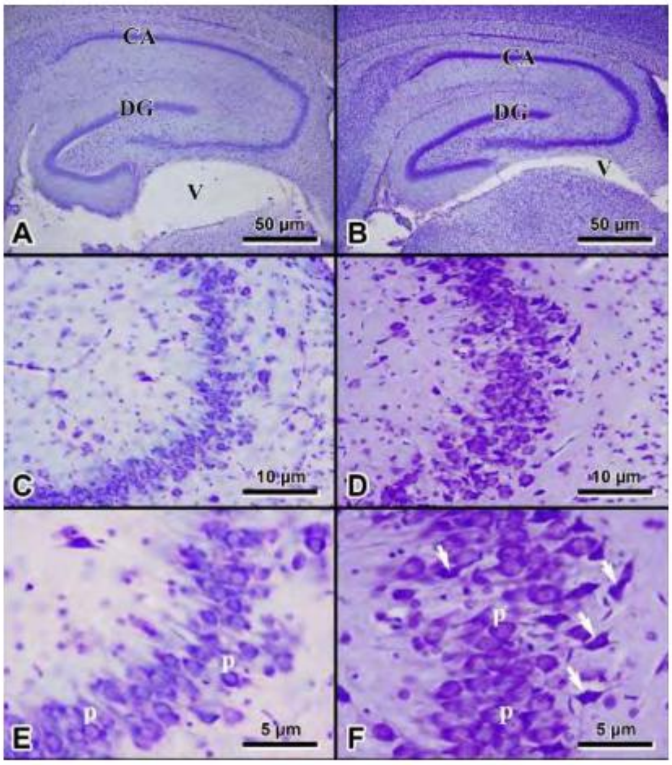

Figure 7: Exposure (left column); control (right column). There are fewer granule cells and morphological differences in pyramidal cells in the hippocampus. Graphic from: Odaci et al. (2008), Crane-Molloy (2024).

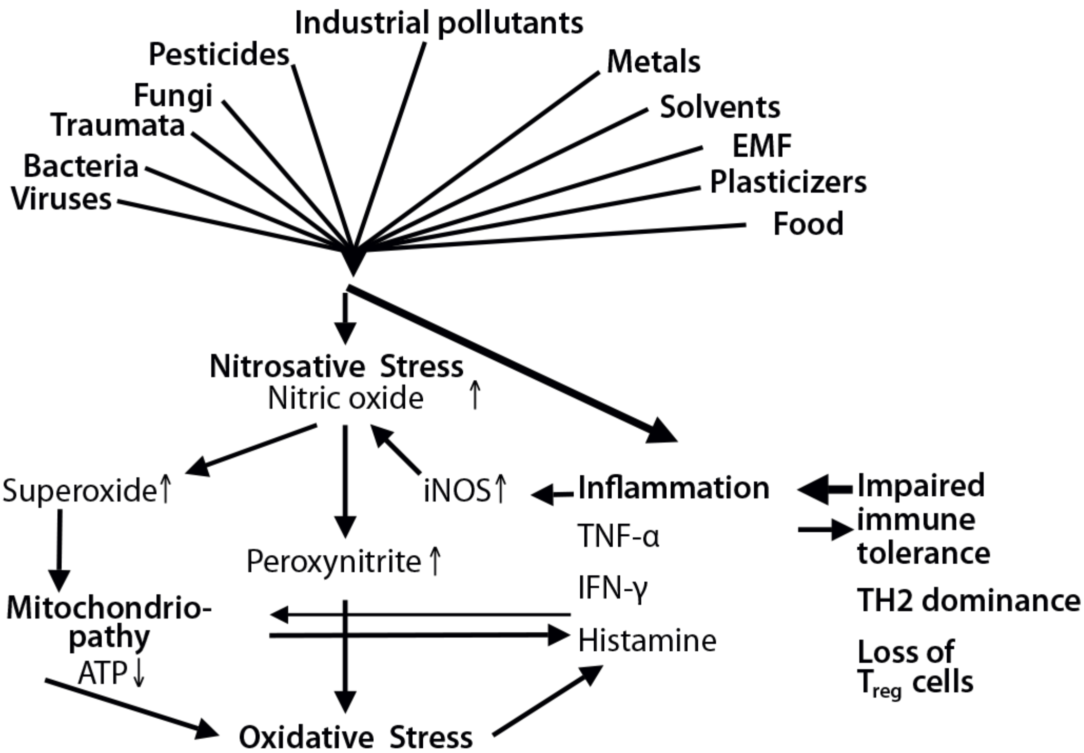

Figure 8: Exposure to trigger factors leads to the pathogenesis of inflammation, mitochondrial dysfunction, and nitrosative stress. The interaction of multiple toxins can lead to inflammatory processes. However, this interaction is usually not investigated. Graphic from: von Baehr (2012), umg.

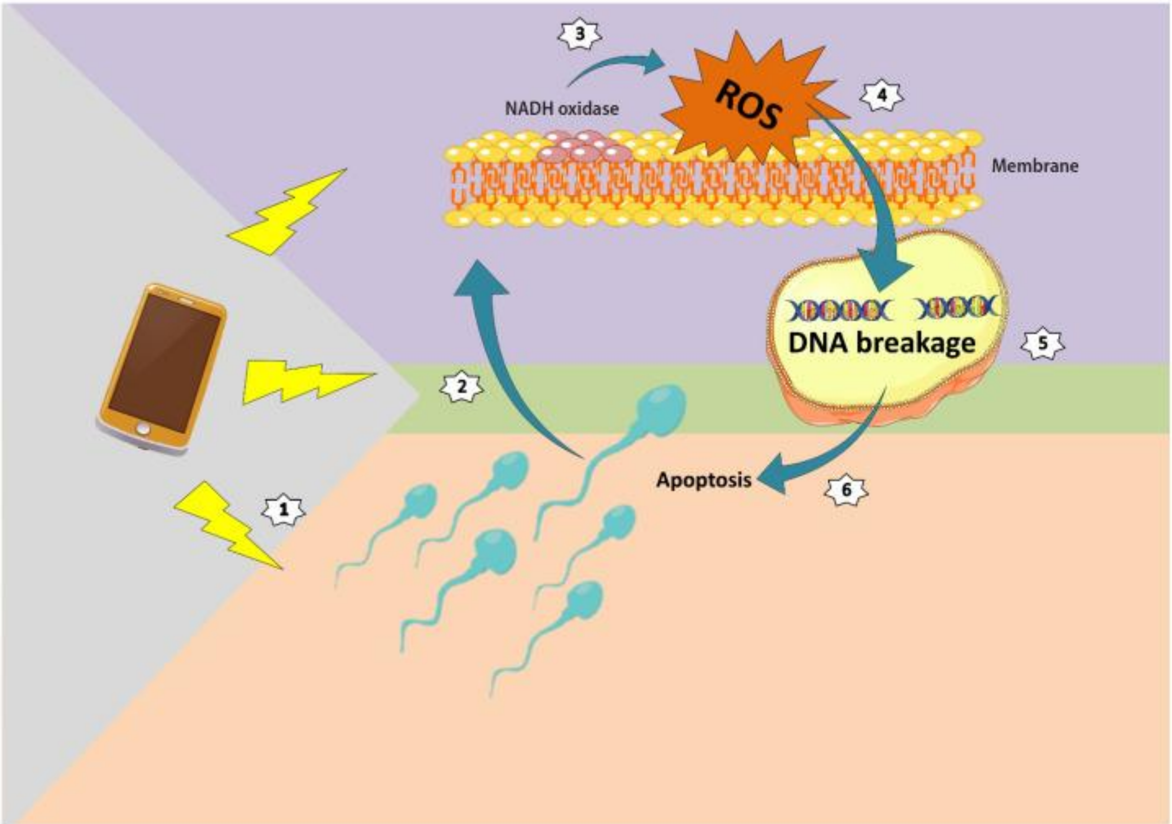

Figure 9: "Electromagnetic waves emitted by mobile phones stimulate nicotinamide adenine dinucleotide hydrogen (NADH) oxidase in the plasma membrane, which in turn affects the integrity of the sperm nucleus. Within the nucleus, the structure of the DNA deteriorates, ultimately guiding the cellular structure towards apoptosis." Quote and graphic from: Koohestanidehaghi Y, Khalili MA, Dehghanpour F, Seify M (2023). Detrimental impact of cell phone radiation on sperm DNA integrity. Clin Exp Reprod Med, 51(1): 13–19. https://doi.org/10.5653/cerm.2023.06121

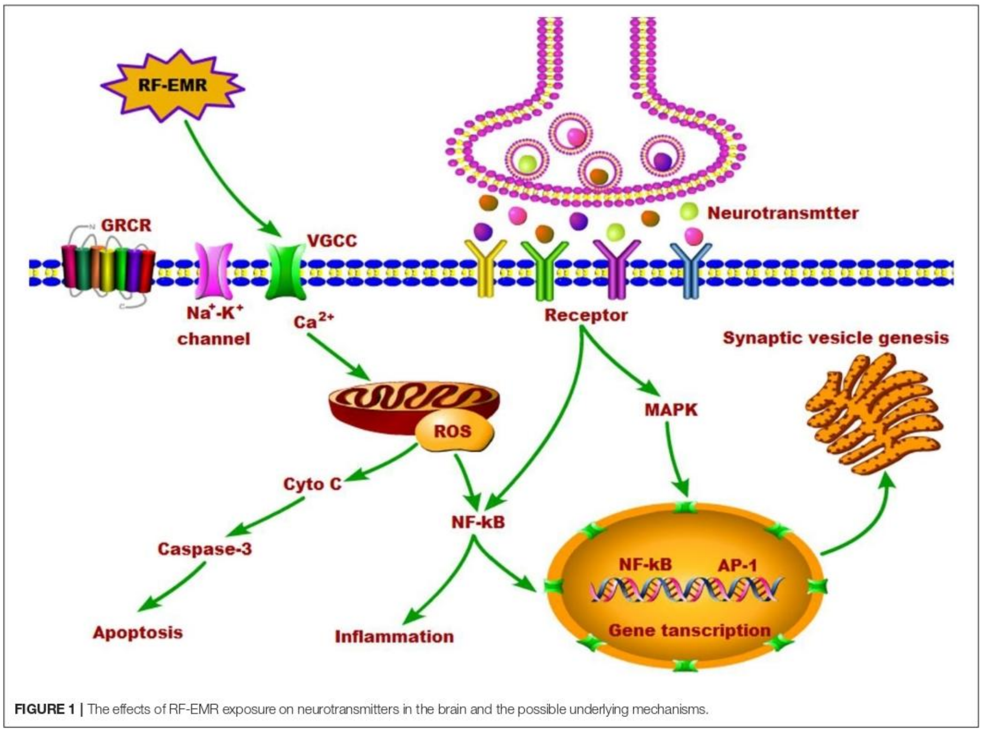

Figure 10: Damaged signaling pathways triggered by radiofrequency electromagnetic fields (RF-EMFs). Graphic from: Hu et al. (2021).

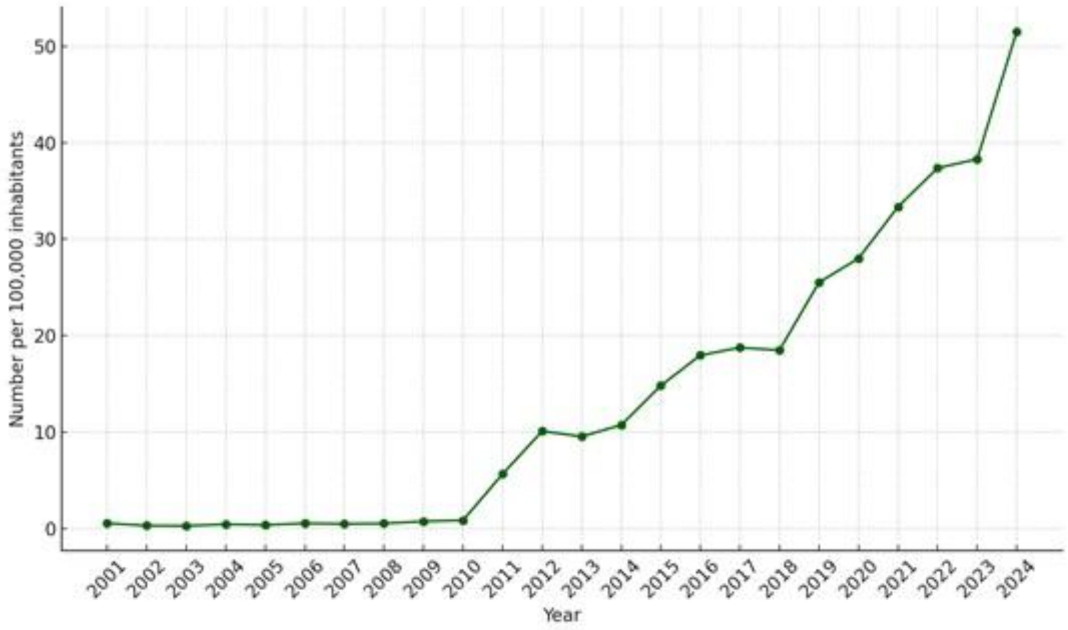

Abb. 8:

Abb. 11: Number of patients aged 5 to 19 per 100,000 inhabitants per year with the main diagnosis of R41.8, "mild cognitive impairment, subjective," in Sweden from 2001 to 2024 (Nilsson M & Hardell L, 2025).

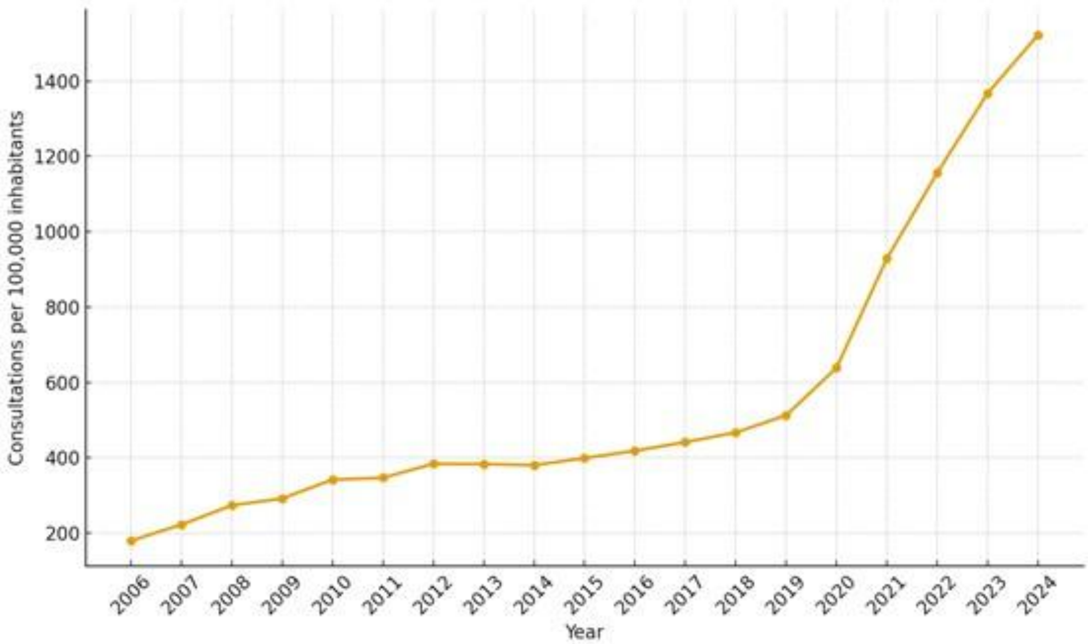

Figure 12: Number of consultations for memory problems (ICPC-2 code P20) in children aged 5 to 19 per 100,000 inhabitants in Norway from 2006 to 2024 (Nilsson M & Hardell L, 2025).