



OVERVIEW

for a clearer picture

No. 4

Does mobile communication affect the brain?



Overview No. 4

Does mobile communication affect the brain?

Updated: 16 September 2026

Summary

The diagnose:funk publication series "OVERVIEW for a clearer picture" reports on research into the health effects of non-ionising radiation from mobile communications. Scientific studies are researched using the databases www.EMFdata.org and www.EMF-Portal.de.

Overview No. 4 addresses the extensive research on the effects of mobile phone radiation on the neurobiological foundations of mental processes. Radiofrequency electromagnetic fields alter central metabolic processes in the brain. Particularly alarming is the resulting desynchronisation of endogenous rhythms: key processes fall out of step and neuronal interaction is severely disrupted. This affects learning, memory and behaviour, potentially extending to neurological and neurodegenerative disorders. More than 60 studies are documented here.

This Overview is based on a lecture given by Peter Hensinger on 3 June 2025 in Dornach at the Medical Section of the Goetheanum.

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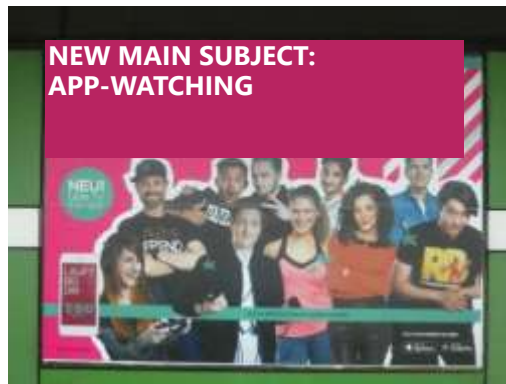
1 Long-term psychosocial effects of digital media use

The psychosocial effects of digital media use on children, such as concentration problems, emotional exhaustion, social withdrawal and a disturbed self-image, are widely discussed. Governments worldwide are banning smartphones in schools, a development few would have expected two years ago.

Alongside these effects, another risk factor is often underestimated: the danger from radiation exposure.

Smartphones and tablets transmit and receive microwave radiation, a form of non-ionising radiation. According to the 2025 Postbank study, children and adolescents now use smartphones and tablets for more than 70 hours a week on average, exposing them to radiation for that long as well.

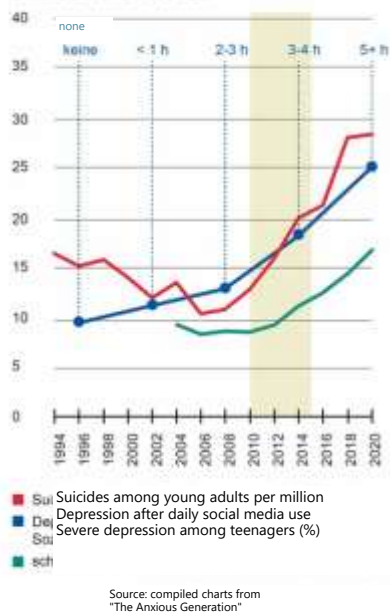
Overall, excessive screen media use has enormous potential to harm children's and adolescents' physical and mental health. The "Guideline for preventing dysregulated screen media use in childhood and adolescence" (2023 Guideline), issued by 11 German professional associations, including the Federal Centre for Health Education (BZgA), evaluates related research and identifies these main risks: obesity, sleep disorders, eye diseases, developmental disorders, attachment disorders, behavioural disorders, internet addiction, bullying and sexual harassment, gambling, radiation exposure, and prenatal and postnatal effects of use during pregnancy. The guideline responds to the consequences of smartphone use since its market introduction in 2007. This turning point continues to have profound effects on families, children, nurseries and schools. In his book "The Anxious Generation", social psychologist Jonathan Haidt defines this change as:



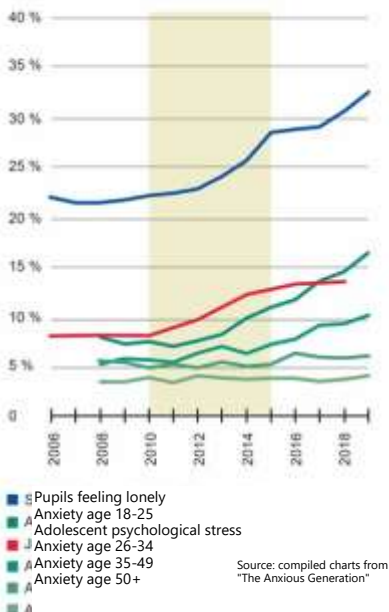
"The complete transition from a play-based childhood, which we had for millions of years, to a phone-based childhood."

Jonathan Haidt writes: "Around 2012, young people's mental health fell off a cliff" (NZZ, 8 April 2024). Charts in Haidt's book show a sharp rise in pathological developments following smartphone use since 2010: depression, suicide, anxiety, loneliness and stress have increased by up to threefold, while friendships and social contacts are declining rapidly (Figure 1). The correlations with smartphone use are obvious.

Suicide, depression and social media



Loneliness, anxiety and stress



Meeting friends, close friends, satisfaction with oneself



Figure 1

Jonathan Haidt: the 2012 tipping point. Smartphone use and its catastrophic effects on children and adolescents.

In March 2025, 75 experts from Germany and Switzerland therefore called for a halt to the digitalisation of educational institutions, a return to pedagogy and humane education, in an appeal initiated by the Alliance for Humane Education (Alliance 2025). Radiation protection experts warn of major harmful health effects (ICBE-EMF 2022, Davis et al. 2023). The now undisputed psychosocial effects interact with the effects of radiation exposure. Does mobile phone radiation cause cancer? Yes or no? This question dominates the discussion. The important debate on cancer (see Overview No. 2) obscures findings on immediate pathological effects, particularly harm to children from non-ionising radiation, including effects on brain metabolism. This Overview examines how non-ionising mobile phone radiation affects brain metabolism. These findings must become part of the public debate: they are highly significant.

2 Radiofrequency radiation in the electromagnetic spectrum

To understand the problem better, we first explain the electromagnetic spectrum. The upper part of Figure 2 shows the natural spectrum of our

environment, with characteristic gaps as it existed around 1900, before human-made radio waves occupied those gaps.

The natural electromagnetic spectrum

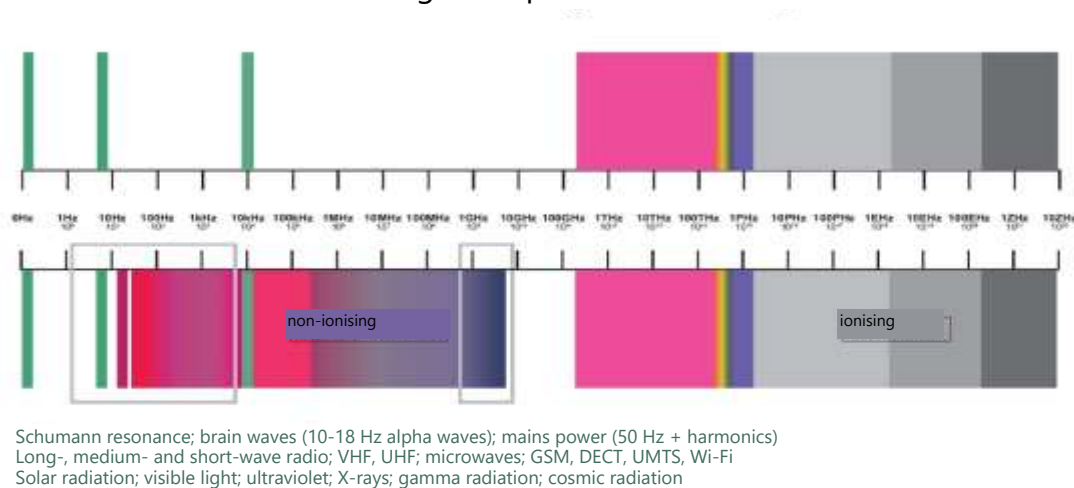


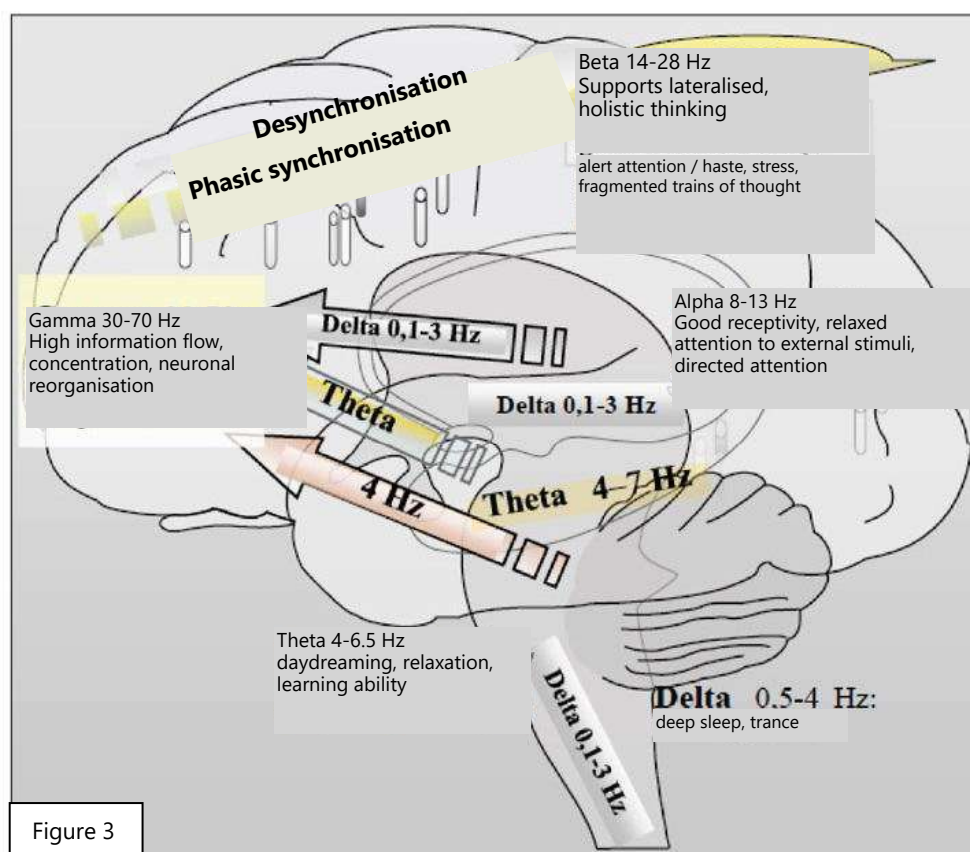
Figure 2 Today's electromagnetic spectrum

The Italian Guglielmo Marconi discovered the potential of technically generated electromagnetic waves for wireless communication and used the frequencies in these gaps. Yet our cells also communicate at these frequencies. The frequency gaps in our environment no longer exist today. They are largely filled by wireless applications using non-ionising radiation (see Glossary), as shown in the lower part of the illustration; the remaining gaps are filled further every year. What happens when technically generated radio waves, which have become increasingly widespread since around 1900 (radio, wireless communications, TV), meet cellular communication and brain rhythms at corresponding frequencies? Researchers are studying this question because human beings are electromagnetic beings.

3 Synchronisation of brain functions by electromagnetic fields

Electromagnetic fields (EMF) play a crucial role in metabolic processes and the control of brain functions. Figure 3 shows the frequencies, in the low-frequency range, occurring in brain rhythms. Neuroscientist Prof. Gertraud Teuchert-Noodt writes:

"Oscillators arise partly from communication between neurochemical cellular processes. They are rhythmically coordinated; interfering sequences synchronise entire brain areas. Activity is central to all neuronal maturation. It is supplied through sensory pathways from the environment and also fed by the brain's own oscillators, then transferred into self-synchronising brain rhythms that form the basis of thinking and learning. Both sources influence each other through brain chemistry, using specific neurotransmitters through which electrical signal currents become embedded in the structures of neural networks. Coupling electromagnetic and chemical signals is a core element of neuronal structure-function coupling" (text and Figure 3: Teuchert-Noodt 2019).



Externally generated EMF can interfere with signal transmission in nerve cells and synapses, thereby modulating or even disrupting signal processing. In the brain and its cells, information is transferred between nerve cells (neurons) in two ways: electrically and chemically. At the end of the axon, in the synaptic terminal, the electrical action potential signal releases chemical messengers, the neurotransmitters. Neural connections change and new traces form in the brain. This process of change represents learning, and electromagnetic fields are involved: "What ultimately happens in the brain depends on how individual neurons transmit signals, and this in turn depends on the activity of molecules within the neurons" (Squire/Kandel, p. 16). Storage of memories rests on changes in the strength of neuronal connections. Essential connections are

strengthened; non-essential, unused or no longer useful ones are silenced (masked) or dismantled. When nerve cells transmit signals (action potentials), electrical currents always flow, inducing magnetic fields. A distinction must be made between externally and internally induced fields. There is a substantial body of research on the effects of radiofrequency radiation, including both its low- and high-frequency components, on cellular communication and brain waves.

4 Scientific studies on radiation¹ and the brain

4.1 Adverse effects on memory and spatial thinking

In Switzerland, the Swiss Tropical and Public Health Institute conducted a study of 700 adolescents to determine how radiation during phone calls affects the brain (Foerster et al. 2018). Mobile phone use among 12- to 17-year-olds was evaluated for one year. Entitled "A Prospective Cohort Study of Adolescents' Memory Performance and Individual Brain Dose of Microwave Radiation from Wireless Communication", it found that radiofrequency electromagnetic fields from mobile phones adversely affect the development of figural memory performance: the ability to store, recognise and name visual impressions (images, shapes, patterns and structures). As expected, frequent callers had higher radiation exposure in the brain. The striking finding: the more phone calls, the poorer the performance in the figural memory test.



Image: pexels-rdne-6849349

¹ Hereafter, "radiation" always means "mobile phone radiation", rather than sunlight or other radiation.

A second study is noteworthy: "Radiofrequency Electromagnetic Field Emissions and Neurodevelopmental Outcomes in Infants: A Prospective Cohort Study" (Setia et al. 2025), conducted by the Mahatma Gandhi Mission (MGM) Institute of Health Sciences and the Medical College and Hospital, all in Navi Mumbai, India. It examined the relationship between household radiation exposure and effects on infants. All radiation sources in the home, including emissions from mobile phone base stations, were recorded. The development of 105 newborns was followed for one year. Particularly interesting: because infants do not make phone calls themselves, the study addresses the effects of ambient radiation. Mean exposure was 8.66 mW/m^2 , ranging from 0.62 to 32.36 mW/m^2 . In communication and gross motor skills, the proportion of children with developmental delays requiring attention ("monitor/refer" classification) was higher among heavily exposed infants than those with lower exposure. For problem-solving, the difference was statistically significant. The authors conclude "that higher radiation levels were associated with poorer outcomes in cognitive developmental domains such as problem-solving and personal and social behaviour ... It may therefore be necessary to consider monitoring neurodevelopment in children expected to experience higher RF-EMF radiation (e.g. close to mobile phone base stations and with too many electronic devices in the household)."

The authors write that this is the first study of its kind, so they do not claim causality. The study makes no statements about the frequently observed practice of mothers and fathers carrying babies against their chest while using a smartphone very close by. This exposes the baby to high levels of near-field radiation.

How can developmental delays in infants and reduced figural memory in adolescents be explained? Medical and biological studies identify radiation-induced changes in brain metabolism as causes of the findings in these epidemiological studies. Such studies exist for all frequencies used in mobile communications to date.

A recent Swedish study shows an alarming rise in memory problems among children and adolescents in Sweden and Norway. The dramatic increase in radiation exposure from wireless technologies over the past ten years is cited as a possible factor (Nilsson / Hardell 2025).

The recent study by Cui et al. (2026) shows that electromagnetic fields can impair fear memory by functionally weakening the neuronal connection between the primary auditory cortex and the emotional fear centre in the amygdala (Au1-BLA circuit), reducing both signal transmission and calcium activity in the nerve cells involved. The pathological changes observed in the affected brain areas confirm that EMF can disrupt memory processes.

4.2 The hippocampus under radiation stress

We begin with a typical finding on the effects of non-ionising radiation on the brain, published in ElektromogReport in April 2018. Two studies by Shahin et al. (2015, 2018) demonstrated the following for Wi-Fi:

"(1) Impaired learning and memory in adult male mice exposed to 2.45 GHz microwaves (i.e. Wi-Fi). (2) Increased hippocampal stress levels. (3) Impaired synaptic plasticity. (4) Reduced expression of signalling pathway components highly important for learning and memory. All these effects depend on exposure duration: the longer the exposure, the more drastic the effect. In the authors' view, the fundamental mechanism by which 2.45 GHz microwaves adversely affect learning and memory in mice has been identified."

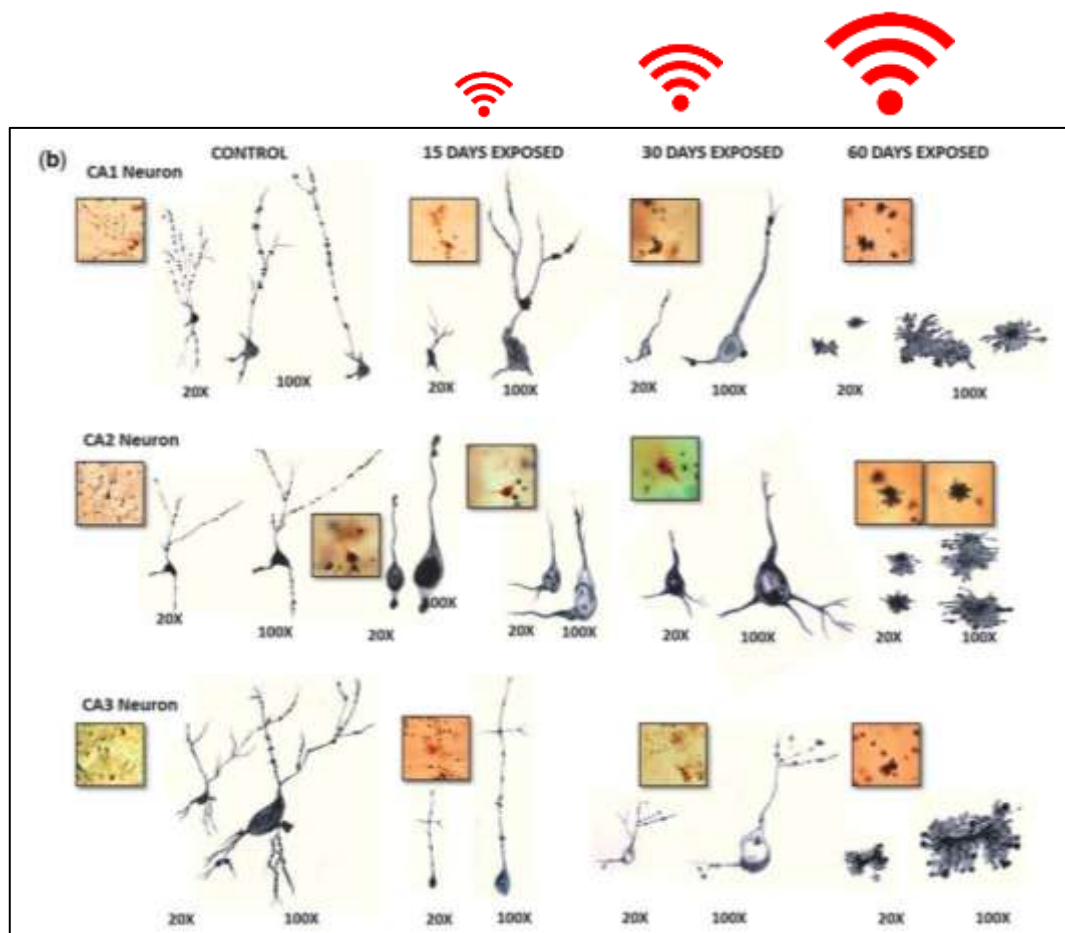


Figure 4: Structure and shape of neurons in the hippocampus of exposed mice after EMF exposure; from Shahin et al. (2015): "The number of dendrites decreased significantly over time in all exposed groups." "The number of dying or degenerating neurons increased in groups exposed to 2.45 GHz for 30 and 60 days." "Note the neuronal clumping or congestion in mice exposed to 2.45 GHz for 60 days."

A study by Azimzadeh et al. (2024) shows that these biological blockages also occur at mobile phone frequencies (900 MHz), beyond Wi-Fi. In rats, it demonstrated that GSM exposure during embryonic development already causes lasting disturbances in the hippocampus. The learning capacity of neural pathways is markedly reduced, later manifesting as cognitive deficits in offspring. Because the plant-derived substance linalool largely alleviated these effects, disrupted trace element balance and the associated oxidative cellular stress are considered the main cause.

As early as 2001, Hoffmann et al. also showed in gerbils that chronic low-frequency fields (50 Hz) can reduce neurogenesis, the formation of new cells, in the hippocampus by almost 30 per cent.

These data support the conclusion that radiofrequency electromagnetic fields attack central hubs of information processing. The demonstrated disturbances of synaptic adaptation and network communication in the brain thus directly conflict with the aims of all learning and mental development.

Two key terms appear in almost all studies: the hippocampus and brain plasticity. Synaptic plasticity is the ability of synapses, the junctions between nerve cells, to change their structure and function according to activity, experience and environmental influences. It is a fundamental property of the nervous system and plays a crucial role in learning and memory (Teuchert-Noodt 2025). The hippocampus plays a central role in learning and controlling brain functions, particularly in these areas:

- Memory formation
- Spatial and temporal orientation: the hippocampus has specific place cells and time cells, allowing experiences to be recalled in terms of content, sequence and spatial context. These discoveries were awarded the Nobel Prize in Medicine in 2014.
- Learning processes
- Coordination with other brain regions

In brief, the hippocampus is a central control hub for memory, learning and orientation. It can form new nerve cells throughout life, a key element of neuronal plasticity (lifelong formation of new nerve cells and their integration into the existing neural network, keeping it flexible). It oscillates at a theta frequency of 4-7 Hz. Without it, the brain's secretary, goal-directed behaviour and conscious recall would be impossible. It also controls the frontal brain, our executive and regulatory organ. Errors in this control have serious consequences, affecting intelligence and potentially leading to neurological and mental illnesses.

4.3 Findings of the studies by Kim et al.: brain desynchronisation

The studies by the South Korean research group of Kim et al. (2021, 2024) illustrate the consequences of radiation exposure. Their titles are:

- "Exposure to RF-EMF Alters Postsynaptic Structure and Hinders Neurite Outgrowth in Developing Hippocampal Neurons of Early Postnatal Mice" (2021). (diagnose-funk.org/1748)
- "Exposure to Radiofrequency Induces Synaptic Dysfunction in Cortical Neurons Causing Learning and Memory Alteration in Early Postnatal Mice" (2024). (diagnose-funk.org/2146)

Kim et al. exposed newborn mice to mobile phone radiation for four weeks from day 1 after birth. The mothers were present for the first three weeks. The young animals were exposed at 1850 MHz, a typical mobile phone frequency. The SAR was 4 W/kg, corresponding in various countries to the maximum permissible exposure for ordinary mobile phone users. Using electron microscopy, the scientists examined neuronal development and synapse formation, focusing on dendritic spines.

Kim et al. showed how radiation affects metabolism in the brain at the molecular level. Radiation inhibits the development and density of synaptic structures and neurite growth, adversely affecting behaviour, spatial learning and memory. Causes include changes in two substances: reduced BDNF expression and glutamate receptor expression (NMDA/AMPA). In other words, two central components of brain development are inhibited.

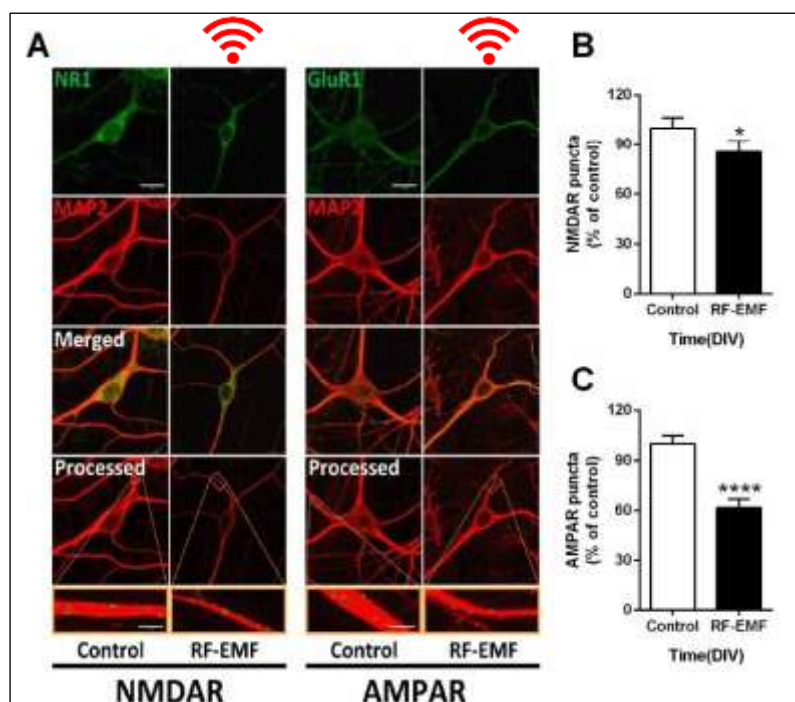
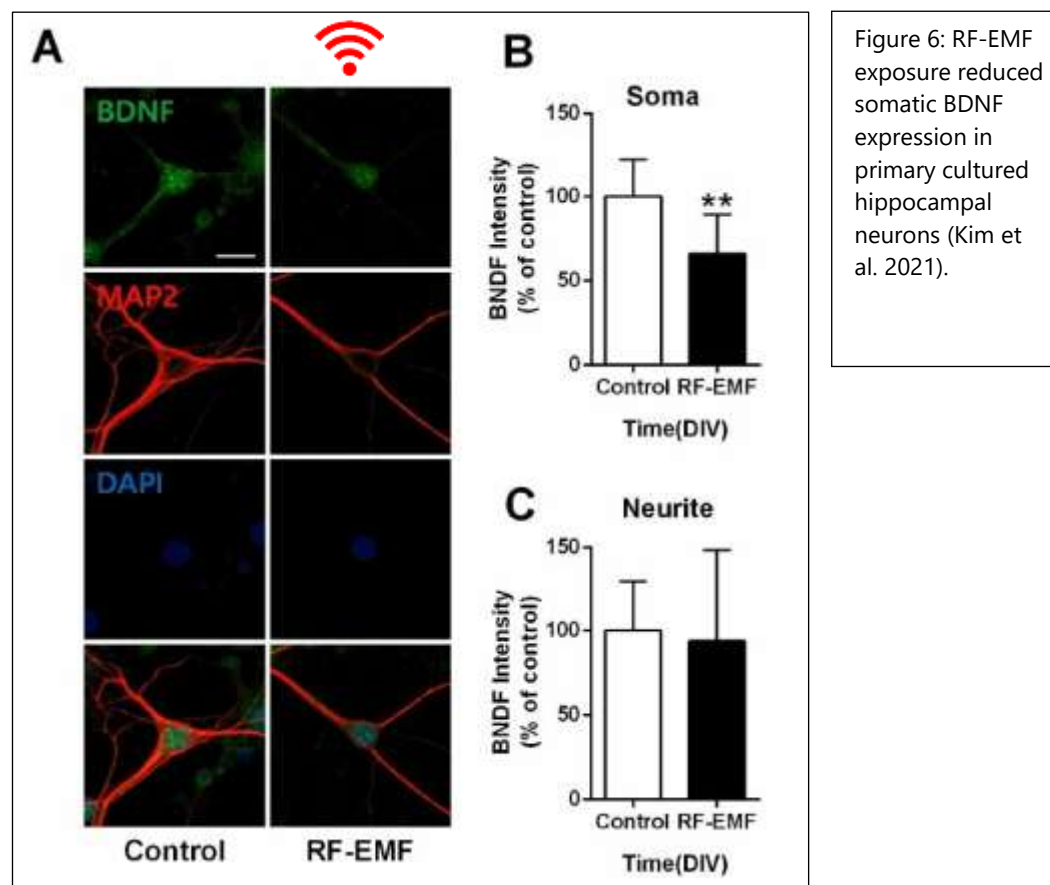


Figure 5: RF-EMF exposure reduced expression of NMDAR and AMPAR. (A) The images show hippocampal neurons: AMPAR (GluR1, green) and NMDAR (NR1, green), with MAP2 (marker, red) (Kim et al. 2021).



Like Kim et al., Bodin et al. (2025) found that the "in vivo results showed a decrease in BDNF levels". Summarising its overall findings, this French research group concludes that even "during prenatal development, continuous exposure to RF-EMF waves at regulatory thresholds ... reduces synaptogenesis in the immature rodent brain" and warns: "These data support the hypothesis that developing organisms are susceptible to RF-EMF exposure and favour caution regarding RF-EMF exposure of pregnant women and young children when using telecommunications devices."

Another prenatal effect of electromagnetic fields concerns the production and plasticity of neurons (granule cells) in the dentate gyrus, which are crucial to central hippocampal functions. Among other tasks, these cells filter information from the frontal brain and pass it into the memory loop. Odaci et al. (2008) showed that prenatal EMF exposure reduces the number of granule cells in rats' dentate gyrus (see Figure 7).

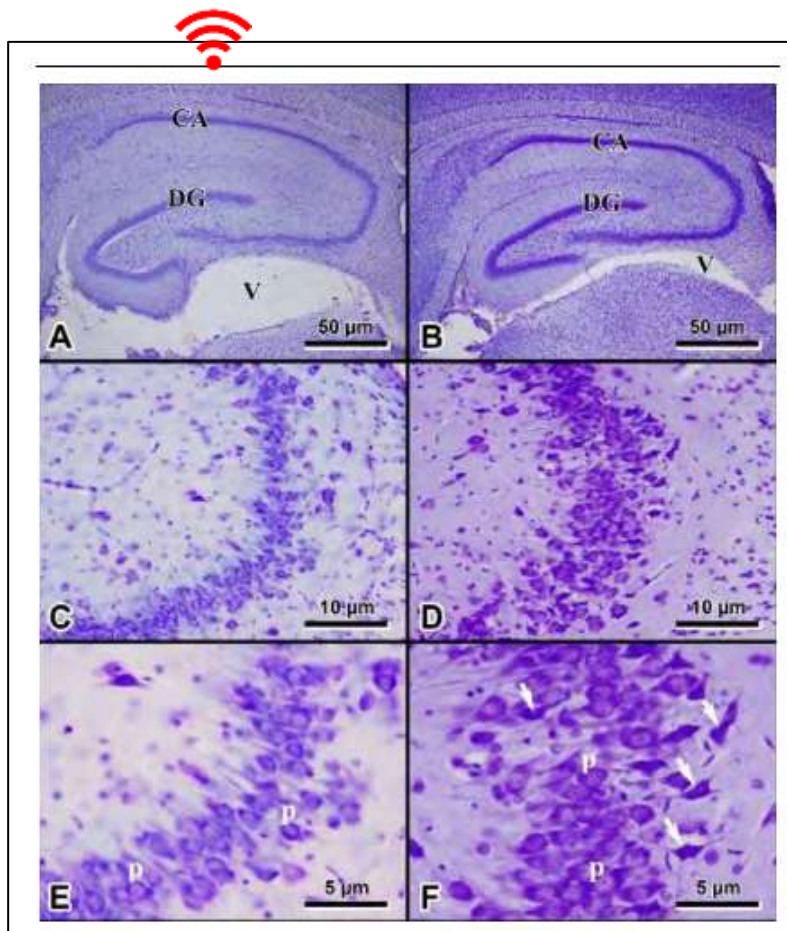


Figure 7: Exposure (left column), control (right column). Reduced number of granule cells and morphological differences in hippocampal pyramidal cells (Odaci et al. 2008).

4.3.1 Effects of electromagnetic radiation (RF-EMF) on neurotransmitters

The narrative, peer-reviewed review by the Chinese research group Hu et al. (2021) addresses individual mechanisms. It describes how electromagnetic fields in the mobile communication frequency range, including Wi-Fi, affect neurotransmitter systems in the brain, particularly glutamate / NMDA, dopamine, serotonin, GABA and acetylcholine. These systems govern thinking and learning. A key statement of the study is:

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

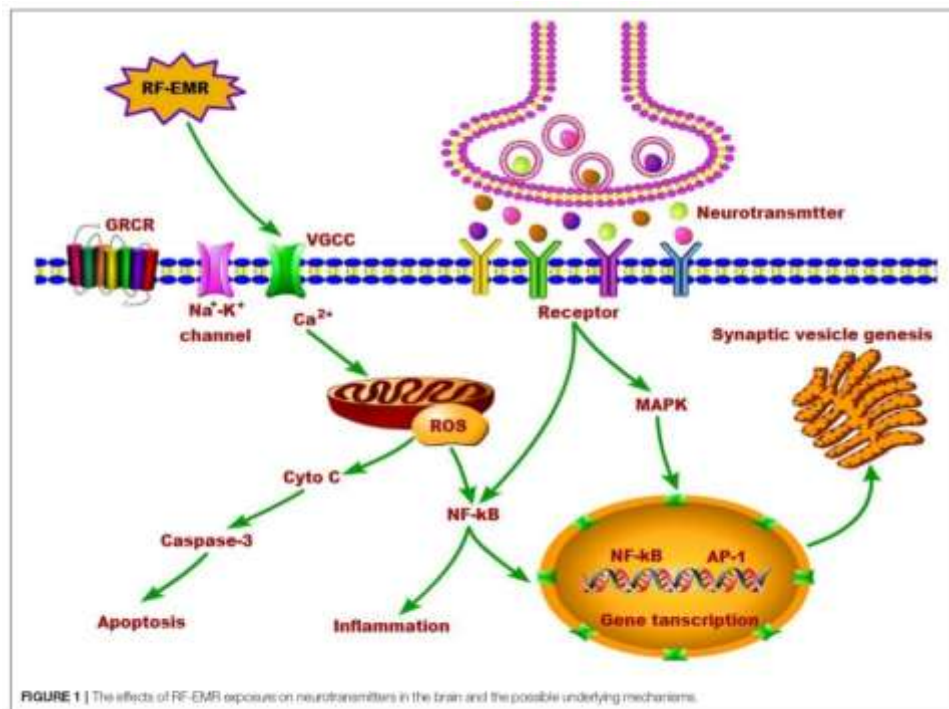


Figure 8: Harmful cellular cascades triggered by radiofrequency electromagnetic fields; illustration from Hu et al. 2021.

The authors report four central findings: RF-EMF cause

1. Neurotransmitter imbalance: biochemical dysregulation.
2. Oxidative stress and apoptosis: cellular damage.
3. Behavioural and memory changes: functional consequences.
4. Potentially irreversible developmental disorders: developing brains (fetuses, children) are more sensitive because their neural networks and neurotransmitter systems are still forming.

The changes depend on frequency and dose. Taken together, they indicate pathophysiological impairment of the brain by RF-EMF. The finely orchestrated interaction between neurotransmitters falls out of step.

Detailed information on the study: <https://diagnose-funk.org/2287>

What does this mean? Let us examine these findings more closely.

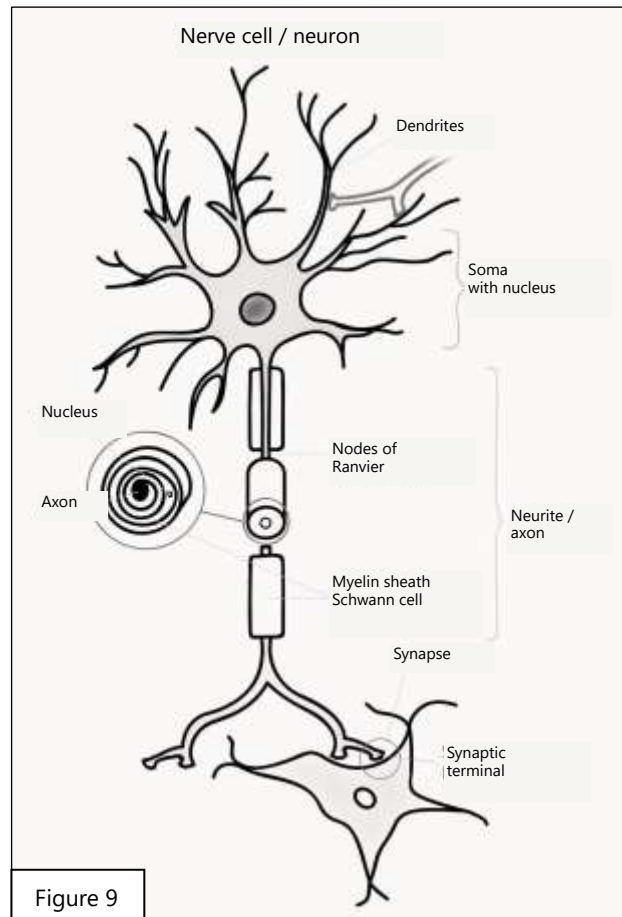
4.4 Background: how brain cells learn and store information

4.4.1 First digression: the nerve cell in the brain (neuron)

To understand the significance of Kim et al.'s findings, we begin with a digression on the nerve cell in the brain, the neuron: "Our entire mental life rests on their ability to transmit signals, from sensory perception to movement control,

from thinking to feeling" (Squire/Kandel, p. 27). Our brain contains 80-100 billion nerve cells (neurons) (10^{11}). Each neuron forms about 1,000 connections to other neurons at synapses. Approximately 100 trillion (10^{14}) synapses, the basic units of memory storage, communicate in our brain. The components and their functions are defined below:

1. Neurons: specialised nerve cells that generate, process and transmit electrical and chemical signals for communication in the nervous system.
2. Synapses: junctions between neurons where information is transmitted as chemical and electrical signals. There is a presynapse and a postsynapse, comparable to a transmitter and receiver.
3. Dendrites (input channels): branched extensions of neurons that receive incoming signals from other neurons and pass them to the cell body. They form the reception region for incoming signals, increasing the contact area.



4. Number of dendritic spines: the number of small, mushroom-shaped structures on dendrites that form synapses, affecting neuronal signal processing and plasticity.
5. Axons (output channels): long neuronal extensions that carry electrical impulses from the cell body to other neurons, muscles or glands.
6. Neurites: all neuronal extensions, both dendrites and axons, that receive or transmit signals.
7. Cell body: the cell body (soma) contains the nucleus and DNA encoding the neuron's genes.

Metabolic processes responsible for nerve cell growth and function are influenced by electromagnetic fields: "Like the action potential, the synaptic potential is an electrical signal" (Squire/Kandel, pp. 33, 117; Kandel, pp. 192, 296). Once the action potential reaches the presynaptic terminal, a

neurotransmitter is released (Squire/Kandel, p. 31). Kandel describes the response to a series of action potentials at a synaptic connection as "simultaneous firing", leading to long-term potentiation (LTP), a lasting strengthening of a neuron's synaptic transmission (Kandel, p. 700): "A single high-frequency series of electrical stimuli can double the strength of a synaptic connection" (Squire/Kandel, p. 115). LTP represents the storage of memories.

4.4.2 Second digression: brain-derived neurotrophic factor (BDNF) - the growth factor for nerve cells

BDNF is the brain's fertiliser, a small protein that shapes brain development. It is a neurotrophic substance, promoting nerve growth (Kandel, p. 112 ff.). Imagine the brain as a garden. Neurons are plants that grow, branch and form connections. BDNF is the fertiliser supporting this growth. It is produced in the brain, particularly in the hippocampus, cortex and other areas relevant to learning. Its discovery was an important milestone in neuroscience, particularly in understanding learning, memory, mental disorders and neurodegenerative diseases.

BDNF promotes the formation and strengthening of synaptic connections, providing a foundation for learning and memory. It supports the maturation of neural networks, helping stabilise useful connections and eliminate superfluous ones. BDNF promotes new nerve cell formation in the hippocampus, even in adulthood, and is essential for long-term potentiation (LTP), crucial to storing information in long-term memory. Without BDNF, important neural connections would never form or would quickly disappear. It helps the brain store information by strengthening connections between nerve cells. It acts as a natural booster for neural networks and is essential to a brain capable of learning and remembering.

4.4.3 Third digression: Hebb's learning rule

The Hebbian learning synapse plays a central role in learning, particularly associative learning. It rests on the principle formulated by Canadian psychologist Donald Hebb in 1949: "Neurons that fire together, wire together."

A synaptic connection between neurons, between their dendrites and axons, initially does not exist or exists only temporarily. Hebb's learning rule states that a synapse strengthens when the presynapse, the presynaptic neuron (transmitter, axon), and the postsynapse, the postsynaptic neuron (receiver, dendrite), are repeatedly active at the same time, like a self-reinforcing echo. Synapses showing these properties are called Hebbian synapses. This strengthens the connection between the two nerve cells, making signal transmission more efficient. This form of strengthening is called long-term potentiation (LTP), essential for storing information in memory (Kandel, p. 236 ff., p. 700). The NMDA glutamate receptor (see Glossary) enables long-term potentiation. It ensures that synaptic strengthening occurs only when

presynapse and postsynapse are active simultaneously ("Neurons that fire together, wire together"). BDNF strengthens and stabilises this activity structurally. This complex interaction is described in Squire/Kandel's textbook (pp. 61, 112 ff., 115 ff., 133 ff.).

BDNF and NMDA are thus complementary components in learning and its implementation at the Hebbian learning synapse. NMDA: "recognise learning"; BDNF: "consolidate what has been learned". High-frequency electrical impulses (action potentials) trigger LTP. The highest NMDA density occurs at the entrance to the hippocampus and cortex, so most long-term potentiation occurs there. Memory therefore has no single seat. Squire and Kandel write: "Hebb's idea of distributed information storage was far-sighted ... There is no single memory region, and many brain regions contribute to representing each individual event ... In the modern view, memory is distributed throughout the brain, but different areas store different aspects of the whole" (pp. 10, 71).

4.5 Mobile phone radiation causes synaptic dysfunction

The crucial question is whether mobile phone radiation affects this highly complex process in our thinking apparatus. Many studies give clear results. Radiation from smartphones, tablets and other devices inhibits expression of glutamate receptors and BDNF (see Section 4.3). In plain terms, radiation inhibits key functions in learning. The main findings of Kim et al. are therefore that RF-EMF exposure disrupts the homeostasis of important brain processes, throwing them out of balance.

Radiation causes the following nerve cell dysfunctions:

1. Reduced glutamate receptor expression: expression of NMDA/AMDA glutamate receptors, essential for synaptic plasticity and learning, was reduced.
2. Reduced BDNF expression: brain-derived neurotrophic factor (BDNF), a factor in neuronal survival, growth and plasticity, and thus learning and memory, decreased significantly in the cell body (soma) of hippocampal neurons.
3. Impaired synapse maturation: RF-EMF exposure reduced the density of postsynaptic proteins essential for synapse maturation. Neurite outgrowth and neuronal branching were also impaired.
4. Fewer dendritic spines: mice exposed to 1850 MHz mobile phone radiation had significantly fewer dendritic spines in the prefrontal cortex. In particular, mushroom-shaped spines, known for strong synaptic signals, were reduced.
5. Impaired neurite growth: neurite length and the number of branches decreased significantly.

For thinking and learning, this entails the following short- and long-term risks:

1. Impaired learning and memory performance.
2. Slower growth and fewer connections mean information is stored more slowly and less accurately.
3. Weakening the brain's communication lines, desynchronising brain activity, weakens figural memory.

Lost competencies

Figure 10

Figure 1: national proportion of pupils at the end of Grade 4 who do not meet minimum standards.

"The longer children spend on smartphones and social media in their free time, the poorer their academic performance."
(Zierer meta-study 2020)

Smartphone introduction 2007: start of phone-based socialisation

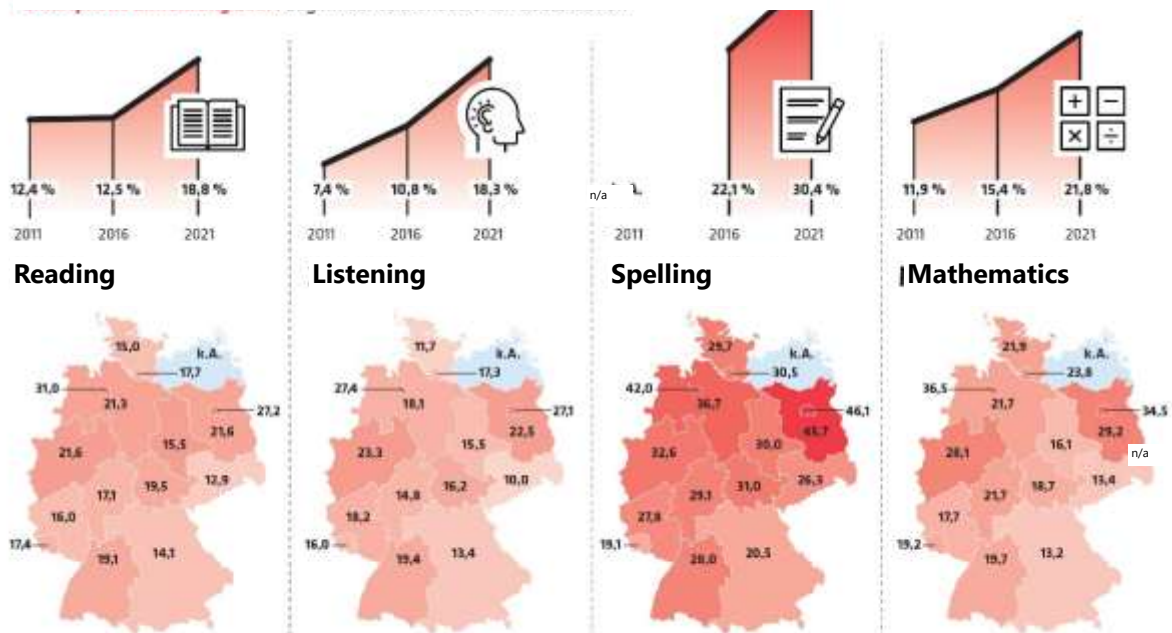


Figure 2: proportion of Grade 4 pupils in the federal states in 2021 who do not meet minimum standards.

Source: IQB Education Trends 2021; no precise data for Mecklenburg-Western Pomerania. Graphic: diagnosefunk

Conclusion: radiofrequency electromagnetic fields demonstrably alter central metabolic processes in the brain adversely. Particularly alarming is the resulting desynchronisation of the entire brain: key processes fall out of step and neuronal interaction is severely disrupted. This explains radiation's adverse effects on figural memory in Foerster's study (see 4.1). It is clear that this relates to effects on place and time cells in the hippocampus. Neurobiologist Dr Keren Grafen interprets the findings in an interview with our magazine Kompakt (1/2025):

- "Exposure to radiofrequency electromagnetic fields adversely affects axons and dendrites of nerve cells in the hippocampus. The branches of the

neuronal trees wither, their number decreases, and the network loses stability ... The anatomical correlate of all learning is impaired." This is a highly significant finding. It could explain many pathological symptoms described by Haidt (see Figure 1) and the performance decline documented in the IQB Education Trends (Figure 10). Prof. Gertraud Teuchert-Noodt therefore described digital media's effects as a cyberattack on the brain.

5 Further studies on RF-EMF and the brain

Kim et al.'s findings are supported by further studies. Sun et al.'s (2025) "Compound exposure of 2.8 GHz and 9.3 GHz microwave causes learning and memory impairment in rats" examines combined microwave exposure on rats' brains. Combined exposure significantly worsened learning and memory, more than separate exposures. Abnormally elevated theta and delta waves indicated neuronal dysfunction. Mitochondrial damage associated with cognitive deficits occurred. The study identifies BDNF as a potential biomarker of microwave-induced neuronal damage.

Iranfar et al. (2025) established a direct connection to humans.

Magnetoencephalography (MEG) examined people holding a GSM phone to their left ear. Measurements showed clear disturbances of functional connectivity in the opposite, right hemisphere. Coordinated data exchange in the temporal lobe was acutely blocked, affecting precisely the networks responsible for memory, emotions and the auditory centre.

Such effects are now demonstrated for all frequencies in use. We focus below on Wi-Fi findings because this technology is most widely used in schools (see Overview No. 6 on Wi-Fi). Wi-Fi studies demonstrate direct effects on the hippocampus and its neurons. Consequences include stress responses (Yang et al. 2012), impaired spatial learning and memory (Lai and Singh 2014, Wang/Lai 2000, Chaturvedi et al. 2011), and cognitive behavioural disorders accompanied by loss of mitochondrial function (Gupta et al. 2018).

Karimi et al.'s (2018) study has the self-explanatory title "2.45 GHz microwave radiation impairs learning, memory, and hippocampal synaptic plasticity in the rat". Behavioural tests showed that 2.45 GHz microwave radiation from a Wi-Fi device worsens rats' spatial memory and learning behaviour. Long-term neuronal plasticity was also adversely affected.

Zhu et al.'s (2021) findings indicate that a single brief RF exposure caused significant changes in learning and memory, and in hippocampal structure and energy metabolism. The authors interpret the EEG changes as suppression of electrical brain activity.

Bamdad et al. (2019) obtained similar results. They used three psychological tests with female pupils to examine Wi-Fi's effects on short-term memory, selective attention (focusing on one thing) and divided attention (multitasking). The Wi-Fi group performed significantly worse in memory tests. The authors suggest overproduction of free radicals (ROS) as one cause, also shown in brain studies by Yang (2012), Bamdad (2019) and Zhu (2021). This mechanism, oxidative cellular stress disrupting redox balance, is a cause of inflammatory disease (Warnke 2013, Naziroglu 2014, Yakymenko 2015, Schürmann 2021).

Laván et al.'s (2025) recent systematic review provides a fuller picture. Researchers evaluated 49 studies and mapped genetic interactions. Although they stress that there is no direct proof of Wi-Fi causing Alzheimer's, the indirect link through oxidative stress is alarming: 2.4 GHz Wi-Fi exposure demonstrably alters expression of genes responsible for DNA repair and mitochondrial function. This attacks brain cells' genomic stability: radiation-induced cellular damage intersects at the molecular level with known Alzheimer's risk genes.

The appendix lists 64 studies reviewed in ElektrosmogReport that demonstrate effects on brain metabolism, primarily at GSM, UMTS, LTE and Wi-Fi frequencies, with a few on 5G. In May 2025, Mevissen, Fröhlich and Schürmann (Universities of Basel and Bern) published the review "Electromagnetic fields in the frequency range 5.8-200 GHz: biological effects and consequences for health", commissioned by the Swiss Federal Office for the Environment (FOEN). It confirms potential harm to the brain. Two excerpts follow:

"Overall, seven of the eight in vivo studies examined effects related to neurodegeneration or neurological effects, including behaviour relating to learning and memory (de Seze et al. 2020; Liu et al. 2022; Qi et al. 2022; Romanenko et al. 2019; Rui et al. 2022; Wang et al. 2023a; Wang et al. 2023b). Six studies at 5.8-29 GHz examined memory performance, some also investigating structural changes in the brain or specific structures. Most studies used 5.8-9.4 GHz, with inconsistent results. Some effects depended on frequency: behavioural deficits and morphological changes seen at a lower frequency (1.5 GHz) were not observed at 9.4 GHz (Wang et al. 2023a). Another study by the same authors, also in young rats, found behavioural deficits and structural changes in the

hippocampus, and different levels of proteins involved in synaptic signalling, after chronic exposure for six minutes a day, five days a week, for six weeks (Wang et al. 2023a)" (p. 11). "Studies of neuronal effects of RF-EMF exposure at 5.9-10 GHz found impaired memory and morphological structure in brain regions of young laboratory rodents (Liu et al. 2022; Wang et al. 2023a; Wang et al. 2023b). Other studies (Rui et al. 2022) found no effects compared with sham-exposed animals. No comparable studies exist for millimetre waves (MMW), but sub-MMW RF-EMF also produced learning deficits (Bodera et al. 2017; Kerimoglu et al. 2016; Ragy 2015; Shahin et al. 2018; Sharma and Shukla 2020; Tan et al. 2017; Tang et al. 2015). Several MMW studies indicate increased ROS production accompanied by impaired cognitive abilities. Similar findings at 900 MHz and 2.5 GHz were also associated with morphological brain changes (Bodera et al. 2017; Kerimoglu et al. 2016; Ragy 2015; Schuermann and Mevissen 2021)" (p. 31).

"In summary, some in vivo studies provide evidence of structural brain changes and deficits in learning, memory and synaptic plasticity" (p. 32).

All these studies reinforce Dr Keren Grafen's conclusion: "The anatomical correlate of all learning is impaired." Industry and authorities in particular will probably try to dispute their relevance because they challenge the multibillion business of digitalising education (Overview No. 7, Krautz 2014, Münch 2018). Yet all these studies are peer-reviewed publications and thus a recognised part of scientific knowledge.

The German Bundestag's unanimously adopted 2023 technology assessment report (TAB) supports this. It lists some studies cited here and describes research on children: "A total of 17 studies found indications of various effects. Epidemiological studies most often described behavioural abnormalities, especially in children who used phones themselves or were exposed in utero during pregnancy. Children and adolescents also reported health complaints (headaches, fatigue, etc.) when making mobile phone calls. Effects on cognition in adolescents were also found. Experimental studies provided individual indications of changes in brain activity and skin resistance, and impaired cognitive performance" (TA report, pp. 14, 148).

5.1 Underdeveloped spatial and temporal processing

Figure 11 shows one consequence of the described metabolic disturbances, including hippocampal functions. Neurobiologist Prof. Teuchert-Noodt and psychologist Angelika Supper (Supper 2021) investigated how smartphone use affects the frontal brain and spatial and temporal processing. Children had to write the word "Schneeballschlacht" (snowball fight) in predefined boxes. Children who did not use smartphones completed the task; those who played on them frequently did not. Result: heavy smartphone users had underdeveloped spatial and temporal processing. This agrees with Foerster et al.'s findings on radiation and figural memory (see 4.1).



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

Figure 11

Another major cause is lack of exercise. A child sitting indoors at a screen for hours lacks movement through space. The brain thus lacks building material for further development of the thinking apparatus, and construction slows. Neurobiologist Manuela Macedonia confirms this in "Move! And Your Brain Says Thank You" (2024): "Movement releases a star substance, nerve growth factor" (p. 122), i.e. BDNF. She adds: "One major motivation for exercising is concern about not producing enough BDNF" (p. 129). Alongside continuous EMF effects on brain metabolism that reduce BDNF, lack of exercise adds a further risk. Mutual reinforcement can be assumed.

5.2 The whole person thinks

Physician and psychiatrist Prof. Thomas Fuchs, holder of the Jaspers Chair in Heidelberg, reflects on these effects of virtualisation, which lead to a disembodied living environment for children:

"A shared feature of media and virtual worlds is separation from immediate bodily experience, a 'disembodiment'" (Fuchs, p. 132). Regarding the concept of using tablets in nurseries to raise IT-savvy children, he writes: "Even in kindergarten, scientifically oriented pedagogy confronts children with experiments, measurements and sensory illusions, to transform their intuitive relationship with the world into an experimental or constructivist approach ... In this neuroconstructivist conception, the real world differs dramatically from the one we experience. We perceive not things themselves but images or representations they evoke in the brain" (pp. 146/147). He continues: "Only the sensing and simultaneously moving organism shapes experienced space from coherently linked patterns of movement and sensation, including balance. We therefore experience even something as fundamental as space only as embodied, acting beings ... During development, this interaction includes shaping the brain structures needed to perceive the environment adequately ... Perception means sensorimotor interaction with the environment" (pp. 153/154). Prof. Fuchs's embodiment theory describes the complex network of body and mind.



What appears on a screen is a substitute for reality. The early separation of movement and perception emerges as a serious consequence of digitalisation. Jonathan Haidt puts it succinctly: "It is as if we gave toddlers tablets showing films about walking,

but the films were so captivating that the children never took the time or made the effort to actually learn to walk" (p. 73). The isolated, obese child swiping a tablet becomes a modern Kaspar Hauser.

5.3 Hyperpermeability of the blood-brain barrier

Another serious EMF effect on the brain has been known for about 30 years and repeatedly confirmed. The blood-brain barrier (BBB) protects the brain against toxins. Its opening after mobile phone exposure has been convincingly demonstrated by Leif Salford's studies since around 2000 (Salford 2003, Persson 2021). Result: GSM radiation opens the BBB, allowing toxins into the brain. In 2022, we published the diagnose:funk documentation "Opening the blood-brain barrier through mobile phone radiation: findings of the Salford studies" as a Brennpunkt.

Aggarwal et al. (2013) show that low, chronically acting field strengths at 2.45 GHz alter neuronal electrophysiology. According to the researchers, firing neurons' synchronisation / desynchronisation changes, affecting the BBB and neurotransmitter metabolism at synapses.

Kizilçay et al. (2024) found that 2100 MHz electromagnetic radiation significantly changed BBB permeability in New Zealand rabbits at exposure levels far below the limits, in the non-thermal range.

In 2022, neurobiologist Dr Keren Grafen published the review "Albumin as a key marker" on the plausibility of BBB effects in DHZ - Deutsche Heilpraktiker Zeitschrift (Thieme) (Grafen 2022).

5.4 Non-specific symptoms

Annual health insurer surveys confirm the epidemic rise in headaches and sleep disorders. Several Wi-Fi studies show significant associations with headaches and exhaustion (Chiu 2015, Cho 2016, Redmayne 2013, Wang 2017). Mortazavi et al. (2011) confirmed this in 469 pupils examined for consequences of mobile phone use. Call duration was statistically significantly associated with the frequency of headaches, muscle pain, palpitations, fatigue, tinnitus, dizziness and sleep problems. Problems with attention, concentration and nervousness were also greater than expected among frequent users.

5.5 Effects of Wi-Fi's 10 Hz pulsing

The alpha-wave component of the human electroencephalogram has a mean frequency of 10 Hz (Hecht 2017, see Figure 3). The study

by Rütger Wever in the famous Andechs bunker demonstrated the relationship between human circadian rhythms and the 10 Hz frequency of the Earth's electromagnetic fields (Schumann resonances, see Figure 2) (Hecht 2018).

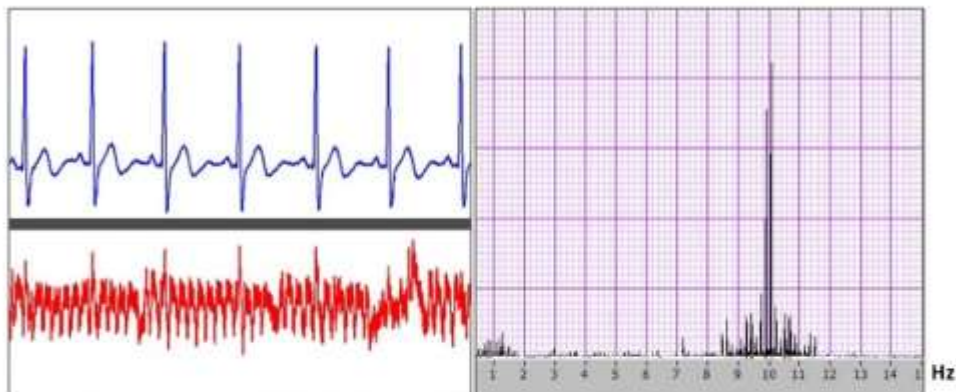
Wi-Fi pulses at 10 Hz. Research by Prof. Lebrecht von Klitzing (1995, 2022) shows its potential pathological effects on the brain. A medical physicist, he headed the clinical experimental research facility at Lübeck Medical University from 1975 to 2002. An EMF research pioneer, he has had 23 papers listed in EMF-Portal since 1986. He discovered that Wi-Fi's 10 Hz timing affects bodily functions. In an interview with our magazine kompakt, he said:

"Nerve signals can be recorded in an electromyogram (EMG), at the nerves themselves and in their nearby periphery, on the overlying skin. An electrode matrix on the skin allows non-invasive recording. After exposure, the 10 Hz Wi-Fi signal was predominantly detectable in these recordings in groups describing themselves as electrosensitive. This reveals particular dynamics in nerve signal changes ... One finding was that the cardiac symptoms atrial flutter/fibrillation were frequently detected. The closeness of the frequency to Wi-Fi is striking" (diagnose-funk.org/1964).

The graphical FFT records (Figure 12) show the changes (FFT = fast Fourier transform, determining the frequencies in a signal by their strength). A medicine would immediately be withdrawn given this evidence. In "Effects of the 10 Hz pulsing of Wi-Fi electromagnetic radiation on humans", Prof. Karl Hecht (2018) concludes: "With permanent long-term exposure, 10 Hz pulsing of Wi-Fi EMF radiation can form a Wi-Fi EMF stress memory. This is an enormous threat to human health, especially children. Equipping schools with Wi-Fi systems must be prohibited by law" (Hecht 2018).

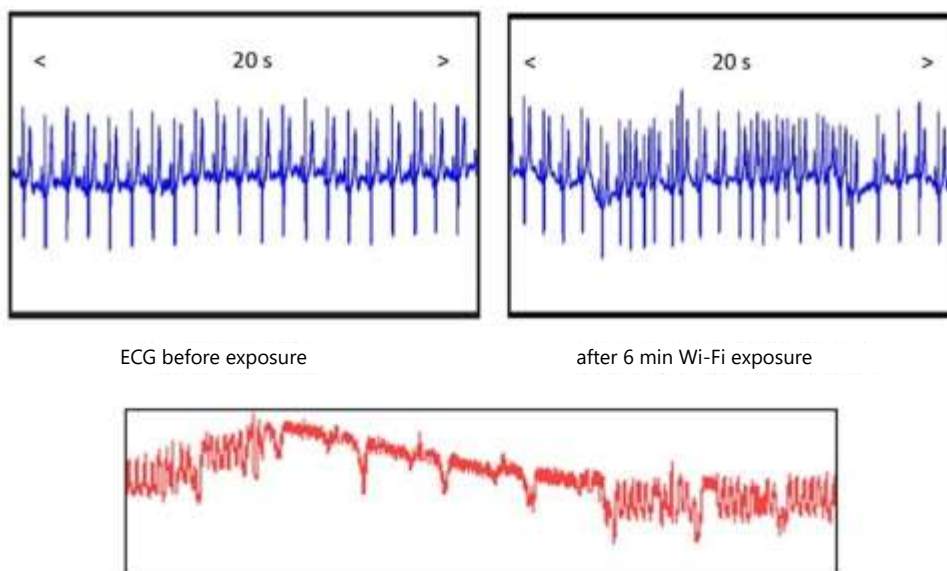
Panagopoulos et al. (2026) confirm that real Wi-Fi, 4G and 5G signals contain pronounced, highly variable ELF pulse components. Their pulsed, polarised, coherent structure represents a central non-thermal mechanism acting through ion oscillation at voltage-gated ion channels, highly relevant to assessing the biological significance of real communication signals.

Patient reports headaches during / after work in an open-plan office

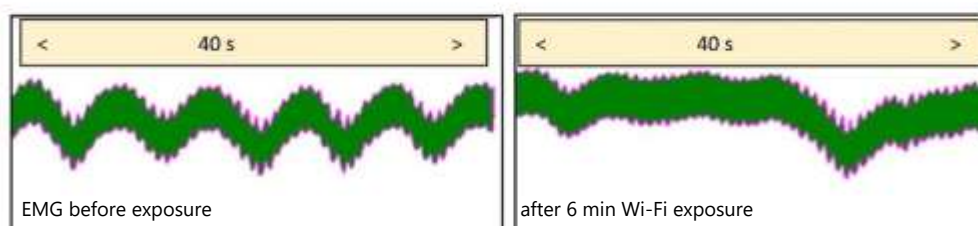


EMG (red) and FFT (black) show a clear 10 Hz signal after previous Wi-Fi exposure. About 30 h elapsed between the last exposure and measurement. Key finding: the artificial signal is retained for a long time.

Patient reports breathlessness during and after computer work



This patient also showed spontaneous EMG changes after exposure and ...



... disturbed (= inactive) microcirculation

5.6 Studies on the particular radiation risk in epilepsy

Epilepsy's main disturbance is abnormal electrical overactivity of brain neurons, causing sudden, uncontrolled discharges manifested as seizures. Neuronal hyperexcitability can trigger a seizure, for example through an imbalance of excitatory (e.g. glutamate) and inhibitory (e.g. GABA) neurotransmitters.

We know of ten studies in EMF-Portal demonstrating, among other findings, that non-thermal metabolic disturbances triggered by mobile phone radiation can provoke a seizure (Carballo-Quintas et al. 2012). Esmekaya et al. (2018) conclude that "exposure of mice to a 900 MHz electromagnetic field could increase oxidative stress in the brain during an epileptic seizure". Kouchaki et al. (2016) reached the same conclusion. EMF-Portal describes Maby et al.'s (2006) finding: "GSM exposure increased the EEG signal in all frequency bands, without local differences. This suggests GSM mobile phones could have a biological effect on EEG signals."

Lopez-Martin's (2009) findings are summarised: "Compared with unmodulated signals, 900 MHz GSM exposure increased neuronal excitability in picrotoxin-treated rats, manifested as changes in behaviour (seizures), EEG and neuronal c-Fos expression."

Vecchio et al. (2012) showed that, "compared with controls, epileptic patients had statistically significantly greater interhemispheric coherence of temporal and frontal alpha rhythms (approximately 8-12 Hz) during GSM mobile phone exposure than during sham exposure".

A report to the Swiss government confirmed these effects: "Research provides observations of varying certainty of other biological effects not attributable to warming. An influence on brain waves is sufficiently demonstrated according to scientific criteria" (Swiss Federal Council 2025).

The appendix lists the epilepsy studies discussed in EMF-Portal.

6 The addiction mechanism

In addition to radiation's effects on the brain, addiction is triggered by endlessly offered stimuli that entice users to give in. According to the 2025 DAK study, about 25% of German 10- to 17-year-olds show risky or pathological smartphone and social media use, about 1.4 million children and adolescents. Around 4.7% of this age group are considered addicted to social media, an estimated 260,000 adolescents. This is a human-made epidemic. Smartphones and apps are programmed for addiction. Children's and adolescents' immature

impulse control cannot withstand the flood of stimuli. Space and time are constantly accelerated: consuming ever-new stimuli that children's brains cannot adequately process leaves no room for slow thinking and thorough information processing, the consolidation phase needed for memory storage. The danger is that this relentless bombardment produces feelings of happiness. The brain demands more; impulse control cannot develop or is overridden. The mechanism was identified at Prof. G. Teuchert-Noodt's institute: overstimulation accelerates dopamine supply to the reward system, while the frontal brain receives too little dopamine. This blocks the dynamic phase of brain maturation, particularly of the frontal brain: "In the brain, digital acceleration impedes neuronal sequence formation and neurochemical communication between cell groups transmitting excitation patterns to distant neural networks. This produces cognitive impotence" (Teuchert-Noodt 2017).

7 Solutions for an environment with minimal radiation

We have comprehensively presented evidence on the pathological effects of non-ionising radiation on the brain, across frequency ranges and specifically for Wi-Fi (see Overview No. 6). Radiation has diverse toxic effects on the organism. Such indications, even contradictory evidence, call for the precautionary principle. Given what is known about non-ionising radiation, particularly Wi-Fi, hazard prevention should apply.

Alternatives exist. Wired connections must be mandatory wherever possible; LiFi (Light Fidelity), the light-based alternative to Wi-Fi, is ready for series production. The STOA study for the European Parliament's technology assessment committee proposes these policy options:

- Develop safer devices with lower radiation emissions
- Lower exposure limits and introduce precautionary values
- Use alternative infrastructure (fibre-optic expansion, LiFi)
- Establish wireless-free zones in public areas
- Inform people about potential health risks, alternatives and protective measures

8 Conclusions

Authorities must stop suppressing study findings and the reality of increasing deficits among school pupils.

While many countries reverse the digitalisation of educational institutions, the new German government's coalition agreement plans a "digital-only" society, including a Digital Pact for Schools 2.0 and digitalised autonomous learning. Harm to children documented in the screen media guideline will increase further. The 2025 KKH study (Kaufmännische Krankenkasse Hannover) found speech and language disorders among 6- to 18-year-olds rose 77% from 2008 to 2023. Nine per cent of young people have a language deficit requiring treatment, rising to 17% among 6- to 10-year-olds. Motor disorders also rose 37%. KKH explicitly highlights correlations with smartphone use. PISA and reading studies document declining mental performance. Acknowledging these risks and radiation's contribution is necessary to avoid them. RF-EMF harm health, from inhibiting brain development to affecting fertility and causing cancer. Protective policy and user education are therefore needed. Please contribute, particularly if you work in education or healthcare.

Further reading

Specialist articles on diagnose-funk.org

Keren Grafen (2026): Effects of a digitalised childhood on the brain's cognitive and emotional maturation; published in 5 languages, diagnose-funk.org/aktuelles/2323

Keren Grafen (interview, 2025): It is high time the adverse effects of RF-EMF on children's and adolescents' brain development were taken seriously! Published in 8 languages, diagnose-funk.org/2186

Peter Hensinger (2025): Effects of mobile communication electromagnetic fields on brain metabolism; published in 5 languages, diagnose-funk.org/aktuelles/2323

Peter Hensinger (2023): A paradigm shift at the door: publication of the "Guideline for preventing dysregulated screen media use in childhood and adolescence" - an assessment. Download: diagnose-funk.org/2033

Peter Hensinger / Bernd I. Budzinski: Why electromagnetic hypersensitivity (EHS) is a biologically expected response to harmful radiation, diagnose-funk.org/2098

Manfred Spitzer (2022): Digitalisation in kindergarten and primary school harms children's development, health and education (review). Download: diagnose-funk.org/2153

Teuchert-Noodt G, Hensinger P (2025): No way out of the smartphone epidemic without taking into account the findings of brain research, diagnose-funk.org/2205; German translation and download: diagnose-funk.org/2159

Alliance for Humane Education (2025): 75 experts: end digital education policy, smartphone-free schools! Appeal to the new government: "Humane and emancipatory education policy versus digital transformation", diagnose-funk.org/2191

Ralf Lankau / Peter Hensinger (2026): AI in schools: "Nobody is born stupid, people are made stupid ...". Artificial intelligence, avatars, (chat)bots and digital pacts: the ABC of dehumanising schools and teaching, diagnose-funk.org/2376

diagnose:funk article series on digital education, diagnose-funk.org/1926

Glossary

AMPA: a synthetic agonist activating AMPA glutamate receptors and triggering rapid postsynaptic signalling in the brain.

BDNF: brain-derived neurotrophic factor, a growth factor protein in the neurotrophin family. Found mainly in the central nervous system, it promotes new synapse growth and is essential to hippocampal neurogenesis.

Dendrite: a branched extension of a nerve cell (neuron) receiving electrical impulses from other cells and carrying them to the cell body.

Hebbian learning synapse: a neurophysiological principle in which repeated simultaneous activation strengthens the synaptic connection between two neurons ("Neurons that fire together, wire together"), a basis for synaptic plasticity and learning.

Glutamate: the brain's most important excitatory neurotransmitter. Through NMDA and AMPA receptors, it mediates synaptic plasticity, the biological foundation of learning and memory.

Hippocampus: a brain region particularly important for memory.

Ionising radiation: radiation with a wavelength below 200 nm causing ionisation as it passes through matter, removing an electron from an atom or molecule to produce an ion and a free electron (e.g. alpha particles, X-rays and gamma rays).

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

Neurogenesis: formation of nerve cells by stem cell differentiation and division.

Non-ionising radiation: all radiation and fields in the electromagnetic spectrum with insufficient energy to cause ionisation, e.g. radio waves, microwaves, infrared radiation and visible light.

NMDA glutamate receptor: an ionotropic glutamate receptor that, unlike AMPA, is strongly voltage-dependent. The key receptor for neuronal plasticity, synaptic strengthening (long-term potentiation) and cellular learning processes in the brain.

Synapse: a microscopic junction transmitting a signal from a nerve cell to another target cell (another nerve cell, muscle cell or gland cell).

Literature

Azimzadeh M, Noorbakhshnia M (2024): Maternal linalool treatment protects against radiofrequency wave-induced deteriorations in adolescent rats: A behavioral and electrophysiological study. Scientific Reports, 14(1), 17257, <https://www.emf-portal.org/de/article/55427>

Bodera P (2017): The effect of 1800MHz radio-frequency radiation on NMDA receptor subunit NR1 expression and peroxidation in the rat brain in healthy and inflammatory states. Biomed Pharmacother 2017;92:802-809, [emf-portal.org/en/article/32122](https://www.emf-portal.org/en/article/32122)

Bodin R (2025): Altered development in rodent brain cells after 900 MHz radiofrequency exposure. Neurotoxicology. 2025;111(August), <https://www.emf-portal.org/de/article/60768> Alliance for Humane Education (2025): 75 experts: end digital education policy, smartphone-free schools! Appeal to the new government: "Humane and emancipatory education policy versus digital transformation", diagnose-funk.org/2191

Cui Z (2026): Involvement of the Primary Auditory Cortex-Basolateral Amygdala Circuit in Altered Conditioned Fear Memory Retrieval Following Electromagnetic Field Exposure in Mice. J Integr Neurosci [Internet]. 2026 Apr 17;25(4), <https://www.emf-portal.org/de/article/63180>

Davis et al. (2023): Wireless technologies, non-ionizing electromagnetic fields and children: Identifying and reducing health risks. Curr Probl Pediatr Adolesc Health Care 2023; 53 (2): 101374. pubmed.ncbi.nlm.nih.gov/36935315/, in German: diagnose-funk.org/2004

de Seze R et al. (2020): Repeated exposure to nanosecond high power pulsed microwaves increases cancer incidence in rat. PLoS One 2020;15:e0226858, [emf-portal.org/en/article/42216](https://www.emf-portal.org/en/article/42216)

diagnose:funk Brennpunkt (2022): Opening the blood-brain barrier through mobile phone radiation: findings of the Salford studies, diagnose-funk.org/1809

diagnose:funk Brennpunkt (2020): LED light for data transmission - Wi-Fi without health risks? by Klaus Scheler, diagnose-funk.org/1576

Foerster M et al. (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, [emf-portal.org/de/article/35641](https://www.emf-portal.org/de/article/35641)

Fuchs T (2022): In Defence of the Human Being: Fundamental Questions of an Embodied Anthropology, Suhrkamp

Grafen K (2022): Albumin as a key marker. DHZ - Deutsche Heilpraktiker Zeitschrift, 2022; 6: 56- 59 | © 2022, Thieme

Haidt J (2024): The Anxious Generation: How we are losing our children to the virtual world and jeopardising their mental health, Rowohlt Verlag

Hecht K (2018): Effects of the 10 Hz pulsing of Wi-Fi electromagnetic radiation on humans, diagnose:funk Brennpunkt

Hecht K (2017): The electromagnetic ocean: a vital environmental factor in danger, Die Naturheilkunde, 1/2007

Hensinger P (2020): Wi-Fi in nurseries and schools: hype conceals the risks, umwelt · medizin · gesellschaft 1/2020, diagnose-funk.org/1537

Hensinger, P. (2025): Effects of mobile communication electromagnetic fields on brain metabolism. Die Naturheilkunde, 6/2025

Hensinger P, Wilke I (2016): Mobile communications: new findings confirm risks of non-ionising radiation, umwelt · medizin · gesellschaft | 29 (3) | 3/2016, 205-215; diagnose-funk.org/1141, diagnose-funk.org/1537

Hoffmann et al. (2001): Electromagnetic exposure effects the hippocampal dentate cell proliferation in gerbils [Meriones unguiculatus], Indian Journal of Experimental Biology, Vol. 39, December 2001, pp. 1220-1226

Hu C et al. (2021): Effects of Radiofrequency Electromagnetic Radiation on Neurotransmitters in the Brain, Review, <https://doi.org/10.3389/fpubh.2021.691880>, diagnose-funk.org/2287

ICBE-EMF (2022): International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF). Scientific evidence invalidates health assumptions underlying the FCC and ICNIRP exposure limit determinations for radiofrequency radiation: implications for 5G. Environ Health21, 92 (2022). <https://doi.org/10.1186/s12940-022-00900-9>; in German: diagnose-funk.org/1937

Iranfar S (2025): Modulation of brain functional connectivity in healthy young adults following GSM radiofrequency exposure: A magnetoencephalography and magnetic resonance imaging study. Neuroscience, 591, 103-109. DOI: 10.1016/j.neuroscience.2025.11.007, <https://www.emf-portal.org/de/article/61337>

Kandel / Schwartz / Jessel (1996): Neuroscience: An Introduction, Spektrum

Kerimoglu G et al. (2016): Pernicious effects of long-term, continuous 900-MHz electromagnetic field throughout adolescence on hippocampus morphology, biochemistry and pyramidal neuron numbers in 60-day-old Sprague Dawley male rats. J Chem Neuroanat 2016;77:169-175, emf-portal.org/en/article/29918

Kim JH et al. (2021): Exposure to RF-EMF Alters Postsynaptic Structure and Hinders Neurite Outgrowth in Developing Hippocampal Neurons of Early Postnatal Mice, Int. J. Mol. Sci. 2021, 22, 5340 emfdata.org/de/studien/detail?id=606

Kim JH et al. (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). emfdata.org/en/studies/detail?id=860

Kizilçay AO et al. (2024): Effects of 1800 MHz and 2100 MHz mobile phone radiation on the blood-brain barrier of New Zealand rabbits. Effects of 1800 MHz and 2100 MHz mobile phone radiation on the blood-brain barrier of New Zealand rabbits, Med Biol Eng Comput 2024

Klitzing v. L (2022): Healthy disorders by WLAN-exposure, Journal of Clinical Images and Medical Case Reports, Volume 3, <https://doi.org/10.52768/2766-7820/1639>, jcimcr.org, Download diagnose-funk.org/1964

Klitzing v. L (1995): Low-Frequency pulsed electromagnetic fields influence EEG of man. Published in: Phys Med 1995; XI (2): 77-80, Download diagnose-funk.org/1964

KKH study (2025): When smartphones silence children: alarming increase in speech and language disorders among young people, diagnose-funk.org/2242

Krautz J (2014): Education as a Commodity: Schools and Universities under the Dictates of Economics, München

Laván D et al. (2025): Review of the Evidence on the Influence of Wi-Fi 2.4 GHz Radiation on Oxidative Stress and its Possible Relationship with Alzheimer's Disease. *Frontiers in Neurology*. 2025 Oct 3;16:1616435, <https://www.emf-portal.org/de/article/61179>

Guideline (2023): Download the guideline: awmf.org/service/awmf-aktuell/praevention-dysreguliertenbildschirmmediengebrauchs-in-kindheit-und-jugend

Münch R. (2018): *The Education-Industrial Complex: Schools and Teaching in the Competitive State*, Beltz Juventa

Liu JJ et al. (2022): 20-Hydroxyecdysone Improves Neuronal Differentiation of Adult Hippocampal Neural Stem Cells in High Power Microwave Radiation-Exposed Rats. *Biomed Environ Sci* 2022;35:504-517, [emf-portal.org/en/article/47904](https://www.emf-portal.org/en/article/47904)

Macedonia M (2024): *Move! And Your Brain Says Thank You: How to Become Smarter, Think Better and Protect Yourself against Dementia*, Brandstätter Verlag

Mevissen M, Fröhlich J, Schürmann D (2025): Electromagnetic fields in the frequency range 5.8-200 GHz: biological effects and consequences for health, Swiss FOEN

Naziroglu M, Akman H (2014): Effects of Cellular Phone - and Wi-Fi - Induced Electromagnetic Radiation on Oxidative Stress and Molecular Pathways in Brain, in: I. Laher (ed): *Systems Biology of Free Radicals and Antioxidants*, Springer Berlin Heidelberg, 106, pp. 2431-2449

Nilsson, Hardell (2025): Increasing Numbers of Children Aged 5-19 Years with Memory Problems in Sweden and Norway. *Archives of Clinical and Biomedical Research*. 9 (2025): 431-439.

Odaci E, Bas O, Kaplan S (2008): Effects of prenatal exposure to a 900 MHz electromagnetic field on the dentate gyrus of rats: a stereological and histopathological study. *Brain Res* 2008; 1238 : 224 - 229

Panagopoulos DJ et al. (2026): Recording the extremely low frequency pulsations of wireless communication electromagnetic fields. *Electromagnetic Biology and Medicine*, 1-10, <https://www.emfdata.org/de/dokumentationen/detail?id=262>

Persson BRR (2021): „More Probable than Unlikely“- A Tale of the Blood-Brain Barrier and Mobile Communication. Dedicated to Leif G. Salford on his 80th birthday, 2021-12-07

Qi M et al. (2022): Behavioral Effect of Terahertz Waves in C57BL/6 Mice. *Biosensors* 2022;12

Ragy MM (2015): Effect of exposure and withdrawal of 900-MHz-electromagnetic waves on brain, kidney and liver oxidative stress and some biochemical parameters in male rats. *Electromagn Biol Med* 2015;34:279-284, [emf-portal.org/de/article/24632](https://www.emf-portal.org/de/article/24632)

Romanenko S et al. (2019): Millimeter Wave Radiation Activates Leech Nociceptors via TRPV1-Like Receptor Sensitization. *Biophys J* 2019;116:2331-2345, [emf-portal.org/de/article/38385](https://www.emf-portal.org/de/article/38385)

Rui G et al. (2022): Effects of 5.8 GHz microwave on hippocampal synaptic plasticity of rats. *International Journal of Environmental Health Research* 2022;32:2247-2259, [emf-portal.org/en/article/45327](https://www.emf-portal.org/en/article/45327)

Salford LG et al. (2003): Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. *med./bio. [Nerve cell damage in mammalian brains after exposure to microwaves from GSM mobile phones]*. 111 (7): 881-3, [emf-portal.org/de/article/9462](https://www.emf-portal.org/de/article/9462)

Schuermann D., Mevissen M. (2021): Manmade Electromagnetic Fields and Oxidative Stress - Biological Effects and Consequences for Health. Int. J. Mol. Sci. 2021, 22, 3772. <https://doi.org/10.3390/ijms22073772>, diagnose-funk.org/1692

Swiss Federal Council (2015): Future-ready mobile networks: Federal Council report in fulfilment of the Noser (12.3580) and FDP Liberal Group (14.3149) postulates; bakom.admin.ch/dam/bakom/de/dokumente/zukunftstauglichemobilfunknetze.pdf.download.pdf/zukunftstauglichemobilfunknetze.pdf; snf.ch/SiteCollectionDocuments/nfp/nfp57/nfp57_synthese_d.pdf, p. 10

Setia MS et al. (2025): Radiofrequency Electromagnetic Field Emissions and Neurodevelopmental Outcomes in Infants: A Prospective Cohort Study. Cureus 17(7): e87671. <https://www.emf-portal.org/de/article/60360>

Shahin S et al. (2018): 2.45 GHz microwave radiation induced oxidative and nitrosative stress mediated testicular apoptosis: Involvement of a p53 dependent bax-caspase-3 mediated pathway. Environ Toxicol 2018;33:931-945, emf-portal.org/de/article/35419

Sharma S, Shukla S (2020): Effect of electromagnetic radiation on redox status, acetylcholine esterase activity and cellular damage contributing to the diminution of the brain working memory in rats. J Chem Neuroanat 2020;106:101784, emf-portal.org/en/article/42061

STOA study (2021): Health-Impact of 5G, diagnose-funk.org/1740

Sun L et al. (2025): Compound exposure of 2.8 GHz and 9.3 GHz microwave causes learning and memory impairment in rats. Heliyon 2025; 11 (1): e41626

Supper A, Teuchert-Noodt G: "How learning doesn't work" Children evaluate their cell phone use - An empirical pilot study . Neurol Neurosci. 2021; 1(3):1-9

Squire LR, Kandel ER (2009): Memory: The Nature of Remembering, Heidelberg: Spektrum Akademischer Verlag

TAB (2023): Technology assessment (TA) - possible health effects of electromagnetic fields in different frequency ranges (RF-EMF), Bundestag document 20/5646, diagnose-funk.org/1954

Tan S et al. (2017): Study on dose-dependent, frequency-dependent, and accumulative effects of 1.5 GHz and 2.856 GHz microwave on cognitive functions in Wistar rats. Sci Rep 2017;7:10781, emf-portal.org/en/article/33085

Tang J et al. (2015): Exposure to 900 MHz electromagnetic fields activates the mmp-1/ERK pathway and causes blood-brain barrier damage and cognitive impairment in rats. Brain Res 2015;1601:92-101, emf-portal.org/de/article/26411

Teuchert-Noodt G (2019): The host cannot be left out of the reckoning: the child's brain. In: Lankau R, Bleckmann P (2019): Digital Media and Teaching: A Controversy, Beltz, Weinheim

Teuchert-Noodt G (2017): CYBERATTACK on the brain's neural networks: where is the digital revolution heading? umwelt · medizin · gesellschaft | 30 (3) | 3/2017, 28-32

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, diagnose-funk.org/2205, German translation: download at diagnose-funk.org/2159

Wang H et al. (2023): Changes in cognitive function, synaptic structure and protein expression after long-term exposure to 2.856 and 9.375 GHz microwaves. Cell Commun Signal 2023a;21:34, emf-portal.org/en/article/49939

Wang H et al. (2023): Disrupted Topological Organization of Brain Network in Rats with Spatial Memory Impairments Induced by Acute Microwave Radiation. Brain Sci 2023b;13, emf-portal.org/en/article/51302

Warnke U, Hensinger P (2013): Increasing burnout incidence from technically generated magnetic and electromagnetic fields in mobile and wireless communications, umwelt · medizin · gesellschaft, 1/2013, emfdata.org/de/dokumentationen/detail?id=59

Wilke I (2018): Biological and pathological effects of 2.45 GHz radiation on cells, fertility, brain and behaviour. Review: umwelt · medizin · gesellschaft | 31 (1) | 1/2018, 58-69, emfdata.org/de/studien/detail?id=439

Yakymenko I et al. (2016): Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. Electromagn Biol Med 2016; 35 (2): 186-202, published as a diagnose:funk Brennpunkt, diagnose-funk.org/1001

Sources / studies



1. Wi-Fi studies

Overview No. 6 on Wi-Fi documents more than 60 studies.

Aggarwal Y et al. (2013): Chronic exposure of low power radio frequency changes the EEG signals of rats: low power radio frequency alters EEG. Advances in Biomedical Engineering Research (ABER) 1 (2), emf-portal.org/de/article/35733

Bamdad K et al. (2019): Complications of nonionizing radiofrequency on divided Attention. Journal of Cellular Biochemistry 120 (6), emfdata.org/de/studien/detail?id=555

Chaturvedi CM et al. (2011): 2.45 GHz (CW) microwave irradiation alters circadian organization, spatial memory, DNA structure in the brain cells and blood cell counts of male mice, mus musculus. Progr Electromagn Res B 29, 23-42, emfdata.org/de/studien/detail?id=238

Chiu CT et al. (2015): Mobile phone use and health symptoms in children. J Formos Med Assoc 2015; 114 (7): 598-604, emf-portal.org/de/article/25628

Gupta SK et al. (2018): Electromagnetic radiation 2450 MHz exposure causes cognition deficit with mitochondrial dysfunction and activation of intrinsic pathway of apoptosis in rats, J Biosci 43, 263-276 (2018), emfdata.org/de/studien/detail?id=679

Karimi N et al. (2018): 2.45 GHz microwave radiation impairs learning, memory, and hippocampal synaptic plasticity in the rat. Published in: Toxicology and Industrial Health 2018; 34(12), 873-883, emfdata.org/de/studien/detail?id=507

Lai H, Singh NP (1996): Single- and double-strand DNA breaks in rat brain cells after acute exposure to radiofrequency electromagnetic radiation. *Int J Radiat Biol* 1996; 69 (4): 513-521, emfdata.org/de/studien/detail?id=402

Mortazavi SM et al (2011): The pattern of mobile phone use and prevalence of self-reported symptoms in elementary and junior high school students in Shiraz, Iran. *Iran J Med Sci* 2011; 36 (2): 96- 103, emfdata.org/de/studien/detail?id=211

Naziroglu M, Akman H (2014): Effects of Cellular Phone - and Wi-Fi - Induced Electromagnetic Radiation on Oxidative Stress and Molecular Pathways in Brain, in: I. Laher (ed): *Systems Biology of Free Radicals and Antioxidants*, Springer Berlin Heidelberg, 106, pp. 2431-2449, emfdata.org/de/studien/detail?id=410

Redmayne M et al. (2013): The relationship between adolescents' well-being and their wireless phone use: a cross-sectional study. *epidem. Environ Health* 2013; 12: 90, emfdata.org/de/studien/detail?id=302

Shahin S et al. (2015): 2.45 GHz Microwave Radiation Impairs Learning and Spatial Memory via Oxidative/Nitrosative Stress Induced p53-Dependent / Independent Hippocampal Apoptosis: Molecular Basis and Underlying Mechanism. *Toxicological Sciences* 148 (2), 380-399, emfdata.org/de/studien/detail?id=198

Shahin S et al. (2018): 2.45-GHz Microwave Radiation Impairs Hippocampal Learning and Spatial Memory: Involvement of Local Stress Mechanism-Induced Suppression of iGluR/ERK/CREB Signaling. *Toxicological Sciences* 161 (2), 349-374, emfdata.org/de/studien/detail?id=734

Wang B, Lai H (2000): Acute exposure to pulsed 2.450 MHz microwaves affects water-maze performance of rats. *Bioelectromagnetics* 21 (1), 52-56, emfdata.org/de/studien/detail?id=268

Wang J et al. (2017): Mobile Phone Use and The Risk of Headache: A Systematic Review and Metaanalysis of Cross-sectional Studies. *Sci Rep* 2017; 7 (1): 12595, emf-portal.org/de/article/33360

Wilke I (2018): Biological and pathological effects of 2.45 GHz radiation on cells, fertility, brain and behaviour. Review: *umwelt-medizin-gesellschaft* 2018 Feb 31(1), emfdata.org/de/studien/detail?id=439

Yang XS et al. (2012): Exposure to 2.45 GHz electromagnetic fields elicits an HSP-related stress response in rat hippocampus. *Brain Res Bull* 88 (4), 371-378, emfdata.org/de/studien/detail?id=269

Zhu R et al. (2021): Effects of 1.5 and 4.3 GHz microwave radiation on cognitive function and hippocampal tissue structure in Wistar rats. *Scientific Reports*, 11(1), 1-12, emfdata.org/de/studien/detail?id=761

2. Studies on epilepsy

Carballo-Quintas M et al. (2012): A study of neurotoxic biomarkers, c-fos and GFAP after acute exposure to GSM radiation at 900MHz in the picrotoxin model of rat brains. *Neurotoxicology* 2011; 32 (4): 478-494. "Most brain regions, except the piriform cortex, showed significant increases in neuronal activation 24 hours after exposure and picrotoxin administration ... The results indicate a need for further investigation of mobile phone exposure in epileptic patients." (quoted from EMF-Portal) emf-portal.org/de/article/19230

Cinar N et al. (2013): What is the impact of electromagnetic waves on epileptic seizures? *Med Sci Monit Basic Res* 2013; 19: 141-145. "The mean latency to the first seizure was significantly shorter in the 2-hour exposure group than the 12- and 20-hour groups." (quoted from EMF-Portal) emf-portal.org/de/article/22456

Ertilav K et al. (2018): Long Term Exposure to Cell Phone Frequencies (900 and 1800 MHz) Induces Apoptosis, Mitochondrial Oxidative Stress and TRPV1 Channel Activation in the Hippocampus and Dorsal Root Ganglion of Rats. *Metab Brain Dis* 2018; 33 (3): 753-763. emfdata.org/de/studien/detail?id=674

Esmekaya MA et al. (2016): Effects of cell phone radiation on lipid peroxidation, glutathione and nitric oxide levels in mouse brain during epileptic seizure. *J Chem Neuroanat* 2016; 75 Pt B: 111-115. "Brain lipid peroxidation and total nitric oxide were significantly higher in both exposed groups (1 and 2) than the sham group (3) ... The authors conclude that exposing mice to a 900 MHz electromagnetic field could increase oxidative stress in the brain during a seizure." (quoted from EMF-Portal) emf-portal.org/de/article/28763, emfdata.org/de/studien/detail?id=675

Fröhlich F, McCormick DA (2010): Endogenous Electric Fields May Guide Neocortical Network Activity. *Neuron* 2010; 67 (1): 129-143. emf-portal.org/de/article/18507, emfdata.org/de/studien/detail?id=350

Guo Y et al. (2020): Electromagnetic activity: a possible player in epilepsy. *Acta Epileptologica* 2, 9 (2020). emfdata.org/de/studien/detail?id=639, springermedizin.de/electromagnetic-activity-a-possible-player-in-epilepsy/25672908

Kouchaki E et al. (2016): Effect of mobile phone radiation on pentylenetetrazole-induced seizure threshold in mice. *Iran J Basic Med Sci* 2016; 19 (7): 800-803. "Animals chronically exposed to electromagnetic fields (groups 4-6) showed significantly lower threshold doses for tonic and clonic seizures than controls ... The authors conclude that chronic 900-950 MHz GSM exposure could increase seizure risk in mice." (quoted from EMF-Portal) emf-portal.org/de/article/30342, emfdata.org/de/studien/detail?id=14

Lopez-Martin E et al. (2009): The action of pulse-modulated GSM radiation increases regional changes in brain activity and c-Fos expression in cortical and subcortical areas in a rat model of picrotoxin-induced seizure proneness. *J Neurosci Res* 2009; 87 (6): 1484-1499. "Compared with unmodulated signals, 900 MHz GSM exposure increased neuronal excitability in picrotoxin-treated rats, manifested as behavioural changes (seizures), EEG changes and neuronal c-Fos expression." (quoted from EMF-Portal) emf-portal.org/de/article/16675

Maby E et al. (2006): Short-term effects of GSM mobiles phones on spectral components of the human electroencephalogram. *Conf Proc IEEE Eng Med Biol Soc* 2006; 1: 3751-3754. Healthy participants showed a significant fall in EEG across frequency bands, most clearly in alpha waves at occipital electrodes. The opposite occurred in epileptic patients: GSM increased EEG in all bands without local differences. The findings suggest a biological effect of GSM mobile phones on EEG signals. (quoted from EMF-Portal) emf-portal.org/de/article/15056

Vecchio F et al. (2012): Mobile phone emission increases inter-hemispheric functional coupling of electroencephalographic alpha rhythms in epileptic patients. *Int J Psychophysiol* 2012; 84 (2): 164-

171. "Compared with controls, epileptic patients showed statistically significantly greater interhemispheric coherence of temporal and frontal alpha rhythms (approximately 8-12 Hz) during GSM mobile phone exposure than sham exposure" (quoted from EMF-Portal). emf-portal.org/de/article/20245;emfdata.org/de/studien/detail?id=294

3. ElektrosmogReport 2019-2026: studies on the brain, behaviour and learning

Authors / study	Experimental conditions	Findings	Conclusions
Akakin et al. (2021) 'Electromagnetic Waves from Mobile Phones may Affect Rat Brain During Development' ElektrosmogReport 2-2022	Rats exposed daily for 2 h from gestation day 14 to birth to 1800 MHz (1.79 W/kg). After birth: 5 groups of 6 males (control, standby and call mode, each with/without further exposure to day 60).	All exposed groups: nerve cell damage in cortex and hippocampus; increased MDA (oxidative stress marker); significantly reduced GSH (antioxidant) in three groups; neuronal degeneration; increased GFAP. More degenerated axons in trigeminal tissue, with significant changes only after long-term exposure.	Mobile phones affect brain development even in standby mode. 1800 MHz radiation (1.79 W/kg) damages the trigeminal nerve and nerve cells in fetal/postnatal stages. Oxidative stress activates brain astroglia; call mode has stronger effects. Indicates risk to children/adolescents from intensive use; first demonstrated effect on trigeminal ultrastructure. Long-term use may cause greater damage.
Akefe et al. (2023) 'Myrtenal improves memory deficits in mice exposed to radiofrequency-electromagnetic radiation during gestational and neonatal development via enhancing oxido-inflammatory, and neurotransmitter functions' ElektrosmogReport 1-2024	35 male mice exposed in utero and postnatally (days 7-8), 1 h/day at 900 MHz via mobile phone; maximum power 2 W/kg, SAR 1.25 W/kg, maximum power density 145 μ W/cm ² . Four exposed groups: II exposure only; III +100 mg/kg myrtenal; IV +200 mg/kg myrtenal; V +0.5 mg/kg donepezil (Alzheimer's drug).	RF exposure caused memory impairment, anxiety-like behaviour and biochemical cellular damage. Higher-dose myrtenal protected by reducing adverse effects on behaviour, oxidative stress markers and neurotransmitters.	RF exposure during early development can cause cognitive deficits, behavioural changes and oxidative/inflammatory processes in mouse brains. Myrtenal alleviated effects, improving neurotransmitter balance and memory. Myrtenal-containing food is recommended for early mobile radiation exposure.
Alkis et al. (2019) 'Effect of 900-, 1800-, and 2100MHz radiofrequency radiation on DNA and oxidative stress in brain' ElektrosmogReport 1-2019	28 male rats, four groups, exposed 2 h/day for 6 months (900, 1800, 2100 MHz). Whole-body SAR: 0.638, 0.166 and 0.174 W/kg.	2100 MHz group: significantly more DNA single-strand breaks. All exposed groups: higher TOS and OSI, lower TAS, higher MDA and 8-OHdG; increased nitrite at 1800 and 2100 MHz.	Mobile phone radiation appears capable of causing oxidative stress, lipid peroxidation and DNA damage in the frontal lobe, and may be responsible for biological tissue damage.



Authors / study	Experimental conditions	Findings	Conclusions
Aliyari et al. (2024) 'Environmental Effect of High-voltage Towers on the Cerebellum and Cognitive Impairments in the Monkey' ElektrosmogReport 4-2024	Two adult rhesus monkeys (one exposed, one control). Experimental animal exposed 4 h/day for 1 month to a simulated high-voltage field (50/60 Hz, 3 kV/m).	Exposed monkey: poorer learning/memory, increased ACTH, reduced GR expression, cerebellar haemorrhage, marked behavioural changes and about 1 kg weight loss.	High-voltage fields caused significant cognitive, hormonal and behavioural changes. Increased ACTH, GR suppression and poorer performance indicate disturbed cortisol regulation. Cerebellar bleeding suggests tissue damage. High-voltage towers may pose a risk to residents' cognitive functions.
Asl et al. (2020) 'The radio-protective effect of rosmarinic acid against mobile phone and Wi-Fi radiation-induced oxidative stress in the brains of rats' ElektrosmogReport 2-2023	Male Wistar rats exposed 1 h/day for 1 month at 915 MHz (0.98 mW/cm ²) and 2450 MHz (0.79 mW/cm ²); additional rosmarinic acid (20 mg/kg) in saline.	Significant increase in oxidative stress markers after RF exposure at both frequencies. Rosmarinic acid significantly protected against some stress markers at both frequencies.	RF exposure appears to weaken antioxidant protection and increase oxidative stress in rat brains, particularly at 2450 MHz. Rosmarinic acid protected against this, so its consumption is recommended to reduce RF-induced stress responses.
Azimzadeh et al. (2024) 'Maternal linalool treatment protects against radiofrequency wave-induced deteriorations in adolescent rats: A behavioral and electrophysiological study' ElektrosmogReport 1-2026	20 pregnant rats, 4 groups (control, linalool, exposure, exposure+linalool). Prenatal 900 MHz exposure (Nokia 1616 GSM phone), head SAR 1.19 W/kg / whole-body 0.32 W/kg; 1 h 40 min/day for 21 days.	Prenatally exposed offspring: anxiety, poorer learning/memory, reduced neuronal excitability, deficient LTP, disturbed trace element homeostasis. Linalool markedly reduced all effects, nearly normalising them.	Prenatal mobile phone exposure caused persistent neurobehavioural and electrophysiological deficits in both sexes and disturbed trace element homeostasis. Linalool was neuroprotective and restored most parameters.
Bamdad et al. (2019) 'Complications of nonionizing radiofrequency on divided Attention' ElektrosmogReport 1-2020	312 female pupils (14-17 years): 138 non-Wi-Fi users, 174 users (>1 year). Wi-Fi duration and router location recorded; three tests of short-term memory, selective and divided attention.	Wi-Fi group performed significantly worse at multitasking.	Electromagnetic fields from 2.4-2.8 GHz Wi-Fi routers adversely affect female pupils by reducing multitasking ability.
Bodin et al. (2025) 'Altered development in rodent brain cells after 900 MHz radio-frequency exposure' ElektrosmogReport 4-20	Male rats exposed in utero from gestation day 8 to PNT 17 at 900 MHz, SAR 0.08 or 0.4 W/kg (public/occupational limits). n=9 controls; n=8 per exposure group.	Proteomics: 10 altered proteins (synapses/cell growth). Hippocampus: fewer synapses at PNT 8, more inhibitory synapses (both resolved by PNT 17). Cortex: changed synapse ratio, less proliferation (PNT 8), reduced BDNF (PNT 17). No oxidative stress changes. In vitro: increased apoptosis, proliferation, DNA double-strand breaks, altered differentiation.	Even exposure within ICNIRP limits can impair brain development. A shift towards more inhibitory synapses could indicate increased neuronal excitability; such changes are associated with developmental disorders. Developing organisms are sensitive to mobile phone radiation. Authors recommend caution with wireless devices, particularly for pregnant women and toddlers.



Authors / study	Experimental conditions	Findings	Conclusions
Broom et al. (2019) 'Early-Life Exposure to Pulsed LTE Radiofrequency Fields Causes Persistent Changes in Activity and Behavior in C57BL/6J Mice' ElektromogReport 1-2020	Mice exposed from gestation day 13.5 to postnatal day 21 to pulsed LTE radiation (1846 MHz), 30 min/day, 5 days/week; whole-body SAR 0.5 or 1 W/kg. Drinking, movement and feeding observed in home cages from weeks 12-28.	0.5 W/kg: significantly reduced drinking frequency and movement distance. 1 W/kg: significantly increased drinking frequency and movement duration. Effects dose-dependent and detectable long-term.	Repeated low-field exposure to pulsed 1846 MHz mobile radiation (simulated downlink, whole-body SAR 0.5 and 1 W/kg, in utero and shortly after birth) produces persistent, long-lasting after-effects in male mice exposed early in life.
Cakir et al. (2025) 'Radiofrequency regulates the BET-mediated pathways in radial glia differentiation in human cortical development' ElektromogReport 4-2025	Cortical organoids from human stem cells; exposure from patterning day 10, 12 h/day or continuously, to Bluetooth 2.4 GHz, 4 dBm (2.4 mW), field strength 2.5 mW/m ² . Controls in separate incubators.	Bluetooth exposure altered stem cell development, produced autism-like features, more synapses and higher neuronal activity. Shielding or blocking certain gene-regulatory proteins reduced effects.	Bluetooth radiation can impair development of early brain structures. Shielding or blocking certain gene-regulatory proteins markedly reduced effects. These organoids are suitable for studying early environmental effects on human brain development.
Cantiello et al. (2025) 'Differences in brain microtubule electrical activity of the Hippocampus and Neocortex from the Adult Rat' ElektromogReport 2-2026	Adult rat brain tissue (cortex, hippocampus); patch-clamp recordings; Fourier analysis; varied ion concentration (KCl incubation); tested microtubule contribution using paclitaxel (MT stabiliser).	Cortex and hippocampus showed spontaneous electrical oscillations (~38 Hz), dependent on stimulus strength and polarity. KCl altered patterns; paclitaxel markedly suppressed oscillations (almost completely in hippocampus).	Microtubules play a central role in electrical oscillations observed in brain tissue. Marked suppression by paclitaxel shows the cytoskeleton contributes substantially to intracellular electrical signals.
Chen et al. (2021) '1800 MHz Radiofrequency Electromagnetic Field Impairs Neurite Outgrowth Through In-hibiting EPHA5 Signaling' ElektromogReport 2-2021	Embryonic neural stem cells and Neuro-2A cells exposed in vitro to 1800 MHz GSM (SAR 4 W/kg); RNA sequencing and pathway analysis.	Altered gene expression in neurite formation, reduced EPHA5 expression, affected CREB/RhoA pathway, reduced neurite length and branching.	RF radiation appears to inhibit neurite (dendrite and axon) growth by disrupting EPHA5-mediated signalling.
Cui et al. (2026) 'Involvement of the Primary Auditory Cortex-Basolateral Amygdala Circuit in Altered Conditioned Fear Memory Retrieval Following Electromagnetic Field Exposure in Mice' ElektromogReport 2-2026	10-week-old mice exposed for 7 days to 9.375 GHz (2.58 W/kg) and/or a 100 mT magnetic field; control group unexposed.	Combined exposure only: measurable fear memory disturbances, marked cellular damage in involved brain areas, weakened signalling between auditory processing and emotional centre, reduced neuronal activity during fear response.	Reduced activity and cellular damage in the involved nerve cells appear to cause the behavioural changes. Effects occur without hearing impairment and directly involve central circuits for anxiety and fear responses.



Authors / study	Experimental conditions	Findings	Conclusions
Dasgupta et al. (2022) 'Transcriptomic and Long-Term Behavioral Deficits Associated with Developmental 3.5 GHz Radiofrequency Radiation Exposures in Zebrafish' ElektrosmogReport 3-2022	Zebrafish embryos exposed 6-48 h after fertilisation to 3.5 GHz (SAR 8.27 W/kg).	Disturbed carbon and amino acid metabolism; significant behavioural changes in adults (e.g. predator avoidance, social behaviour).	RF radiation could affect zebrafish social and anxiety behaviour, possibly from brief exposure three months earlier. Evidence of molecular changes in nucleic acid synthesis and metabolism and potentially impaired neural development.
DastAmooz et al. (2023) 'A primary study on rat fetal development and brain-derived neurotrophic factor levels under the control of electromagnetic fields' ElektrosmogReport 3-2026	Pregnant Wistar rats exposed throughout gestation for 20 days, 6 h/day, to 2.4 GHz Wi-Fi (modem 1 m away). Controls in a shielded room.	Exposed offspring had longer bodies/tails at birth but shorter tails on days 21 and 56. Body weight on day 56 about 10% lower (not significant). BDNF significantly reduced on day 56 (-4%).	Prenatal Wi-Fi exposure was associated with growth changes and a small BDNF decrease. Limitations: small sample, short exposure duration and no hormone measurements.
Delen et al. (2021) 'Effects of 2600 MHz Radiofrequency Radiation in Brain Tissue of Male Wistar Rats and Neuroprotective Effects of Melatonin' ElektrosmogReport 2-2021	Male rats (6 groups), 2600 MHz exposure 30 min/day for 30 days, with/without melatonin (10 mg/kg/day), under defined SAR conditions (e.g. brain 0.44 W/kg).	Reduced antioxidant enzymes, increased oxidative markers and apoptosis, especially in hippocampus; cellular changes, dilated brain vessels. Control/melatonin groups largely normal. Melatonin markedly reduced oxidative damage and apoptosis. Immunohistochemistry confirmed neuronal/glial damage from radiation.	Findings suggest possible risk of neurodegenerative disease and brain tumours. Reduced exposure and melatonin protection are recommended.
Echchgadda et al. (2022) 'Changes in the excitability of primary hippocampal neurons following exposure to 3.0 GHz radiofrequency electromagnetic fields' ElektrosmogReport 3-2022	Embryonic rat hippocampal cells exposed for 60 min at 3.0 GHz, low dose (~0.3 W/kg, maximum ~0.7 W/kg).	Significantly reduced action potential amplitude; greater resting potential depolarisation and neuronal excitability; lower action potential threshold; sharp increase in spontaneous action potentials; increased intracellular Ca^{2+} and synaptic activity. 3.0 GHz potentiates excitatory/inhibitory postsynaptic currents. RF exposure increases neuronal excitability and synaptic plasticity.	Findings suggest potentially altered brain function. Effects on hippocampal excitability, calcium and synaptic transmission show that more research is needed to understand EMF mechanisms.



Authors / study	Experimental conditions	Findings	Conclusions
Farashi et al. (2022) 'Mobile phone electromagnetic radiation and the risk of headache: a systematic review and meta-analysis' ElektrosmogReport 1-2025	PRISMA systematic review (search: 1990-February 2021; 33 studies). Web of Science, PubMed and Scopus searched for digital mobile phone studies across all ages/headache types; no exposure duration limit.	Phone/base station EMF associated with headache in many studies (25 significant). Pooled OR=1.30: significant association, especially exposure > 100 min/week (OR=1.41). Age had no relevant influence; duration was decisive. Base station effect smaller, non-significant (OR=1.14).	The pooled effect indicates a significant association of mobile phone use with headache prevalence, regardless of age. Phone users also appear to have higher headache risk than people living near base stations.
Gao et al. (2023) 'Electromagnetic pulse induced blood-brain barrier breakdown through tight junction opening in rats' ElektrosmogReport 1-2024	Adult male rats exposed at 50, 100, 200 and 400 kV/m. EMP parameters: 200 pulses, pulse width $\tau=200$ ns, repetition rate 1.0 Hz.	BBB permeability depended on field strength. Microscopy: widened tight junctions, basement membrane changes, swollen astrocyte endfeet. Relevant TJ protein expression tended to decrease at high intensity.	EMP can increase rats' BBB permeability depending on field strength and molecular size. Smaller molecules pass at lower intensity. Although TJ protein expression did not change significantly, functional disturbances of cell junctions may matter. Initial evidence of a mechanistic link between EMP and BBB disruption.
Gökçek-Saraç et al. (2021) 'Possible effects of different doses of 2.1 GHz electromagnetic radiation on learning, and hippocampal levels of cholinergic biomarkers in Wistar rats' ElektrosmogReport 2-2022	Male rats exposed at 45 or 65 V/m for one week to 2.1 MHz (217 Hz modulation) via signal generator, 2 h/day.	Significant reductions in behavioural tests at 65 V/m; reduced ChAT, AChE, VACHT and their hippocampal mRNA expression.	Mobile radiation impairs hippocampal activity, morphology and behaviour in animals. Learning/memory measurably impaired after exposure; hippocampal cholinergic system central to cognition. First evidence of dose-dependent effects of short 2.1 GHz exposure on behaviour and cholinergic biomarkers (AChE, ChAT, VACHT + mRNA).
Guo et al. (2020) 'Electromagnetic activity: a possible player in epilepsy' ElektrosmogReport 2-2022	Systematic review based on PubMed, Medline and EMBASE literature searches.	Geomagnetic storms increase seizure susceptibility in animals; human effects unclear. rTMS can trigger/reduce seizures (up to 50%). EEG/Schumann frequency overlap (8-13 Hz) stabilises brain activity. Epileptic patients show greater alpha coherence after GSM than healthy people, indicating greater neuronal synchronisation/sensitivity.	Whether electromagnetic activity affects human epilepsy or seizure thresholds requires research; data are sparse. Despite initial positive rTMS findings, rigorous studies are needed to establish safety and long-term effects.



Authors / study	Experimental conditions	Findings	Conclusions
Hasan et al. (2022) 'Effect of 2400 MHz mobile phone radiation exposure on the behavior and hippocampus morphology in Swiss mouse model' ElektrosmogReport 1-2022	30 mice in 3 groups; 2400 MHz for 60 days (40/60 min/day, SAR 2.7 W/kg). Free movement, no other devices; Huawei phone radiation continuously monitored.	Significantly greater anxiety in exposed mice (especially 60 min/day); drastic hippocampal/dentate gyrus cell loss, degenerative changes, fewer viable pyramidal/granule cells. More dark, degenerated cells with longer exposure: evidence of neurodegeneration.	2400 MHz exposure caused markedly greater anxiety and damaged hippocampal cells (especially CA1-CA3, dentate gyrus), particularly pyramidal and granule cells. Possible long-term cognitive impairment.
He et al. (2024) 'The role of digital device use on the risk of migraine: a univariable and multivariable Mendelian randomization study' ElektrosmogReport 3-2022	Genetic, health and self-report data from >380,000 UK Biobank participants on digital device use (phone, TV, computer, games), compared with migraine data from FinnGen and IHGC. Univariate/multivariate Mendelian randomisation examined causality, accounting for potential confounders such as sleep, blood pressure and depression.	Phone use and TV viewing significantly associated with migraine overall and without aura (MO). No association with migraine with aura (MA). Computer use/gaming tended to be negatively associated with MO. Three phone-related SNPs involved genes with known functions (PHLPP2, ARPP21, FOXP2).	Observational studies suggest a link between excessive electronic device use and migraine; a meta-analysis confirmed a positive phone-use association. Possible causes include blue light (TV) and EM radiation (phones), enhancing visual stimuli, disrupting sleep and affecting the nervous system. Oxidative stress and neurotransmitter disturbances may contribute. Mechanisms are complex and need further research.
Hinrikus et al. (2021) 'Threshold of radiofrequency electromagnetic field effect on human brain' ElektrosmogReport 1-2022	Review of 76 high-quality studies (2007-2021) on RF-EMF and brain activity (e.g. EEG, PET), EMF-Portal database.	76.7% of resting EEG studies showed effects, mainly alpha, sometimes beta/gamma/theta. 41.7% of sleep EEG studies showed effects. PET: changed glucose metabolism near antenna. Higher SAR produced stronger EEG changes; effects from 2.45 V/m.	Many studies showed EEG changes after RF-EMF (especially alpha/beta/gamma and increased complexity), resembling depression patterns. Only some people were sensitive (13-31%). Cognition unaffected, but EEG changes frequent. Lowest effective field: 2.45 V/m, typical of phone/Wi-Fi use.



Authors / study	Experimental conditions	Findings	Conclusions
Hinrikus et al. (2022) 'Possible health effects on the human brain by various generations of mobile telecommunication: a review-based estimation of 5G impact' ElektrosmogReport 4-2022	Review of 73 experimental studies from the past 15 years (EMF-Portal), examining mechanisms/ influences; categories: EEG, sleep, cognition, brain metabolism.	Few quantitative studies; many observational effects. Higher modulation frequency tended to reduce effects. Suspected cause: dielectric polarisation by external fields. Thermal effects at high intensity, non-thermal at low intensity. Water molecule orientation polarisation decreases with frequency. Theoretical effective brain frequencies: 14-40 Hz; no effects observed at ≥ 1000 Hz.	Many studies concern 2G/3G/4G RF-EMF (450-2500 MHz), but few data cover 5G or >2500 MHz. No consistent effects by generation. Below 10 GHz, 5G is expected to differ little from earlier standards; reduced penetration at higher frequencies may weaken effects. Above 10 GHz, experimental/theoretical foundations are lacking, making future risks difficult to estimate and research urgent.
Hu et al. (2021) 'Effects of Radiofrequency Electromagnetic Radiation on Neurotransmitters in the Brain' ElektrosmogReport 4-2022	40 PubMed experimental RF studies analysed: 21 on short-term and 19 on long-term neurotransmitter effects.	RF affects multiple neurotransmitters (dopamine, serotonin, GABA, acetylcholine), with short- and long-term exposure. Metabolic disturbances, receptor changes, cognitive deficits. Possible mechanisms: electrical brain activity, Ca^{2+} balance, apoptosis, membrane changes.	Assessment is difficult because studies are inconsistent and neurotransmitters act in closely linked ways. RF-induced increases in intracellular calcium and ROS may disrupt cellular functions and cause neurotransmitter imbalance.
Iranfar et al. (2025) 'Modulation of brain functional connectivity in healthy young adults following GSM radiofrequency exposure: A magnetoencephalography and magnetic resonance imaging study' ElektrosmogReport 1-2026	32 healthy adults in two sessions, each exposed 25 min to 900 MHz GSM (0.7 W/kg) or a sham device at the left ear. MEG before/ after exposure.	Exposure significantly altered cooperation between right-hemisphere regions. Three connections had reduced synchronisation, mainly in alpha frequencies (rest, attention, sensory processing).	Authors suggest radiation may affect neuronal activity in the ear, since auditory processing is largely contralateral (opposite the phone held at the left ear).
Jing et al. (2024) 'Multi-frequency electromagnetic radiation induces anxiety in mice via inflammation in the cerebral cortex' ElektrosmogReport 3-2024	Male mice exposed 2 h/day (40 min/frequency) for 4 weeks to 0.9/1.5/2.65 GHz RF-EMF, whole-body SAR 4.0 W/kg.	Significantly greater anxiety-like behaviour; markedly reduced GABA, dopamine, serotonin; more inflammatory cells and increased proinflammatory marker expression.	Multifrequency RF exposure caused anxiety-like reactions, probably through neurotransmitter homeostasis disturbances and inflammation via CREB-BDNF-TrkB. Proinflammatory signals increased, anti-inflammatory signals decreased, causing mild but significant cerebral cortex inflammation.



Authors / study	Experimental conditions	Findings	Conclusions
Karimi et al. (2018) '2.45 GHz microwave radiation impairs learning, memory, and hippocampal synaptic plasticity in the rat' ElektromogReport 1-2019	11 rats exposed to 2.45 GHz Wi-Fi radiation, 2 h/day for 40 days.	Microwaves caused learning and spatial memory deficits. Electrophysiology showed reduced excitability of hippocampal CA1 pyramidal neurons after exposure.	2.45 GHz Wi-Fi microwaves impair rats' spatial memory and learning. Possible cause: reduced hippocampal pyramidal neuron excitability and adverse effects on long-term neuronal plasticity.
Khayat et al. (2023) 'Effects of prenatal mobile phone radiation exposure on MMP9 expression: Implications for inflammation, oxidative stress, and sensory-motor impairment after neonatal hypoxia-ischemia in rats' ElektromogReport 1-2026	Pregnant Wistar rats exposed to 900 MHz mobile radiation during gestation. Male offspring tested after birth in four groups: sham, EXP, HI, HI/EXP.	Combined HI/exposure caused significantly larger infarcts, greater oedema, worse sensorimotor performance and molecular marker values (except MMP-2) than HI alone.	Prenatal mobile exposure worsens prognosis in hypoxia-ischaemia. It alters MMP expression, probably increasing MMP-9 activity and weakening the BBB. This promotes inflammation, oxidative stress and immune cell infiltration, worsening cerebral oedema and ischaemic damage.
Kim et al. (2016) 'Long-term exposure to 835 MHz RF-EMF induces hyperactivity, autophagy and demyelination in the cortical neurons of mice' ElektromogReport 3-2019	12 male mice (6 weeks old), 835 MHz exposure 5 h/day for 12 weeks; whole-body SAR 4.0 W/kg.	Evidence of hyperactivity; upregulated autophagy genes/proteins, autophagosomes and autolysosomes in cortical neurons. Cortex damage despite absent apoptosis; damaged myelin sheaths with frayed lamellae and atypical protrusions.	Autophagy appears to protect against radiation-induced cellular stress, preventing possible cell death. RF-EMF also damaged the myelin sheath, which is associated with multiple sclerosis.
Kim et al. (2021) 'Exposure to RF-EMF alters postsynaptic structure and hinders neurite outgrowth in developing hippocampal neurons of early postnatal mice' ElektromogReport 3-2021	In vivo: newborn mice exposed 28 days to 1850 MHz, 4 W/kg, 5 h/day; hippocampal analysis. In vitro: hippocampal neurons exposed 9 days to 1760 MHz, 4 W/kg.	In vivo: fewer dendritic/mushroom spines, reduced AMPA/NMDA receptors and BDNF. In vitro: reduced somatic PSD95, glutamate receptors and BDNF; shortened/branched dendrites; constant cell body size.	RF exposure during early brain development can disrupt hippocampal synapse formation through fewer dendritic spines, glutamate receptors and reduced BDNF. This could impair memory.
Kim et al. (2024) 'Exposure to Radiofrequency In-duces Synaptic Dysfunction in Cortical Neurons Causing Learning and Memory Alteration in Early Postnatal Mice' ElektromogReport 4-2024	Newborn mice exposed continuously to unmodulated 1850 MHz RF waves from day 1 after birth, 5 h/day for 4 weeks; whole-body SAR 4 W/kg.	Significantly fewer dendritic spines and restricted dendrite/neurite development. Markedly reduced synapse-related gene and CDK5 developmental protein expression in prefrontal cortex -> significantly impaired spatial learning/memory.	Findings suggest potential harm regarding neurodevelopmental disorders such as autism spectrum disorder.



Authors / study	Experimental conditions	Findings	Conclusions
Kim et al. (2026) 'Electromagnetic field-inducible in vivo gene switch for remote spatiotemporal control of gene expression' ElektrosmogReport 2-2026	Murine brain cells and transgenic mice exposed to ELF-EMF (2.0 mT; 60 Hz); exposure duration unspecified.	EMF precisely activated the gene switch with spatial/ temporal control. Cyb5b acts as EMF sensor; rhythmic Ca^{2+} oscillations activate the EMF-inducible element. In vivo: targeted induction of OSK for partial rejuvenation, mutant APP for Alzheimer's modelling, Tph2 for restoring serotonin activity.	First molecularly verified mechanism by which EMF trigger specific gene expression changes. Cyb5b and voltage-gated calcium channels mediate responses through characteristic calcium oscillations, a biological frequency code. Low-frequency EMF can alter gene expression, refuting the thermal dogma. Evidence suggests existing exposure limit models are inadequate and need revision.
Kizilçay et al. (2024) 'Effects of 1800 MHz and 2100 MHz mobile phone radiation on the blood-brain barrier of New Zealand rabbits' ElektrosmogReport 1-2025	Female rabbits in metal cages for 38 min to minimise external interference; single RF exposure to 1800 or 2100 MHz GSM at 15 dBm.	Increased BBB permeability. Both frequency groups showed increased brain Evans blue concentrations, significant at 2100 MHz. Marked left/right brain absorption difference at 620 nm.	A single non-thermal exposure at RF intensity about tenfold below the "normal value" increased BBB permeability at 2100 MHz. This could favour neurological diseases including Alzheimer's, stroke and multiple sclerosis.
Kumar et al. (2020) 'Effect of mobile phone signal radiation on epigenetic modulation in the hippocampus of Wistar rat' ElektrosmogReport 3/4-2020	Male Wistar rats exposed for 1, 3 or 6 months at 900, 1800 and 2450 MHz.	Frequency/time-dependent increased EHMT1 expression and histone methylation, reduced DNMT1 expression and DNA cytosine methylation. Strongest changes at 2450 MHz after 6 months.	Findings may indicate impaired brain performance and help assess mobile radiation health risks and establish policy guidelines.
Lai et al. (2023) 'Hippocampal ferroptosis is in-volved in learning and memory impairment in rats induced by microwave and electromagnetic pulse combined exposure' ElektrosmogReport 4-2023	197 rats, 4 groups; 15 min whole-body exposure to microwaves (MW, 1.5 GHz, 30 mW/cm ²) and/or EMP (400 ±25 kV/m).	Temperature rose with MW and MW+EMP. Behaviour changed after 6 h with MW+EMP, from day 1 in all groups. EEG alpha reduced on day 1 in all groups. Hippocampal micro/ ultrastructure damage, especially MW+EMP. Combined exposure had strongest biological effects overall.	MW and EMP separately or together can damage hippocampal cells and impair learning/ memory; combined exposure causes greater damage. Hippocampal ferroptosis may be a general oxidative-stress mechanism impairing learning and memory.



Authors / study	Experimental conditions	Findings	Conclusions
Lameth et al. (2017) 'Acute Neuroinflammation Promotes Cell Responses to 1800 MHz GSM Electromagnetic Fields in the Rat Cerebral Cortex' ElektrosmogReport 2-2019	Young/adult male rats examined for inflammation after LPS injection and/or single 1800 MHz exposure; gene expression/ inflammatory markers analysed after 24 h.	Radiation reduces inflammatory markers [...] reduced AMPA receptor phosphorylation.	Single GSM1800 MHz exposure (2.9 W/kg) temporarily alters inflammatory brain gene activity and activates microglia, affecting neuronal signalling.
Lameth et al. (2025) 'Repeated Head Exposures to a 5G-3.5 GHz Signal Do Not Alter Behavior but Modify Intracortical Gene Expression in Adult Male Mice'	Adult male C57BL/6 mice exposed to 5G 3.5 GHz, 1 h/day, 5 days/week for 6 weeks (dipole antenna 5 mm from head). Asymmetric exposure: SAR right 0.43 W/kg, left 0.14 W/kg, whole brain 0.19 W/kg.	Significant cortical gene changes: right 77 DEGs, left 84 (<1% of genes). Marked right-side mitochondrial OXPHOS upregulation; glutamatergic synapse gene enrichment on both sides.	Chronic 5G exposure changes intracortical gene expression, particularly glutamatergic transmission and mitochondrial energy genes, without measurable behavioural/memory effects. Gene response is not linear with SAR, indicating biological activity despite non-thermal exposure.
Laván et al. (2025) 'Review of the evidence on the influence of Wi-Fi 2.4 GHz radiation on oxidative stress and its possible relationship with Alzheimer's disease' ElektrosmogReport 4-2025	PRISMA systematic search on 2.4 GHz EMF and gene expression, oxidative stress, DNA repair, metabolism and Alzheimer's-associated genes.	49 studies show 2.4 GHz Wi-Fi influences genes important to DNA replication/repair, metabolism and cellular homeostasis, affecting processes linked to oxidative stress and Alzheimer's mechanisms.	Oxidative stress may amplify Alzheimer's-related gene changes. Given its central role in neuronal damage, a possible indirect relationship is research-relevant and needs further investigation.
Li et al. (2021) '1800 MHz Radiofrequency Electromagnetic Irradiation Impairs Neurite Outgrowth With a Decrease in Rap1-GTP in Primary Mouse Hippocampal Neurons and Neuro2a Cells' ElektrosmogReport 1-2022	Double-blind in vitro study in primary mouse neurons/ Neuro2a; 1800 MHz GSM (SAR 4 W/kg), up to 48 h in 5/10 min intervals. Cell survival, neurite growth, protein expression/activity examined.	Cell survival unaffected. Neurite growth markedly reduced after 48 h. Rap1 expression unchanged, active Rap1-GTP reduced; p-MEK1/2 reduced. Rap1 overexpression prevented growth impairment.	1800 MHz RF can disrupt neurite growth, probably by reducing Rap1 pathway activation. Restoration by active Rap1 suggests its key role. Potential developmental disorders in children are particularly concerning; effects on immature brains merit attention.



Authors / study	Experimental conditions	Findings	Conclusions
Mevisen et al. (2021) 'Is there evidence of increased oxidative stress from electromagnetic fields?' ElektrosmogReport 1-2021	About 150 experimental animal/cell studies (2010-2020) analysed, low/ RF EMF (50 Hz-2.5 GHz). Focus: oxidative stress, DNA damage, calcium influx and nervous/ reproductive/immune impairments, even below current limits.	Oxidative stress, increased ROS, DNA damage and nervous/immune/ reproductive dysfunction, sometimes at weak fields and below limits.	Most animal studies and over half of cell studies indicate increased oxidative stress from RF-EMF and LF-MF. Very young, elderly and already vulnerable people (immune deficiency, diabetes, neurodegenerative disease) may experience greater harm.
Narayanan et al. (2019) 'Radiofrequency electromagnetic radiation-induced behavioral changes and their possible basis' ElektrosmogReport 1-2020	73 studies analysed: behavioural, histological and biochemical investigations in rats/mice involving RF electromagnetic radiation.	92%: altered anxiety. 80%: reduced movement after exposure. 96%: effects on brain regions (e.g. hippocampus, amygdala), neuronal degeneration/loss, apoptosis, nuclear deformation. 67%: glial impairment. 100%: neurotransmitter effects (e.g. thalamic imbalance).	Combined effects in brain regions may cause behavioural changes. Mechanisms: increased ROS/membrane damage; ROS-induced DNA breaks -> apoptosis; calcium imbalance -> dendritic remodelling/cell death; inflammation -> necrosis; altered glial physiology; neurotransmitter imbalance.
Narayanan et al. (2025) 'Possible effects of radiofrequency electromagnetic radiation on contextual fear conditioning, hippocampal perivascular space, apoptosis and adrenal gland microarchitecture in rats' ElektrosmogReport 2-2025	Rats exposed to 900 MHz GSM, 1 h/day for 4 weeks; SAR 1.15 W/kg.	Hyperactivity/anxiety-like behaviour; significantly impaired memory; enlarged hippocampal perivascular spaces; apoptosis trends in CA3; zona fasciculata histological changes.	Chronic non-thermal mobile exposure significantly altered fear memory, accompanied by structural changes in hippocampus and adrenal cortex.
Nilsson, Hardell (2026) 'Increasing numbers of persons with sleeping problems in Sweden' ElektrosmogReport 2-2026	Swedish patient register 2001-2024, outpatient principal diagnoses G47 (organic sleep disorders), F51 (non-organic); five age cohorts per 100,000 population.	G47 sharply increased at all ages, most among 5-19-year-olds (17-fold). Also marked increases in toddlers, young/ older adults and seniors. Rise accelerated after 2009. F51 unchanged.	Authors identify a population-wide rise in diagnosed sleep disorders coinciding with expanded mobile infrastructure/device use. Possible causes: mobile radiation effects on brain activity and melatonin suppression by screen blue light. Increased reporting does not explain the rise; further studies requested.



Authors / study	Experimental conditions	Findings	Conclusions
Othmann et al. (2021) 'Exposure to 2.45 GHz radiation triggers changes in HSP-70, Glucocorticoid Receptors and GFAP biomarkers in rat brain' ElektrosmogReport 3-2021	Female rats, 3 groups. A/B: single 30 min exposure at 2.45 GHz, sacrificed 90 min (A) or 24 h (B) later. C: 30 min on 10 weekdays, sacrificed 90 min after final exposure. SAR 0.04-0.08 W/kg; thermal effects excluded.	Group C: significantly increased HSP-70/GCR in limbic cortex; GFAP significantly reduced there and in hippocampus/hypothalamus. A/B: non-significant or reduced values.	Repeated 2.45 GHz RF exposure probably dysregulates HSP-70 and GCR, potentially causing chronic stress that weakens anti-inflammatory responses without stimulating glial division.
Popovičová et al. (2024) 'Effect of microwave radiation on adult neurogenesis and behavior of prenatally exposed rats' ElektrosmogReport 2-2025	Pregnant dams exposed to pulsed 2.45 GHz EMF, 2 h/day during gestation; SAR 1.73 W/kg.	Juveniles: increased proliferation/cell death, fewer nitrergic neurons with delayed maturation. Adults: reduced proliferation, increased RMS cell death, fewer nitrergic neurons, reduced anxiety/increased activity.	Prenatal Wi-Fi can cause lasting postnatal neurogenesis disturbances: biphasic cell division, persistent RMS cell death and behavioural changes correlated with neurogenesis. Parallels to ADHD-like behaviour; relevant given ubiquitous RF exposure.
Qin et al. (2022) 'Effects of radiofrequency field from 5G communications on the spatial memory and emotionality in mice' ElektrosmogReport 4-2022	Adult mice exposed 1 h/day for 21 days at 4.9 GHz, 50 W/m ² .	Greater tail-suspension immobility -> depressive behaviour. Significantly increased blood NSE/S100B -> neuronal damage. Amygdala structural damage/fewer neurons; clear evidence of pyroptosis.	5G caused no anxiety or memory deficits but clear depression-like tail-suspension behaviour. Tissue analysis showed amygdala neuronal loss and pyroptosis, probably linking emotional changes to altered amygdala neurons.
Sharma & Shukla (2020) 'Effect of Electromagnetic Radiation on Redox Status, Acetylcholine Esterase Activity and Cellular Damage Contributing to the Diminution of the Brain Working Memory in Rats' ElektrosmogReport 4-2022	Wistar rats exposed 1-4 h/day for 90 days: 900 MHz, brain SAR 0.231 W/kg; power density 7.737 μ W/m ² .	Significantly impaired working memory (dose-dependent), hippocampal oxidative stress, reduced redox enzyme/acetylcholinesterase activity, DNA strand breaks and neuronal degeneration. Clear dose-response in all parameters.	RF causes oxidative stress, reduced acetylcholinesterase and hippocampal neuronal degeneration in animals, leading to impaired memory.



Authors / study	Experimental conditions	Findings	Conclusions
Singh et al. (2020) 'Effect of mobile phone radiation on oxidative stress, inflammatory response, and contextual fear memory in Wistar rat' ElektromogReport 2-2020	6-week-old Wistar rats exposed via 3G phone (1915 MHz, 4.0 mW/cm ² , SAR 0.36 W/kg).	Hippocampus: increased ROS/oxidised lipids and proteins, reduced antioxidant capacity. Significantly higher serum proinflammatory cytokines, ACTH/CORT; adrenal cortex hypertrophy. Fear memory unaffected.	Mobile radiation can trigger oxidative stress, immune responses and HPA axis dysregulation (hypothalamic-pituitary-adrenal). Despite increased cytokines/stress hormones, fear memory remained unchanged, probably through compensation/adaptation.
Singh et al. (2021) 'A novel pilot study of automatic identification of EMF radiation effect on brain using computer vision and machine learning' ElektromogReport 2-2021	Drosophila exposed for 5 days, 12 h/day, via 2400 MHz horn antenna (29 mW/m ²). Brains imaged microscopically and assessed by computer vision.	Significant brain structure changes, especially shape (eccentricity) and area uniformity (Euler number). Evidence of morphological damage, internal tissue changes and consistent measurable EMF effects on brain tissue.	Pilot study shows EMF can cause measurable morphological changes in Drosophila brains. Automated imaging identified shape changes and greater brain "porosity", both indicating structural damage.
Singh et al. (2023) 'Acute radiofrequency electromagnetic radiation exposure impairs neurogenesis and causes neuronal DNA damage in the young rat brain' ElektromogReport 3-2023	26 male Wistar rats (5 weeks), single 8 h exposure to pulse-modulated 2115 MHz RF; head SAR 1.51 W/kg.	Significantly increased free radicals/DNA damage in cortex and hippocampus; significantly reduced dentate gyrus cell division and increased DG neuronal degeneration.	Animal study suggests potentially harmful brain effects, with limited transferability to humans. After validation, findings may provide a basis for human protective measures.
Sousouri et al. (2025) '5G Radio-Frequency-Electromagnetic-Field Effects on the Human Sleep Electroencephalogram: A Randomized Controlled Study in CACNA1C Genotyped Healthy Volunteers' ElektromogReport 1-2025	Healthy adults exposed on 3 nights for 30 min before sleep to standardised 5G EMF at 700 MHz/3.6 GHz, plus sham. 12.5 Hz amplitude modulation, SAR ≤2 W/kg; double-blind crossover; overnight hd-EEG.	3.6 GHz shifted sleep spindle centre frequency upward in T/C genotypes across a large EEG cluster (50/109 channels). 700 MHz also slightly shifted frequency. Effects genotype-dependent; behaviour/sleep stages unchanged.	5G altered spindle peak components in NREM sleep EEG, especially at 3.6 GHz and T/C genotypes. Authors suggest L-type calcium channel involvement and possible circadian RF-EMF influence. SAR distribution/EEG discrepancy unexplained.
Sun et al. (2025) 'Brain Disease-Modifying Effects of Radiofrequency as a Non-Contact Neuronal Stimulation Technology' ElektromogReport 2-2025	Narrative review of RF-EMF brain effects, 2000-2025, including animal/human studies (e.g. Alzheimer's models).	81% of studies showed effects; 88% at SAR ≤2 W/kg. Both positive (improved cognition) and negative (oxidative stress, EEG disturbances) effects documented.	RF exposure may provide neurostimulation and influence various brain activities.



Authors / study	Experimental conditions	Findings	Conclusions
Tan et al. (2022) 'Changes in the histopathology and in the proteins related to the MAPK pathway in the brains of rats exposed to pre and postnatal radiofrequency radiation over four generations' ElektrosmogReport 1-2024	Rats exposed to continuous 2.45 GHz RF, 12 h/day; adult brain SAR 0.118 W/kg. Four groups: males only, females only, both exposed, control. Four generations exposed, starting before fertilisation.	Severe histopathology (haemorrhage, cell misalignment) in female fetuses/adults; vascular changes; activated MAPK (mitogen-activated protein kinase) pathway; increased concentrations of some phosphorylated proteins.	Continuous 2.45 GHz significantly altered key MAPK pathway components in rats. This pathway participates in learning/memory. Exposure also alters an Alzheimer's pathological feature. Brain tissue histopathology was observed.
Tarsaei et al. (2022) 'Effects of 2.45 GHz Non-Ionizing Radiation on Anxiety-Like Behavior, Gene Expression, and Corticosterone Level in Male Rats' ElektrosmogReport 4-2023	56 male Wistar rats exposed 1 h/day for 7 (short-term) or 30 days (long-term) to pulsed 2.45 GHz RF, 4 mW/cm ² .	Significantly reduced weight after short/long exposure; greater anxiety after short exposure; inconsistent open-field changes; significantly increased corticosterone after short exposure.	2.45 GHz RF induced molecular stress responses and behavioural changes. It may act as an external stimulus altering stress-related gene activation and triggering hippocampal anxiety responses in rats.
Tohidi et al. (2020) 'Long-term exposure to electromagnetic radiation from mobile phones can cause considerable changes in the balance of Bax/Bcl2 mRNA expression in the hippocampus of mice' ElektrosmogReport 3/4-2020	48 male mice, 6 groups, exposed 0.5-4 h/day for 30 days to 900/1800 MHz.	Bax increased in all groups, highest after 2 h. Bcl2 significantly reduced at 2×4 h. Bax/Bcl2 ratio increased with duration, highest at 2×4 h/day.	Mobile radiation can substantially alter the balance of mRNA expression of apoptosis genes Bax and Bcl2 in male mouse hippocampus.
Torkan et al. (2025) 'Effects of Mobile Electromagnetic Exposure on Brain Oscillations and Cortical Excitability: Scoping Review' ElektrosmogReport 3-2025	Scoping review: MEDLINE, PubMed, Web of Science, Scopus, English primary studies in healthy adults; quantitative EEG/TMS only. Characterised frequency (0.45-3.5 GHz), power/SAR, duration/design. 80 studies (78 EEG, 2 TMS), PRISMA evaluation.	Significant brain wave changes in 22/33 eyes-open and 35/48 eyes-closed EEG studies. Heterogeneous changes, more amplitude increases than decreases, especially alpha/beta. Both TMS studies: significantly altered excitability.	Mobile radiation may modulate neuronal oscillations/cortical excitability. Major gaps: current risk assessment, non-thermal effects, 5G millimetre waves. Limitations: very few TMS studies, diverse EEG parameters, absent effect sizes, imprecise participant profiles. More 5G studies (especially mm waves), better participant differentiation and standardised parameters recommended.

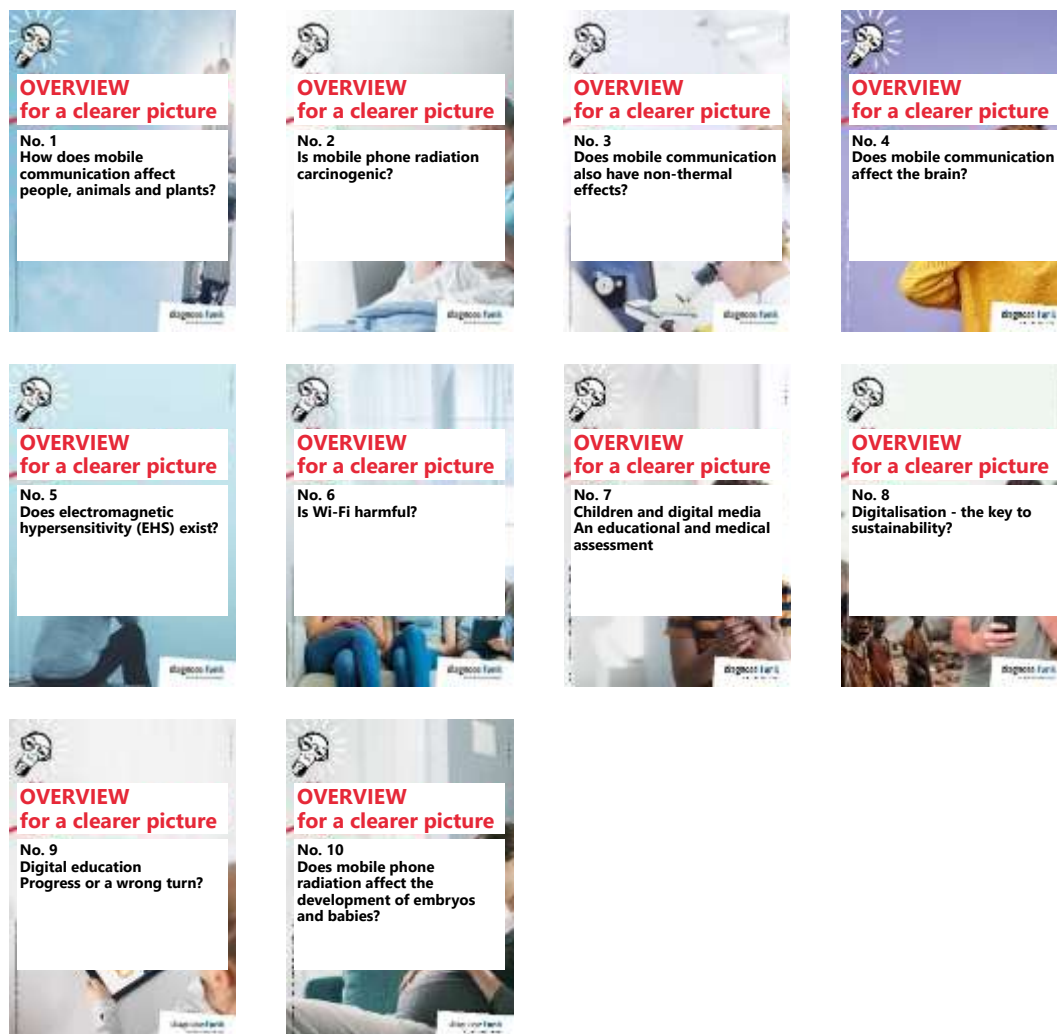


Authors / study	Experimental conditions	Findings	Conclusions
Ullrich et al. (2021) 'Electromagnetic Fields and Calcium Signaling by the Voltage Dependent Anion Channel' ElektrosmogReport 4-2021	Literature search on calcium/voltage-dependent ion channels in biological EMF effects, plus additional mechanisms.	EMF can switch VDAC into Ca^{2+} pores, even in erythrocytes, causing calcium influx, shape changes and cell-death signals. With EMF-sensitive TSPO, VDAC/TSPO may act as biological EMF sensors. Pulsed EMF (5-100 Hz) especially bioactive, possibly explaining psychological symptoms in sensitive people.	EMF may act through VDAC; TSPO may serve as magnetosensor. VDAC/TSPO may detect EMF and influence neural processes. Hypothesis requires experimental testing.
Wang et al. (2022) 'The dose-dependent effect of 1.5-GHz microwave exposure on spatial memory and the NMDAR pathway in Wistar rats' ElektrosmogReport 1-2023	Male Wistar rats exposed to 1.5 GHz (L band) for 6 min at 5, 30, 50 mW/cm ² (SAR 1.85/11.1/18.5 W/kg).	Significant behavioural changes/EEG suppression; dose-dependent hippocampal damage (onset 6 h, peak 7 days, recovery 14 days). Ultrastructure also dose-dependently damaged 7 days after exposure ended.	Robust evidence of impaired spatial memory, suppressed brain waves, altered hippocampal structure/ultrastructure and NMDA receptor pathway components after RF exposure.
Wardzinski et al. (2022) 'Mobile Phone Radiation Deflects Brain Energy Homeostasis and Prompts Human Food Ingestion' ElektrosmogReport 1-2022	15 normal-weight men aged 21-29, exposed 25 min to maximum radiation from 2 phones (SAR 0.97/1.33 W/kg); controlled crossover versus sham.	13/15 participants: highly significant 22-27% increase in calorie intake versus sham, mainly carbohydrates. ATP/Pi and PCr/Pi ratios rose sharply then fell sharply.	Mobile radiation may contribute to overeating and disrupt brain energy homeostasis with increased neuronal glucose demand, potentially affecting mental health, behaviour and organs. Children/adolescents especially vulnerable as their brains absorb more, deeper-penetrating radiation.
Xu et al. (2017) 'Age-dependent acute interference with stem and progenitor cell proliferation in the hippocampus after exposure to 1800 MHz electromagnetic radiation' ElektrosmogReport 2-2019	Newborn (P7) and juvenile mice exposed 8 h/day for 3 days to 1800 MHz (1.16 W/kg).	P7 animals: increased DNA synthesis and fewer hippocampal stem cells.	Developmental sensitivity to 1800 MHz must be considered in assessing protection against EMF.
Zheng et al. (2023) 'Biological effects of exposure to 2650 MHz electromagnetic radiation on the behavior, learning, and memory of mice' ElektrosmogReport 4-2023	60 male mice exposed to synthetic 5G frequency (2650 MHz), whole-body SAR 2.06 W/kg, 4 h/day for 28 days. Electric field 78.9 V/m.	Anxiety-like behaviour, increased plasma corticosterone, significantly reduced behaviour-associated BDNF and GR protein after exposure.	5G RF may cause anxiety-like behaviour in rodents. HPA axis changes, particularly reduced glucocorticoid receptor GR production, may indicate disturbed stress regulation.



Authors / study	Experimental conditions	Findings	Conclusions
Zhu et al. (2021) 'Effects of 1.5 and 4.3 GHz microwave radiation on cognitive function and hippocampal tissue structure in Wistar rats' ElektromogReport 1-2023	140 male Wistar rats (4 groups), each exposed 6 min at 10 mW/cm ² ; SAR 3.3-3.7 W/kg.	Increased escape latency, marked EEG changes and pathological hippocampal findings. Most damage resolved after 14-28 days. Nissl bodies markedly reduced on days 7/14; significantly reduced hippocampal enzyme activity. Combined LC exposure tended to cause greater changes.	Single RF exposure can temporarily impair learning, memory and hippocampal neuronal structures. Reduced Nissl bodies probably relate to reduced learning/memory. Effects appear reversible. No interactions between tested frequencies.

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