

Mobile Phones

The Mobile Phones set of articles is separated into 9 sections, each of which can be individually downloaded. It is a 'work in progress' incorporating new information whenever time permits.

Section 4 **Dementia, reproductive, neurological and cognitive effects**

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2. Are mobile phones a health problem? Is the data trustworthy?
3. Brain tumours and other cancers; 13-nation Interphone study findings, and others; brain tumours; eye cancer; leukaemia; melanoma; personal experiences; pituitary; prostate; salivary gland tumours; skin tumours; stem cells; thyroid cancer; implications; Legal viewpoints
4. Dementia; reproductive effects; neurological effects; cognitive effects; brain activity, children
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Dementia, reproductive, neurological and cognitive effects

There have been many biological effects reported as a result of exposure to mobile phones or to mobile phone-type radiation, besides the cancer risks discussed in section 3. We include here summaries of many of these papers, plus references to the research papers which are listed in full in Section 9.

Dementia

Professor Darius Leszczynski's team at the Radiation and Nuclear Safety Authority in Finland reported that exposing human cells to one hour of mobile phone radiation triggered a response which normally only occurs when cells are being damaged. They believe the changes could disable the blood-brain barrier (BBB) that is meant to protect the brain from harmful substances in the blood. As a result, the cells which make up blood vessel walls shrink, allowing tiny molecules to pass through into brain tissue. Professor Leszczynski said "*If this were to occur repeatedly over a long period of time, it might become a health hazard because of the possible extra-capillary accumulation of molecules that might cause brain tissue damage.*" (Leszczynski, [2002](#)).

The results of a study by Moradi ([2016](#)) and International Commission of Non Ionization Radiation Protection (ICNIRP) reports showed the people who spend more than 50 minutes a day using a cell phone could have early dementia or other thermal damage due to the burning of glucose in the brain. Kerimoğlu ([2016](#)) found that oxidative stress-related damage to the hippocampus and loss of neurons were observed following exposure to 900-MHz EMF throughout the adolescent period.

Tang ([2015](#)) also found that exposure to 900MHz EMF radiation for 28 days significantly impaired spatial memory and damaged the blood-brain barrier (BBB) permeability in experimental rats. Eris ([2015](#)) concluded that even a single 45 minutes exposure may increase 5-HT levels which could lead to a retarded learning and a deficit in spatial memory.

Interesting studies by Sirav & Seyhan ([2009](#), [2011](#)) suggest that there may be an indirect hormonal effect on blood-brain barrier changes. They found that 20 minute exposure to 900 or 1800 MHz emissions increased the permeability of the blood-brain barrier in male rats, but not females.

Xu ([2010](#)) found oxidative damage to mitochondrial DNA (mtDNA) after exposure to 1800 MHz RF radiation, which the authors believed could account for the neurotoxicity of RF radiation in the brain.

Professor Leif Salford and colleagues at Lund University have produced various papers which appear to show that mobile phone users could be at risk of developing Alzheimer's disease, multiple sclerosis (MS) and Parkinson's disease. Only 2 hours of exposure was enough to disable the BBB, allowing proteins and toxins to enter the brain. Further research by Salford ([2003](#)) and Eberhardt ([2008](#)) showed dark neurons (dead cells) in the brain after 2 hours of exposure, particularly in the hippocampal area of the brain. The presence of these dark neurons peaked at 28 days after the exposure, the last time the cells were examined, so it may not have reached the peak by the time measurement stopped. Albumin, a toxic agent, had been allowed into the brain as the result of a breach of the BBB. **The lowest exposure levels did the most damage.** The studies were done on rats, at a similar developmental age to human teenagers. The hippocampus is involved in learning and memory and emotional states. Dark neurons were not found in follow-up studies by Grafström ([2008](#)), de Gannes ([2009](#)) and Masuda ([2009](#)). Daniels ([2009](#)) found that in some exposed animals, there was decreased locomotor activity, increased grooming

and a tendency to increased basal corticosterone levels, suggesting "EMR exposure may lead to abnormal brain functioning."

Learning and memory function in *Drosophila* larvae were affected after exposure to mobile phone radiation. Highly significant differences occurred in the larval speed of movement after exposure to EMF. The authors (El Kholy & El Husseiny [2012](#)) suggested that exposure to EMFs might affect whole body proteins.

Further research from the Salford & Eberhardt team found that exposure to handset radiation destroyed cells in areas of the brain which are important in memory, movement and learning. Another study (Ntzouni [2011](#)) found a severe interaction of RF with the process involved in the consolidation of memory, implying it is the pathway itself, the exchange of information, which creates the problem in memory. A further study ([2013](#)) reported that visual processing mechanisms in the hippocampus, and other areas of the brain were gradually malfunctioning after long-term daily exposure. This effect persisted for some weeks after the exposure stopped. Salford fears that it is likely to cause premature onset of illnesses linked to ageing, particularly teenagers who are heavy users.

Professor Salford said in the 1st Hellenic Congress on the effects of Electromagnetic Radiation in May 2008, (http://multimedia.biol.uoa.gr/Synedrio_Thess/Sunday.htm) "*The mammalian BBB is anatomically the same in the human as the rat's brain. Enzymatic functions in the BBB may be different between the species, even if very little is known about this. With a long series of significant effects of RF-EMF demonstrated in the animal models, it is my sincere belief, that it is more probable than unlikely, that non-thermal electromagnetic fields from mobile phones and base stations do have effects upon the human brain.*" His group have some remarkable results on a low-power bio-effective window regarding blood-brain barrier breakdown and RF exposures from mobile phones and masts at th VERY low levels (like 1/1000 th of ICNIRP). The effect disappears at higher levels – in fact at levels most phone users will experience – **the effect is usually maximal at 1.5 to 2 metres sideways of the actual user.**

The exposures in the Salford and Eberhardt studies were lower than the current recommended ICNIRP levels, and in fact, **the lower SAR values leaked more albumin than higher ones; the weakest fields were biologically more harmful.** The weakest fields could be experienced by people standing close to a mobile phone user, or even people living near mobile phone transmitter masts.

When neurons die, they are dead. They do not get resurrected. To start with effects are not likely to show up at all, but then 'forgetfulness' is likely to increase so that you need to look more things up again and again so that other neuronal pathways can be created in your brain to remember the information. Eventually a point is reached where catastrophic failure occurs with the rapid onset of significant dementia.

The authors write: "*The situation of the growing brain might deserve special concern from the society since biological and maturational processes are particularly vulnerable. The intense use of mobile phones by youngsters is a serious memento. A neuronal damage of the kind, here described, may not have immediately demonstrable consequences, even if repeated. It may, however, in the long run, result in reduced brain reserve capacity that might be unveiled by other later neuronal disease or even the wear and tear of ageing. We can not exclude that after some decades of (often), daily use, a whole generation of users, may suffer negative effects maybe already in their middle age.*"

Supporting Dr Salford's work, Dr Pierre Aubineau and colleague Dr Fatma Töre, found proteins leaked from blood vessels into rat brain meninges after 2 hours of GSM radiation at 900 MHz, both immediately, and seven and 14 days after exposure ([Nittby 2009](#)). They felt that, in humans,

this leakage and resultant inflammation would almost certainly cause severe headaches.
www.tsi.enst.fr/comobio/resultats/SP6.html.

Salford's hypothesis may provide at least a partial answer as to what is responsible for the apparent increase in early onset dementias that is causing some UK hospitals to open new 'early dementia units' to cope with the rising number of people who seem to be developing symptoms similar to those of Alzheimer's Disease in the 45 to 60 age range.

In a personal communication from Idaho, USA, in December 2006, CBS (a national news network) reported that 1 in 10 American families has at least one Alzheimer victim and that the nationwide number of Alzheimer victims under 65 is 640,000 with new cases growing exponentially. The Federal government is trying to find big money to help the crush of new YOUNG demented Americans.

When the blood-brain barrier is breached, the mechanisms which are in place to prevent toxic substances entering the brain begin to deteriorate. This can mean that substances, such as alcohol, and some less legal drugs, which are normally prevented from doing too much damage to the brain because of the barrier, are allowed to enter unhindered, causing cellular damage, and possibly affecting mood and behaviour. The mixture of mobile phone use, alcohol, and other drugs may well be responsible for the increase in city gang aggression, 'lager lout' behaviour, road rage, etc.

A review by Stam (2010) suggested that the breach in the BBB would be reversible, at least for macromolecules, but acknowledged that the literature was too sparse to draw definitive conclusions, especially with respect to human studies. Zhang (2012) found that pulsed EMF exposure led to increased permeability of the blood brain barrier; the permeability became more severe and recovered at 6 hours after exposure. Other measured gene and protein expression changes recovered after 12 hours.

A review in 2008, by Nittby, of the research looking at the effects of ELF EMFs on the blood brain barrier, concluded that the picture was complex; some work showing effects and others not. In fact, Söderqvist (2010) found that mobile phone exposure for 30 minutes increased serum transthyretin (TTR), which is reduced in people with Alzheimer's disease. They suggest that "TTR might be involved in the findings of RF exposure benefit in AD mice." Arendash (2010) also found that mobile phone use provided cognitive benefits that they believed could be protective against Alzheimer's disease. However, in the experimental set-up, the RF exposure was to the whole body from a far-field source and not a near-field head only exposure, and was neither pulsed nor modulated, so did not represent a mobile phone signal. The researchers also found a temperature increase in the exposed animals, which may have affected the results.

Andrew Goldsworthy suggests that mobile phone signals generate brain hyperactivity, possibly as a result of increased membrane permeability and they allow calcium to enter neurones, which reduces the threshold for the release of neurotransmitters. This may be just what Alzheimer's patients need to help their damaged brains lay down new memories. The hyperactivity is likely to be accompanied by attention deficit and loss of concentration due to a proportion of the extra neural activity being spurious. Hamblin (2004) suggested that mobile phone exposure may affect neural activity.

He continues "*It is argued that living cells and organisms perceive the damaging effects of the radiation and put themselves into 'repair mode'. This includes boosting enzymes needed for cellular growth and regeneration and also triggering inflammation to increase the blood supply to the affected region. Some of the mechanisms are generic and may also affect other illnesses, so that very weak radiation may have net beneficial effects, even on systems that are not directly affected by it. Mild inflammation of the brain would*

increase its blood supply and could stave off the degeneration normally associated with Alzheimer's disease."

Reproductive effects

Scientists are warning that rising levels of male infertility have become so perilous that it is a serious public health issue. One in five healthy young men between the ages of 18 and 25 produce abnormal sperm counts. Only 5 to 15% of their sperm is good enough to be classed as 'normal' by the World Health Organisation classification. The core problems of male fertility start in the womb. There is a 'window' of testicular development that begins in the growing foetus and ends in the first six months of life. This clearly has implications for maternal exposure to RF during pregnancy.

In the annual meeting of the American Society for Reproductive Medicine in October 2006, US researchers and doctors in Mumbai, India reported that the more men used a mobile phone, the worse their sperm count and the poorer the quality of their sperm would be. Agarwal ([2008](#)), Adams ([2014](#)) and G Zhang ([2016](#)) found the same. Using the phone for more than 4 hours a day caused a 25% drop in the number of sperm produced and only 20% of these looked normal. Jurewicz ([2014](#)) found that using a cell phone for more than 10 years decreased the percentage of motile sperm cells. Sperm counts in UK men have fallen by 29% in the last decade. As Andrew Goldsworthy says "*The Agarwal study showed that men using their mobiles for more than 4 hours a day had the most sperm damage. When you are using it, it is not in your trouser pocket; heavy users should be the least affected. If the signal is strong enough to reach a base station, which may be over a mile away, damaging levels of RF can reach the testicles, which are just feet away. If this is correct, anyone living or working in an environment where other people are constantly using their mobiles may be taking a similar risk.*"

"Women should also have cause for concern. Whereas sperm take only 3 months to produce and are made continually in their billions, all the eggs that a woman will ever have were in her ovaries before she was born and cannot be replaced. Unlike sperm, these are definitely not expendable."

We do not know what the situation may be if a woman, pregnant with her daughter, uses or carries a mobile phone on standby near the growing baby. Her unborn baby daughter's eggs may be affected in ways we cannot predict.

In a study by Col-Araz ([2013](#)), mothers who used mobile phones or computers during pregnancy had more deliveries before 37 weeks. It is unclear what implications this may have for the subsequent health and development of the baby. However, a study by Luo ([2013](#)) found that mobile phone EMFs might alter the protein profile of chorionic tissue of early pregnancy, during the most sensitive stage of the embryos. The exposure to EMF may cause adverse effects on cell proliferation and development of nervous system in early embryos.

Prolonged mobile phone and computer use have been linked to threatened miscarriage by Tan ([2014](#)).

A study by Banz-Jansen ([2011](#)) concluded "*there is evidence suggesting that environmental factors are causative for the trends in occurrence of male reproductive health problems. The incidence rate of testicular malignancies among infertile men continues to increase in comparison to the incidence rate of the general male population, one has to count on an incremental number of males suffering from subfertility and testicular tumours."*

A serious effect on male fertility may be seen by a decrease in the amount of sperm cells, and changes in their mobility and structure (Dama & Bhat [2013](#)). In a study of males attending infertility clinics, Wdowiak ([2007](#)), Gutschi ([2011](#)) and Radwan ([2016](#)) and Uskalova ([2016](#)) found an increase in the number of abnormally-shaped sperm cells and a decrease in sperm motility associated with the duration of exposure to mobile phone radiation. Gorpinchenko ([2014](#)) and Zalata ([2015](#)) also concluded that a correlation exists between mobile phone radiation exposure,

DNA-fragmentation level and decreased sperm motility. In a review of studies over some decades Kesari (2013) found evidence for decreased sperm count, enzymatic and hormonal changes, DNA damage, and apoptosis formation with mobile phone use.

A study by Q Liu (2015) found that the percentage of apoptotic sperm cells in the group of rats exposed to 600 MHz radiation was significantly increased by 91.42%. Other characteristics were also affected.

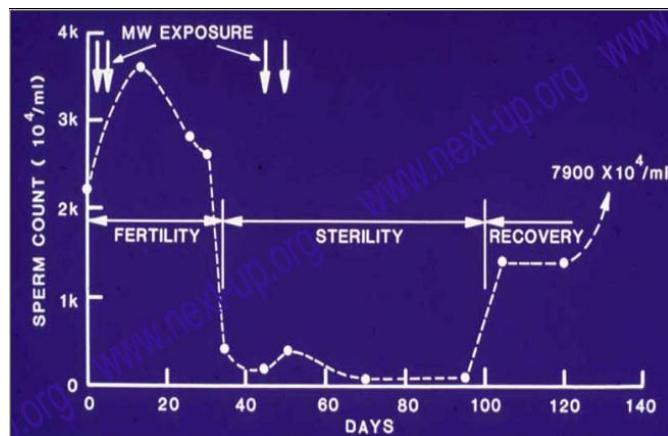
A study by C Liu (2013) found mode-dependent DNA damage which they felt had important implications for the safety of inappropriate mobile phone use by males of reproductive age and they suggested a simple preventive measure, keeping the body from mobile phones as far away as possible, not only during conversations but during "dialled" and "dialling" operation modes as well. C Liu (2013), also found that RF-EMR with insufficient energy for the direct induction of DNA strand breaks may produce genotoxicity through oxidative DNA base damage in male germ cells. Oyewopo (2017) demonstrated that chronic exposure to mobile phone radiofrequency electromagnetic radiation leads to defective testicular function that is associated with increased oxidative stress and decreased gonadotrophic hormonal profile.

Houston (2016) reviewed 27 studies investigating the effects of RF-EMR on the male reproductive system, and found that negative consequences of exposure were reported in 21. Within these 21 studies, 11 of the 15 that investigated sperm motility reported significant declines, 7 of 7 that measured the production of reactive oxygen species documented elevated levels and 4 of 5 studies that probed for DNA damage highlighted increased damage, due to RF-EMR exposure. The authors envisage a two-step mechanism whereby RF-EMR is able to induce mitochondrial dysfunction leading to elevated ROS production.

Kumar (2014), Mugunthan (2014, 2015) and Pandey (2017) said that testicular function is particularly susceptible to the radiation emitted by EMFs. Significant decrease in sperm count, increase in the lipid peroxidation damage in sperm cells, reduction in seminiferous tubules and testicular weight and DNA damage were observed following exposure to EMF in male albino rats. The authors concluded that mobile phone exposure adversely affects male fertility, as they had in an earlier study (Kesari 2011). In a study by Karaman (2014) there were a high number of immature cells in the seminiferous tubule and damage to spermatogenic cell lines in RF exposed rat testes.

Çetkin (2017) found that EMF generated by mobile phones causes degeneration in testicular structure and function.

Men should not carry a phone in their front trouser pockets. Yildirim (2015) found 3 levels of sperm damage depending on where the phone was carried; most if carried in the jacket pocket, next if in trouser pockets (Rago 2013), least damage among those who carried the phone in a handbag. Fejes (2005), Aitken (2005), Erogul (2006), Yan (2007), Agarwal (2008, 2009), Agarwal & Durairajanayagam (2015) and Falzone (2008) concluded that usage of mobile phones, exposure to mobile phone signals, or storage of a mobile phone close to the testes affected sperm counts, motility, viability and morphology. *"In addition to these acute adverse effects of electromagnetic radiation (EMR) on sperm motility, long-term EMR exposure may lead to behavioural or structural changes of the male germ cell. These effects may be observed later in life, and they are to be investigated more seriously."*



C K Chou (from article in Chinese)

De Iuliis (2009) found changes in motility, vitality and viability (K Liu 2014) of human spermatozoa exposed to RF EMF, as well as DNA fragmentation. Liu's study was a review and meta-analysis of 18 studies, which included both human and animal studies.

In view of the fact that foetal testicular development occurs in the first 6 months of pregnancy, it may be worth pregnant women being very careful where they carry a mobile when not in use.

In a study by Mailankot (2009), rats exposed to mobile phone emissions for 1 hour a day for 28 days had impaired semen quality and the authors believed this may impair male fertility. Meo (2010) found that long-term exposure to mobile phone radiation led to a reduction in serum testosterone levels. Testosterone is a primary male gender hormone and any change in the normal levels may be devastating for reproductive and general health. Al-Ali (2013) found a potential correlation with cell phone usage and a negative impact on erectile function.

Pregnancy rates were decreased, the number of foetal deaths increased, histomorphological structures were abnormal, and serum LDH level increased in rats exposed to GSM 900 MHz mobile phone (Liu 2012, Ma 2014). The percentage of dead embryos at the 2-cell stage was significantly higher in EMF-exposed group compared with controls (Safian 2016).

Sepehrimanesh (2014) found that reproductive hormone levels are disturbed as a result of RF-EMF exposure and it may possibly affect reproductive functions. Testosterone and inhibin B concentrations as a fertility marker and spermatogenesis were decreased significantly.

La Vignera (2011) reviewed the literature exploring the effects of RF on male reproductive function and concluded that human sperm exposed to RF have decreased motility, morphometric abnormalities, and increased oxidative stress, and men using mobile phones have decreased sperm concentration (Zilberlicht 2015), motility, normal morphology and viability. Sepehrimanesh (2014) found a 30 day exposure to EMF radiation induces non-thermal stress in testicular tissue.

However, the research does not always find evidence of effects (Pourlis 2009). In 2007, in a study by Ribeiro, rats exposed to GSM phone radiation at just over 1800 MHz showed no changes in testicular function. Neither Ogawa (2009) nor Sommer (2009) who studied 4 generations of the exposed rats found an effect. Takahashi (2010) looked at the effect of RF exposure during rat pregnancy on health effects on the second subsequent generation. They found no adverse effects in either the exposed pregnant rats, or the first or second generation. There are questions about how good the simulated exposure was, so replication would help put this into context.

It is not just male reproductive health that seems to be compromised by mobile phone use.

Gul ([2009](#)) found that intrauterine exposure to RF radiation had a toxic effect on ovaries, and concluded that "*the microwaves of mobile phones might decrease the number of follicles in rats by several known and, no doubt, countless unknown mechanisms.*"

Nakamura ([2000](#)) found that microwaves produced uteroplacental circulatory disturbances and ovarian and placental dysfunction during pregnancy, which the authors felt may pose some risk for pregnancy. Liu ([2007](#)) and Mahmoudabadi ([2015](#)) found that use of a mobile phone increased the risk of early spontaneous abortion. Prenatal exposure to continuous 900-MHz EMF for 1 h each day from days 13-21 led to a decrease in ovarian follicle reservoirs in female rat pups at the beginning of the prepubertal period ([Türedi 2016](#)).

Dr de Pomerai found changes in growth rate and maturation in the reproductive stage of nematode worms, when the larvae were exposed to weak microwave fields ([2002](#)). This is in contrast to heating which has the opposite effect. This does eliminate biological consequence explanations that invoke the bulk heating of tissues by microwaves.

The radiation from a commercial GSM 900 MHz mobile phone on developing quail embryos had a non-thermal impact on embryogenesis ([Tsybulin 2012](#)), increased oxidative stress in the embryos ([Burlaka 2013](#)) and varied according to the length of exposure ([Tsybulin 2013](#)). Exposure to a mobile phone (900-1800 MHz) during pregnancy induced oxidative stress in tissues of dams and their offspring ([Bahreyni Toossi 2018](#)).

Yüksel ([2016](#)) found that mobile phone- and Wi-Fi-induced EMR may be one cause of increased oxidative uterine injury in growing rats and decreased hormone levels in maternal rats.

Mobile phone radiation caused developmental delay in chick embryos in the early period. The authors suggest that the use of mobile phones by pregnant women may pose risks ([Umur 2013](#)).

In a review by Kaplan ([2016](#)), he concludes that recent work has demonstrated that EMFs from mobile phones and other wireless transmitting devices inhibit the formation and differentiation of neural stem cells during embryonic development and also affect reproductive and neurological health of adults that have undergone prenatal exposure. H Chen ([2017](#)) found that 935 MHz can reduce the fertilization rate in mice, and reduce the blastulation rate, thus reducing the possibility of embryo implantation.

A study by Odaci ([2016](#)) showed that prenatal exposure to EMF affects the development of Purkinje cells in the female rat cerebellum and that the consequences of this pathological effect persist after the postnatal period. Hancı ([2013](#)) found that 21-day-old rat testicles exposed to 900-MHz EMF in the prenatal term may be adversely affected, and this effect persists after birth.

Razavinasab ([2106](#)) found that exposure to mobile phones adversely affects the cognitive performance of both female and male offspring rats. Jing ([2012](#)) concluded that being exposed to microwave radiation from cellular phones during pregnancy harmed foetal rat brains.

Panagopoulos' team ([2007](#)) found that when looking at the reproductive capacity of flies, 900 MHz radiation was more bioactive than 1800 MHz, which may account for some of the different results. It is interesting that the experiment included only head exposure. It may be that positioning the radiating source nearer to gonads may have had a different effect, which may also explain some of the conflicting findings in different studies.

Fructose is an important component in semen that facilitates sperm motility. A significant drop in fructose levels was observed in the group exposed to pulsed radio frequency emitted by a mobile

phone kept in the standby position which affected sperm motility in rabbits (Salama [2009](#)). Two further studies by Salama ([2010](#), [2010](#)) have shown that standby signals can affect testicular function and structure, and ejaculatory frequency. Microwaves with the frequency of 950 MHz can decrease the height and diameter of the epididymis, the testosterone level in rabbits and increased apoptosis (Azadi Oskouyi [2015](#)).

Neurological effects

Mobile phones can produce brain changes at 30 metres distance that last for hours after the telephone call.

Professor Preece also found that mobile phone radiation caused blood vessels to dilate, creating a rush of blood to the head. He added "*It is not possible to say what this means to health.*"

Dr Freude ([2000](#)) found that mobile phone radiation caused changes to the brain wave pattern of users. Croft ([2002](#)), Marino ([2003](#)), Perentos ([2013](#)), Ghosn ([2015](#)) and Roggeveen ([2015](#)) also found EEG changes as a result of mobile phone exposure. Lv ([2014a](#), [2014b](#)) found changes in brain and EEG activity as a result of exposure to LTE (4G) signals.

Stefanics ([2008](#)) found that a single 20 minute burst of 3G phone radiation did not affect the EEG parameters measured. There was a 30% reversible decrease in the spontaneous electrical activity of neuronal networks as measured by firing rate (FR) and bursting rate (BR) during a 3 minute exposure to RF (Moretti [2013](#)).

Carrubba ([2010](#)) found that the low-frequency pulses produced by mobile phones evoked potentials in 90% of volunteers assessed using a nonlinear method of EEG analysis. Evoked potentials were not detected when the EEG was analysed using time averaging, the usual metric. Cook ([2009](#)) found EEG changes in the occipital-parietal regions of the brain that depended on which frequency was used, and whether subjects had been previously exposed to the same sort of radiation.

Acetylcholine is a key memory neurotransmitter, and acetylcholine activity in the brain changes when exposed to 1 W/kg (half the permitted SAR level from mobile phones). This may well be a mechanism that could be responsible for learning and memory problems. Abnormal release of neurotransmitters after microwave exposure can cause learning and memory deficits (Aboul Ezz [2013](#), Megha [2015](#)). p-Syn I (ser-553) was found to play a key role in the impaired GABA release and cognitive dysfunction that was induced by microwave exposure (Qiao 2014).

Huber ([2002](#)) found an increase in regional cerebral blood flow, in an area linked to working memory, though in an attempt to replicate this, Perentos ([2007](#)) found no changes; Haarala ([2003](#)) did not find a regional change but in his study concluded that EMF effects may have occurred in other regions. As memory seems to be a function that is dispersed throughout the brain, these two results are not contradictory.

Saikhedkar ([2014](#)) found extensive neurodegeneration in rat brains on exposure to radio waves. Increased production of reactive oxygen species due to exhaustion of antioxidants and increased lipid peroxidation indicate extensive neurodegeneration. This extensive neuronal damage results in alterations in behaviour related to memory and learning. Motawi ([2014](#)) also found significant changes in brain histopathology as a result of mobile phone radiation.

Models for establishing a potential mechanism for mobile phone bioeffects on the brain are based on the coupling of RF and pulsed electromagnetic emissions to biogenic magnetite present in the human brain. Cranfield ([2003](#)) found that exposure to mobile phone emissions resulted in a consistent and significantly higher proportion of cell death in exposed cultures of intracellular biogenic magnetite similar to that present in the human brain.

A series of studies by Wang ([2004](#), [2005](#), [2005](#)) showed changes in rat cerebral cortical neurons after exposure to 900 MHz fields which implied cumulative and 'window' effects. Yan's study in [2008](#) suggested that cumulative injuries, that could eventually lead to clinically significant neurological damage, were a result of mobile phone exposure. Meral's team ([2007](#)), and Cetin ([2014](#)) found that 900 and 1800 MHz radiation might produce oxidative stress in brain and liver tissue and change vitamin levels in the blood, altering enzyme activity and reducing the levels of glutathione (GSH), an antioxidant, essential to the body's wellbeing.

Long duration of exposure to 900 MHz EMFs led to decreased numbers of Purkinje cells in female rats ([Sonmez 2010](#)). In humans, Purkinje cells are affected in a variety of diseases ranging from toxic exposure (alcohol, lithium), to autoimmune diseases and to genetic mutations (including autism) and neurodegenerative diseases that are not thought to have a known genetic basis.

Changes in electroencephalograph (EEG) brain patterns have been found by Borbély ([1999](#)), Krause ([2000](#), [2000](#), [2006](#)), D'Costa ([2003](#)), Kramarenko ([2003](#)), Curcio ([2005](#)), Croft ([2008](#)) and Hinrikus ([2011](#)) amongst others, following exposure to a digital mobile phone signal. These changes were found to influence sleep patterns ([Huber 2000, 2003](#), [Hung 2007](#), [Lowden 2010](#)) and memory functioning and other waking activities. Loughran ([2011](#)) confirmed that mobile phone-like emissions affected the EEG during non-REM sleep, and found the effect was sensitive to individual variability.

Cook ([2006](#)) reviewed a number of papers looking at neurological effects of RF exposure and discussed a number of variables not often considered in human bioelectromagnetics studies, such as personality, individual differences and the specific laterality of ELF MF and mobile phone exposure over the brain.

Von Klitzing also researched the effects of DECT cordless telephones on the EEG. After 5 minutes exposure he found changes in brain wave activity and blood-flow. Localised blood flow and temperature changes were found after an 18 minute exposure ([Masuda 2010](#)). Maby ([2006](#)) and Vecchio ([2012](#)) found that mobile phone radiation affected people with epilepsy.

Danker-Hopfe ([2010](#)) found no effect on sleep patterns in a study of healthy men. Further work by Krause ([2007](#)) produced the conclusion "*the effects of EMF on brain oscillatory responses may be subtle, variable and difficult to replicate for unknown reasons*" Ferreri ([2006](#)) found results that they believed demonstrated that "*GSM-EMFs modify brain excitability*". Papageorgiou ([2004](#)) found differences in men and women. If this were so in other studies, it could explain some of the mixed results.

Spindle (involved in communication) disturbances were found ([Schrader 2011](#)) when exposed to 900 MHz emissions.

Karaca ([2011](#)) suggested that cell phones may change DNA and change gene expression in brain cells. However, the exposure they used was a continuous wave signal at 10 GHz which is unlike any telecommunication signals in use today. It remains hard to interpret the findings, despite their being very strong.

Barcal ([2005](#)) and Bak ([2010](#)) found that exposure to GSM EMFs exerted some effects on the CNS (central nervous system), and Bak found effects on long latency event related potentials (brain response that is directly the result of a thought or a perception), particularly P300 amplitude.

Cognitive effects

Professor Alan Preece, of Bristol University Oncology Centre, found that mobile phone radiation caused a decrease in adult reaction time ([1999](#)), a finding confirmed by Edelstyn & Oldershaw

([2002](#)), Curcio ([2008](#)) Vecchio ([2011](#)) and Mortazavi ([2012](#)). This effect occurred after only short exposures, and Mortazavi found the effect greater in males. Young adolescents' reaction time was quicker under exposure conditions, but less accurate ([Abramson 2009](#)). Kumlin ([2007](#)) found that RF fields significantly improved learning and memory in a water maze test.

Further studies by Professor Preece ([2005](#)) on children, and Curcio ([2012](#)), did not confirm their initial finding. Haarala ([2005](#)) also found no difference in response speed and accuracy in children exposed to mobile phone radiation. It may be significant that the results were different, implying that children may well react differently to radiation compared with adults. Luria ([2009](#)) found effects on reaction time from mobile phone exposure, depending on the duration of exposure, and the side of the head that the phone was held to, relative to the handedness of the subject.

Barth's meta-analysis ([2012](#)) of 17 studies found no significant effects on cognition from either GSM or UMTS mobile phones. Unterlechner ([2008](#)) found no change as a result of exposure to a UMTS signal.

Cellular hands-free conversation caused some subjects to miss significantly more points, react slower to each stimulus, and perform with reduced precision, in a study by Barkana ([2004](#)).

A study by Arns ([2007](#)) suggested that frequently making phone calls in distracting places could be having an indirect cognitive training effect, leading to a more focused attention, rather than a direct effect produced by mobile phone use. Overall they found a subtle slowing of brain activity, not explained by differences in personality. This could also explain the lack of effect found in the study by Russo ([2006](#)). Wiholm ([2009](#)) found that people who were daily mobile phone users, who reported experiencing symptoms as a result of this use, performed better in a series of spatial navigation tasks whilst under exposure conditions, than those who were regular phone users, but without reported symptoms. The exposure was designed to mimic that experienced during a real-life mobile phone conversation. The mechanism is unclear, but there was certainly an effect and a difference between those with RF sensitivity and those without. However, Narayanan ([2009](#)) and Fragopoulou ([2010](#)) found that RF exposure at 900 MHz resulted in mice having difficulties in retaining or retrieving learned spatial information. Maaroufi ([2014](#)) found an impact of EMF on the brain and cognitive processes but this impact is revealed only in a task exploiting spontaneous exploratory activity.

Maier ([2004](#)) found that, after exposure, cognitive performance was impaired in an auditory discrimination task. During exposure, 1800 MHz EMFs interfered with a memory task (Hinrichs & Heinze [2004](#)). Grigorev ([2014](#)) found the following changes in children exposed to RF from mobile phones significant tiredness (40%); decreased performance at school and home (51%), concentration difficulties (productivity 14%, accuracy 19%) and memory (accuracy 19%, duration 30%). Also, there was a slowing down of physical response time (56%) and the response to spoken instructions. The author was suggesting that the current regulatory framework is inadequate with regard to children.

Every phone owner gets to recognise the ring of his or her mobile; most people customise the rings so that they have some personal meaning. Zajdel ([2013](#)) found that this familiarity, the 'bond' that develops between a person and their private phone, can significantly disrupt their attention and thus affect attention-demanding activities. A landline ring does not have this effect.

Dr Krause ([2000](#)) in Finland found that mobile phone radiation affects memory. He exposed 16 subjects to radiation before they completed a memory task. His results suggested "*that the exposure ... modifies the brain responses significantly during a memory task*". Haarala ([2003, 2004](#)) did not find short term memory changes, though the team did wonder whether the magnitude of the effects may have been at the sensitivity threshold of the test used, or that changes occur only occasionally. Sauter ([2010](#)) found different effects on attention and working memory depending

on whether the study participants took part in the morning or the afternoon. The authors felt it necessary to control for time of day of testing. Krause's [2004](#) study found different changes to the 2000 study and concluded "*EMF effects on the EEG and on the performance on memory tasks may be variable and not easily replicable for unknown reasons.*" Schoeni ([2015](#)) found a change in memory performance over one year was negatively associated with the cumulative duration of wireless phone use and more strongly with RF-EMF dose. This may indicate that RF-EMF exposure affects memory performance.

Iranian students who used mobile phones had significantly more concentration problems and lower back pain ([Mortazavi 2011](#)). In a study of Iranian students, more than 23% expressed that mobile phone use has severe adverse effects on their study and academic achievement ([Baghianimoghadam 2013](#)).

In a study of Saudi Arabian medical students, Khan ([2008](#)) found that 77% of the students carried one mobile, and 23% more than one. 56%, of the subjects reported the average daily MP use of less than 30 min, 28%, of 30-60 min, 12%, of 60-90 min and 5% of more than 90 min. 16% of the subjects complained of headache and 24% of fatigue. Impaired concentration was reported by 34% of respondents, memory disturbances by 41%, sleeplessness by 39%, hearing problems by 23%, and facial dermatitis by 17%. The sensation of warmth behind/around the ear was reported by 28%. Out of 286 subjects who participated in this study, 44% related their symptoms to mobile phone use.

Professor Lai and his team ([2000, 2004](#)), and Wang ([2000](#)), Nittby ([2008](#)) Hao ([2013](#)) and Deshmukh ([2013](#)) found that the memory and learning ability of rats was badly affected when they were exposed to RF radiation, though Ammari ([2008](#)) found no such effect. In Lai's study done in 2004, 'randomised', or incoherent magnetic fields seemed to help eliminate the effect. Maier ([2001](#)) found a loss of 'mental regeneration' in subjects exposed to pulsed electromagnetic fields. Haarala ([2007](#)), however, found that neither pulsed nor continuous wave exposure affected human cognitive function as measured by behavioural tests.

In 2001, Dr John Tattersall of the Defence Evaluation Research Agency (DERA) at Porton Down, showed that radiation at 700 MHz, at power levels considerably lower than those which would produce heating effects, affected brain cells and the nervous systems of rats, leading to potential problems with memory, learning and epilepsy.

Transgenic, genetically engineered mice, often used in laboratory experiments, are unique animals and extrapolation to even other normal mice, let alone humans is very tenuous when addressing basic biological functions. Cognitive functions are yet one more step removed in terms of extrapolation – mice and people do not think alike.

One reason for keeping calls short may not sound initially as if it is an adverse effect at all. Mobile phone-type radiation, according to some experimental evidence, including by Professor Lai, can cause the brain to release natural endorphins into the bloodstream. Endorphins are the chemicals that reduce pain when engaged in strenuous or protracted physical activity (like running the marathon). This is very useful in time of need. One reason that long-distance runners say they continue with this gruelling sport is that it gives them a 'high', which they get hooked on. Getting 'hooked' is literally true as endorphins are the body's natural opiates, and like other opiates can lead to addiction. So people may, literally, be becoming addicted to mobile phone use, in fact there are now doctors who specialise in the treatment of 'technological addiction', also treating children addicted to WiFi games.

Brain activity, children

Exposing your unborn child to radiation from a mobile phone can affect its brain development (Aldad [2012](#)). Mice, exposed during gestation, were hyperactive as young adults and their memory was decreased.

Children who use mobile phones for as little as two minutes can have their brain activity altered for up to an hour afterwards. Dr Michael Klieesen, heading a team of scientists at the Neuro Diagnostic Research Institute in Marbella in Spain, fears that these alterations could lead to psychiatric problems, aggressive behaviour, a lack of concentration, memory loss and an inability to learn. They believe that classroom behaviour could be affected if calls were made during break time. They were also concerned that immunity to infection and disease could be affected by the changes in chemical balances in the brain.

A study by Divan ([2008](#)) found an association between maternal mobile phone use during and after pregnancy, and emotional and behavioural problems in the child at around the age of school entry. The RF exposure to the child is likely to be minimal, so perhaps there were blood changes that crossed the placental barrier that were responsible for the changed behaviour. This does not seem to have been discussed. However, a further study by Divan ([2012](#)) found that the highest risk for behavioural problems in children by the age of 7 years, were for children who had both prenatal and postnatal exposure to cell phones, which may suggest that minimal exposure is sufficient to produce change in developing physiological and psychological systems.

Studies by Odaci ([2008](#)) and Bas ([2009](#)) on pregnant rats found that exposure to 900 MHz radiation during pregnancy affected the hippocampus in the offspring. This part of the brain is associated with memory, but may have other effects in exposed humans. Another study (Narayanan [2010](#)) found that RF significantly altered hippocampus changes and the behaviour of rats.

Dr Hyland comments that "*the multi-frame repetition frequency of 8.34 Hz and the 2 Hz pulsing that characterises the signal from a phone equipped with discontinuous transmission (DTX), lie in the range of the alpha and delta brain wave activities, respectively. The fact that these two particular electrical activities are constantly changing in a child until the age of about 12 years when the delta-waves disappear and the alpha rhythm is finally stabilised, means that they must both be anticipated to be particularly vulnerable to interference from the GSM pulsing*".

During 1994 -1996, when Swedish teenagers started using mobile phones, prescriptions for sleeping pills for 15-24 year old young women doubled and those for antidepressants increased by 40%. In November 1999, a Danish psychiatrist said "Teenagers are stressed to pieces" the day after a report that 13% of Gothenburg schoolchildren with normal hearing experience tinnitus, often a sign of social stress.

Bas ([2009](#)) found a statistically significant decrease in brain neurons in GSM exposed rats, and recommended that the results of the study should encourage researchers to evaluate the chronic effects of 900 MHz EMF on teenagers' brains.

We suspect that the extremely low frequency (ELF) magnetic field pulses, due to the handset transmitter pulsing on and off and drawing current from the battery 217 times every second, is the main cause of memory and concentration effects and not the pulsed microwaves.