

Response to HHS Request for Information on Electromagnetic Fields (EMFs), Radiofrequency (RF) Radiation and Wireless Radiation Exposure

Docket No. HHS-OASH-2026-0397

Submitted to: U.S. Department of Human Health Services, Office of the Assistant Secretary for Health

Respondents Oceania Radiofrequency Scientific Advisory Association (Dr Julie McCredden, Victor Leach, Steve Weller)

ORSAA is a not-for profit research entity.

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Response to Question 12. What scientific evidence exists regarding potential adverse health effects associated with RF radiation exposure at levels below current federal exposure limits?

Basis for Submission

Evidence base: ORSAA Database of Electromagnetic Bioeffects (ODEB)

Literature reviews investigating EMF typically use several existing information sources, such as PubMed, EMF-portal, and the Institute of Electrical and Electronics Engineers (IEEE). However, these databases cover a much broader range of topics than the biological and health effects of electromagnetic radiation, such as medical procedures and accidents.

To meet the need for a focused knowledge collection, the Oceania Radiofrequency Scientific Advisory Association (ORSAA; www.orsaa.org) has developed the ORSAA Database of EMF Bioeffects (ODEB) (1) containing peer-reviewed studies investigating the biological and health effects of electromagnetic fields on humans, animals and the environment. ODEB contains all relevant papers from PubMed and the EMF-portal, the entire research database of the Australian Radiation Protection & Nuclear Safety Agency (ARPANSA), military studies from the 70's, biophysics research from the 80's onwards, and all experimental and epidemiological research from both industry and independent scientists since 2012.

Each paper is categorised in ODEB according to a wide range of fields describing different aspects of the study, such as whether it was experimental or epidemiological, what biological or health end points were examined, the frequency ranges used for exposures, the intensity of exposures, whether the signals were real or simulated, pulsed or continuous, and whether effects, no effects, or uncertain effects were found. This categorization process allows ODEB to be used to find papers that address very specific topics. ODEB currently comprises over 5,000 peer-reviewed publications and is being continually updated with both new papers and new categories.

ODEB Search strategy

For the current report, a multidimensional ODEB search was conducted, to find papers with the following characteristics, and the results were then grouped and graphed for clarity of presentation (see later).

- Radiofrequencies in the frequency ranges of VHF (30 MHz-300 MHz), UHF (300 MHz-3 GHz), and SHF (3 GHz - 60 GHz), ranges. It was considered that these ranges would collectively cover most of the waveforms used in global telecommunications, government, military and industry that are relevant to health effects for humans and the environment. Many studies using high frequency signals may have also included low frequency modulations, so that the low frequencies of importance (e.g. pulsing within mobile phone signals) are incorporated into the selected literature base.
- Exposure intensities below the International Commission on Non-Ionizing Radiation Protection (ICNIRP); i.e., the 4 W/kg whole-body Specific Absorption Rate (SAR) limit and the 200W/m² local tissue incident power density limit (2), p. 6–8.
- Laboratory, epidemiological, human provocation studies, case studies.

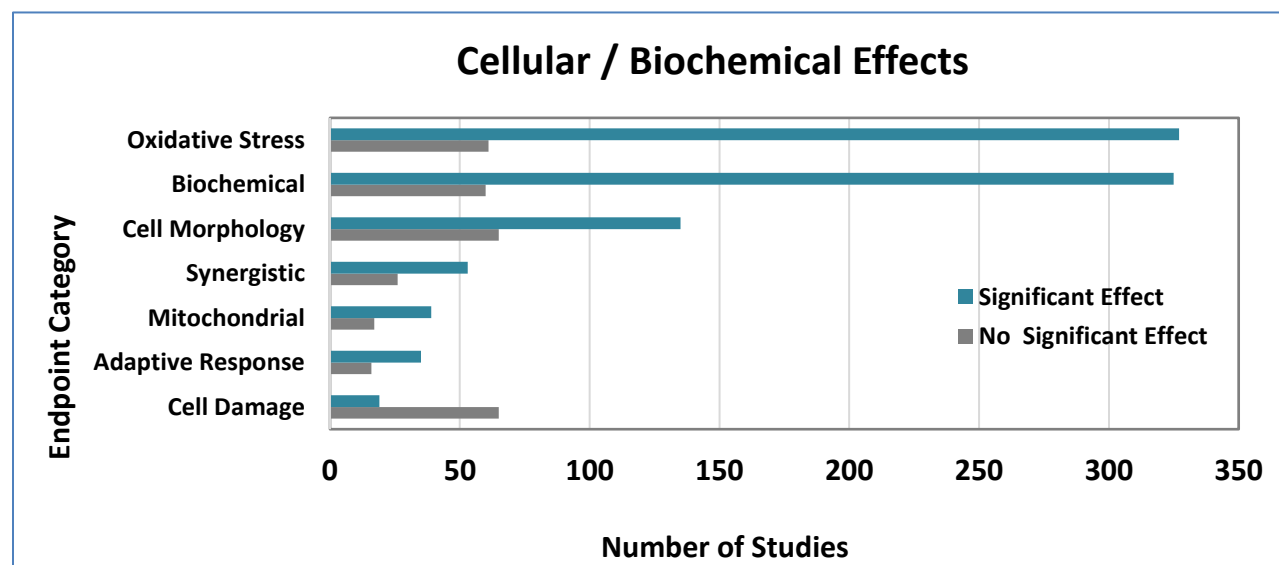
[Note: in the discussion below unless otherwise specified, the term ‘EMF’ refers to electromagnetic radiation and electromagnetic fields that sit in the frequency ranges which are of interest to this report and are of intensities less than the thresholds set by the International Commission of Non-Ionizing Radiation Protection (ICNIRP).]

Graphs and tables were used to map out the main broad biological and health categories that exist within the entire collection of studies. (It is also possible to search ODEB for more specific endpoints). The spreadsheet with the results of this search, used for the graphs and tables is available on the ORSAA website www.orsaa.org.

Overview of effects versus no effects

The ODEB search process resulted in a set of output tables representing the current literature base, comprising over 1700 experimental (laboratory exposure) papers and over 400 epidemiology (real world exposure) papers, investigating humans, animals and other organisms. The entire range of biological and health categories was probed. Within each broad category, the numbers of studies showing significant effects versus no significant effects were calculated.

The sections below present an overview of the main sets of biological and health effect endpoints, showing the numbers of studies that have shown significant effects versus those that have shown no significant effects for the particular endpoint that was investigated. For example, in ODEB there are 327 papers that found significant effects of EMF on the endpoint of oxidative stress levels, while there are 61 papers that found no significant effects of EMF on oxidative stress levels (see the first row of the Cellular/Biochemical Effects graph below).



Studies showing cellular and molecular changes that occur as a result of EMF exposures.

Oxidative Stress

There is strong evidence that EMF exposures create oxidative stress in the body. The state of 'oxidative stress' in cells, proteins, lipids and DNA is a major mediator on the pathway from EMF exposures to detrimental health conditions. Oxidative stress occurs via the following processes.

Normal cell metabolism creates molecules called 'reactive oxygen species' (ROS) as byproduct of creating energy. They are also created by cells to fight and eradicate any intrusion or damaging event. ROS both create immune system responses and are activated by immune system processes and pathways, as well as by inflammation. ROS molecules are thus helpful, when a stressful or damaging event occurs for a short time. However, ROS molecules need to be neutralized by antioxidants, which soon run out. If they are not so neutralized, an accumulation of ROS occurs, and these then go onto create further molecules that are highly damaging to cells, proteins, lipids and DNA. This state of stress in the body is called 'oxidative stress'.

If a stressful or damaging event occurs at an intensity or for long durations, or concurrently with other health conditions, so that all of the body's antioxidant supplies are overwhelmed, oxidative stress occurs, resulting in damage at many physiological levels. Oxidative stress is known to underlie many neurological disorders and many chronic and autoimmune conditions such as Alzheimer's Disease, Parkinson's Disease, Multiple Sclerosis, diabetes, cardiovascular diseases, depression, obesity and cancer (3, 4).

Both ROS and oxidative stress occur as a result of EMF exposures at low intensities, as shown in in (5) and by the graph above .

In many areas of toxicology and environmental health, oxidative stress is accepted as an established mediating pathway that links exposure to the toxin with the health outcome; e.g., in the area of air pollution, toxic air particles are known to lead to oxidative stress, which can then lead to increased risks of cardiovascular disease and stroke.

Underlying causes

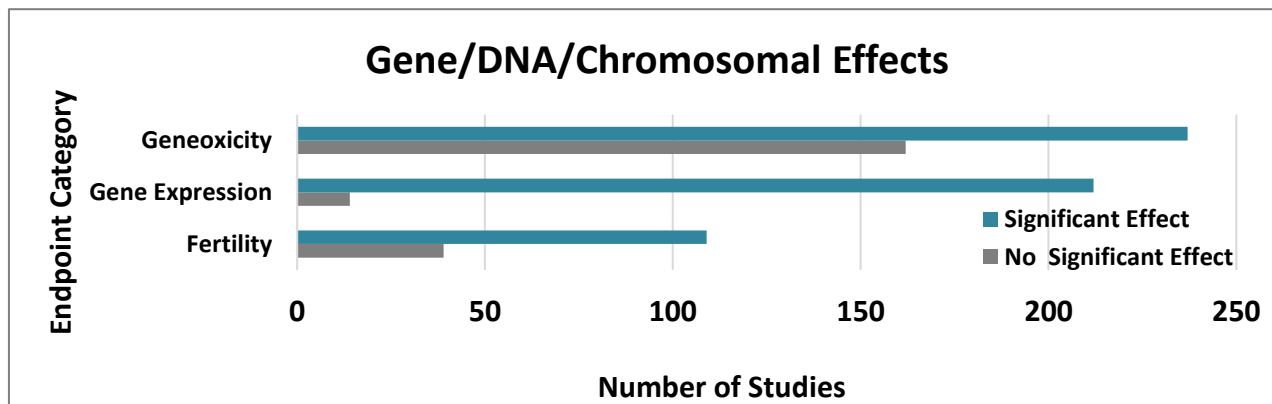
Explanations describing the underlying mechanisms for how EMFs create oxidative stress (as well as other damaging effects) include changes in the radical pair mechanism in human cryptochromes and other molecules (6), irregular opening of calcium gates in cell membranes (7), forced opening of ion channels (8), and many other mechanisms originating in biophysics (5, 9, 10).

Protein unfolding

One of the more prevalent and serious molecular changes caused by EMF exposures is changes in the structure of proteins. This can occur indirectly via oxidative stress, as described above. It can also occur directly through EMF causing proteins to unfold, by breaking or altering the weak links across the folds of a proteins that hold it into shape. It is thought that this may occur via 'resonance effects', whereby the sub-units within the protein begin to vibrate at frequencies corresponding to components of the incoming EMF signal, and that this vibration moves the subunits from their proper positions (11). Protein shape changes may also explain why EMF effects ion transport across cell membranes (12), and the 'heat shock protein' stress response in cells exposed to EMF (13) at similar or much lower intensities as mobile phone exposures. Resonance and changes to the shape of proteins are examples of how damage to molecules can occur at low intensities, used in everyday devices.

Proteins (e.g. collagen) are the building blocks of most tissues in the body: muscle, bones, skin, connective tissue, ligaments, skin and organs. They also act as enzymes, hormones, and antibodies. Unfolding of proteins is thus a fundamental process undermining the structural integrity of the body. Therefore, long term EMF exposures may be eroding the structures of the body, as well as its ability to cope with other stressors (14) day by day.

DNA damage



Studies showing Genotoxicity/DNA damage and associated changes that occur as a result of EMF exposures

Genotoxicity/DNA damage is the outcome of the above cellular and molecular changes, that occur when the body's recovery processes are unable to deal with long-term damage, inflammation or build-up of oxidative stress.

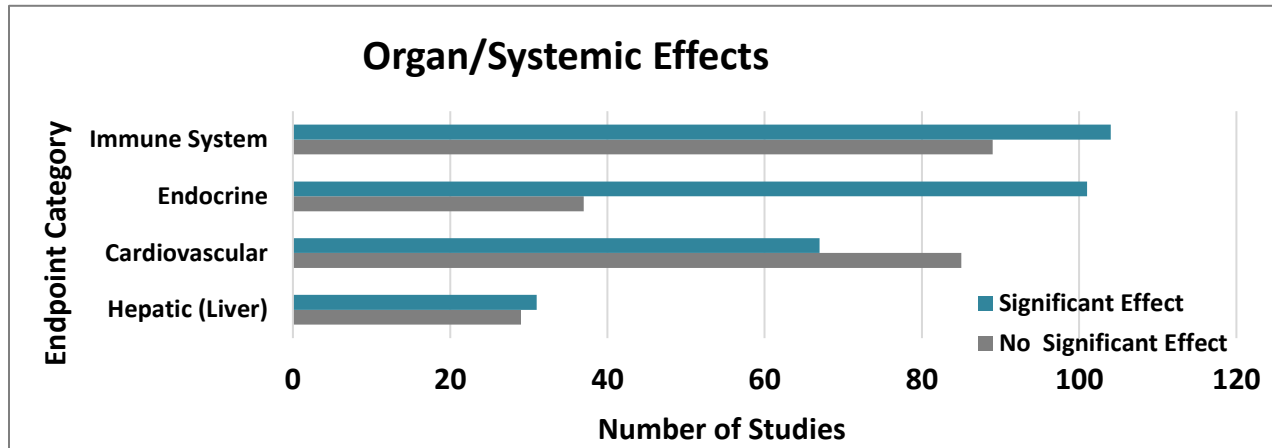
This overload of damage and oxidative stress results in changes to DNA, the code that tells cells what proteins and other molecules to make. There are many types of detrimental changes that can occur, both in the way that cells behave as well as in the messages that they send to one another and to other parts of the body (cell signalling).

Changing the structure or the behaviour of DNA and cells is like corrupting the stored files on your hard drive and putting bugs in the computer programs on your PC. Depending on where and how many changes, the outcomes can vary from mild to catastrophic.

DNA and chromosomal damage results in fertility issues, from compromised sperm and ovaries, to reduced birth rates. EMF exposures result in DNA damage (15). Therefore, ubiquitous EMF exposures, especially close to the body, may be an unrecognised factor in the global declining birth rates.

Our recent review paper (16) explored the ways in which different types of EMFs can affect genetic processes, DNA and chromosomes. It investigated over 500 studies, and found *statistically significant DNA damage in humans and animals resulting from man-made RF-EMF exposures, particularly DNA base damage and DNA strand breaks* with the pathways for these effects most likely being mediated by oxidative stress. DNA damage was found more often in studies that investigated organisms *in vivo* studies (using real humans, animals or plants), for studies with very weak or very strong signal intensities, very short or long exposure durations, frequencies of 900, 1,800 and 2,450 MHz, and those that used GSM-talk mode, pulsed modulations and real-world devices. It also showed that research funded by links to industry and the military have used experimental design parameters that are less likely to produce significant outcomes. Over half of the papers showing damaging DNA effects used experimental exposure intensities that are weaker than the International Commission of Non-Ionizing Radiation Protection (ICNIRP) limits, that are used globally to regulate EMF exposures to the population.

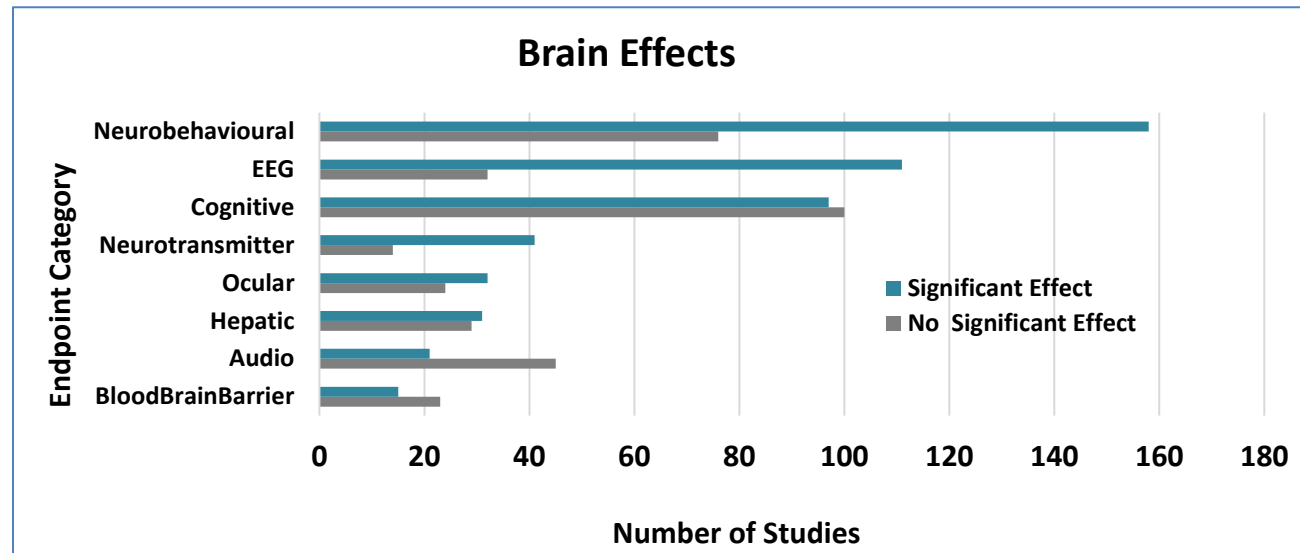
Body organs and systems



Studies showing effects on organs and systems as a result of EMF exposures

The biological and molecular changes induced by EMF exposures have consequences for the human organs and systems that rely on them. If the immune system is compromised, then humans cannot fight disease and damage and age faster. The cardiovascular system is highly susceptible to oxidative stress, and EMFs may be an unrecognised factor in higher rates of heart disease globally (17).

Brain and behaviour



Studies showing effects on the brain and behaviour as a result of EMF exposures

Neurobehavioral studies investigate the effects of EMF on the brain hardware, and subsequent changes in cognitive abilities (short-term or long-term memory, decision making, problem solving etc.) or in behavior. Strong evidence for such effects has been found in rodent studies using water maze tasks. Overall, longer exposures and higher intensities show damage to the hippocampus and cortex and impairment to spatial learning and memory (18-20). Consistent with these results, a population study with adolescents (21) found effects of mobile phone exposures on adolescent figural memory, a visual-spatial short-term memory task. These results indicate effects on the hippocampus and the related spatial memory processes.

Changes in brain activity provide strong, objective measures for the effects of EMF. Measures such as electroencephalography (EEG) have shown effects on the energy of EEG frequency bands, such as alpha brain waves (8 to 12 Hz) and on sleep spindles (12-15Hz)

(22). These effects occur even when the same studies show no outward changes in cognitive abilities (23, 24). Unfortunately, some researchers with potential conflicts of interest ignore these results because, as they say, they don't know how to interpret them.

Two recent WHO commissioned reviews investigated effects of EMF on cognitive function (25). These studies had several major flaws, including leaving out the EEG studies in the analysis of the laboratory studies, as well as using only two of their own studies in the final analysis of long-term effects (26)

The best conducted study investigating the effects of long-term mobile phone use was a 10-year-long study of children in Russian schools (27). At first, daily mobile phone use improved reaction time and psychomotor speeds in the short term, However, greater and longer daily mobile phone use caused these speeds to slow down. Greater daily mobile phone use also resulted in poorer processing speed, poorer executive function (inhibition) and poorer short-term memory / long-term meaningful memory, storage and retrieval, and a decline in simple auditory reaction time (28). For example, the graph below compares the worsening working memory from mobile phone use in one school boy over time (higher numbers indicate better performance). His performance was not just below the control group average but also below the established lower levels of performance level on the cognitive tasks for his age group. These studies were not included in the aforementioned WHO systematic review.

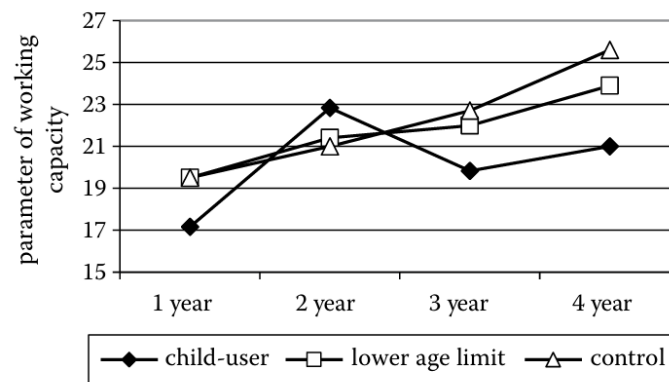
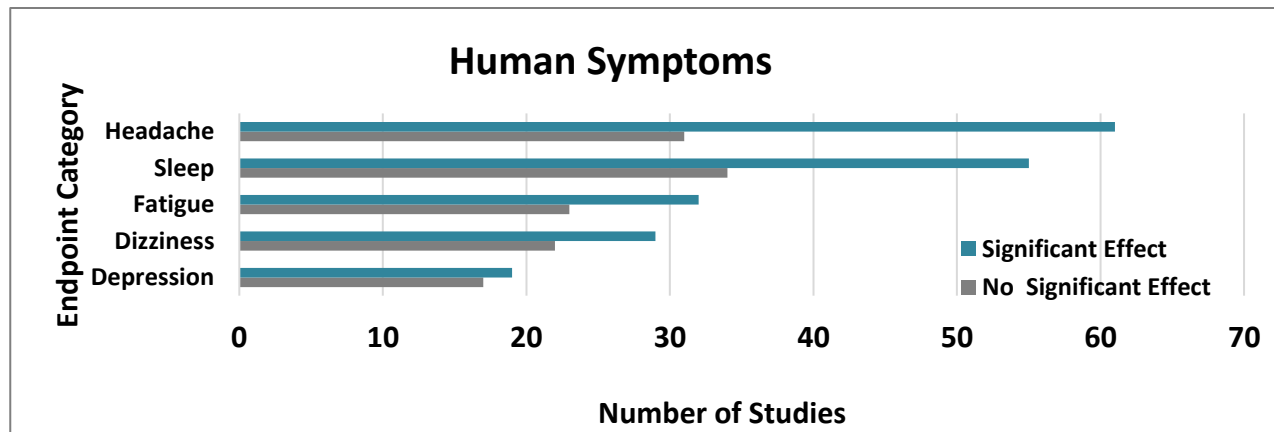


Figure 10.2 from (29), included with permission. Comparison of dynamics of individual parameters of working capacity children from the test and control groups (daily time of use: 1 year—2 min; 2 year—5 min; 3 year—15 min; 4 year—10 min).

The Blood Brain Barrier (BBB) usually protects the brain from toxins in the blood, so that any leakage across the BBB damage to neurons may occur. In repeated experiments spanning decades, EMF has been shown to create BBB leakage, neuronal damage including dark neurons, even at very low exposure intensities (30-32). Before mobile phones existed, Frey found that microwaves induced penetration of the BBB (33). Many industry-linked studies have subsequently shown null results.

Human symptoms

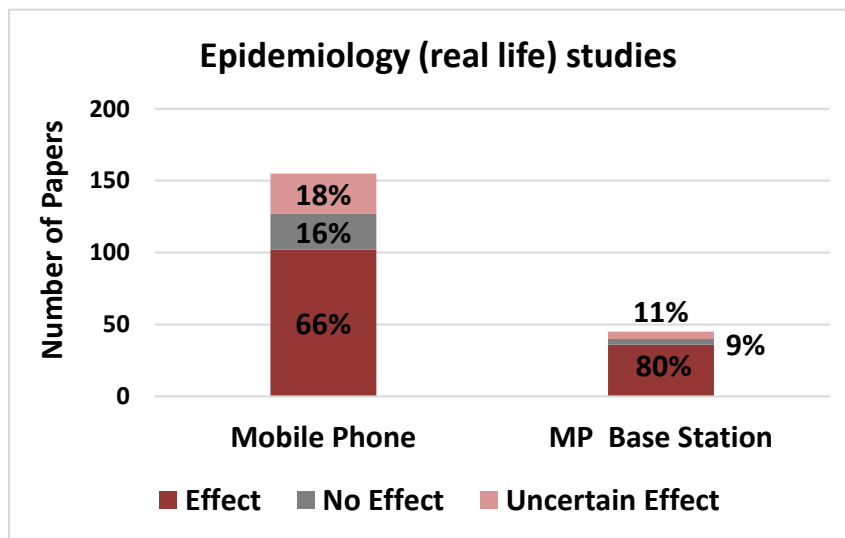


Studies showing effects on the brain and behaviour as a result of EMF exposures

Overall, the results above indicate that substantial evidence exists supporting the conjecture that EMFs in the radio frequency ranges used in telecommunications and modern life are affecting human health and biology. There are there are important health and biological effects in each category

Implications for real life exposures

The above results explain the results of real-world studies showing the effects of mobile phone and mobile phone base stations exposures. Dozens of papers have found an array of symptoms reported by people living or working nearby mobile phone base stations, and over a hundred papers have found an array of symptoms reported from people with higher use of mobile phones in daily life. The pattern of results is shown below, revealing substantial evidence for negative symptoms being reported by populations of people of different ages, genders, occupations and nationalities from all over the world.



The numbers of papers investigating the effects of living near mobile phone base stations and everyday mobile phone use

Mobile Phone Use

The Hardell group has conducted a series of case-controlled studies investigating the effects of mobile phone exposures on brain tumors (34-36). Their results show stronger effects for longer term mobile phone use, and for the same side of the head that the phone is used.

The conclusions drawn from their studies comply with all of the Bradford Hill criteria that are used to assess the reliability of epidemiology studies, and now used in court cases, to assess the quality of evidence (37, 38).

Surprisingly, the recent WHO commissioned systematic review investigating common cancers in humans (39) downgraded all of the Hardell group studies, with no substantial reasoning given, while at the same time used the result of the Danish cohort study, known to be flawed (40).

Living near towers

Most studies in the past have compared the frequency of self-reported symptoms of people living at different distances from mobile phone base stations (MPBS). Reported symptoms include headaches, memory deficiencies, sleep disturbances, tremors, dizziness, depressed mood, anxiety, increased irritability, Irregular heartbeat and chest discomfort, decreased appetite, nausea, difficulties in concentration, visual disturbances, skin disorders, hair loss, sleeping difficulties, and fertility issues.

However, some recent studies have investigated more objective measures such as blood parameters of people living in the vicinity of towers versus those living further away. These papers have shown concerning changes in the DNA and white blood cells of people living closer to MPBS, such as elevated frequency of micronuclei (fragments left behind after errors in cell division) and increased levels of antioxidants shown in human peripheral blood lymphocytes (41) and elevated chromosomal aberrations such as gaps and fragments (42). Such aberrations were at rates that are known to be problematic for exposures to ionizing radiation (high energy radiation that occurs from nuclear events, and that is strictly regulated, globally).

Our recent paper investigated self-reported symptoms in residents living near MPBS, including within 50m, due to rooftop positioning of masts, and hilly terrain (43). Power density of exposure was relatively very high for many nearby residents, in the range of power densities of 5–8 mW/m². Significantly higher numbers of symptoms were reported by residents with higher exposures across four main health categories (1) Mood-Energy: anxiety, agitation, increased irritability, fatigue, dizziness; (2) Cognitive- Sensory: concentration problems, memory problems, problem-solving issues, ear problems, skin problems, abnormal sensations; (3) Inflammatory: headache, allergy, increased infections, weight problems, chest pain, irregular heart beat; (4)

Anatomical: joint pain, muscle problems, nerve pain, digestive problems, loss of appetite, nausea. Moreover, the younger individuals (under 40 years) reported more inflammatory issues (infections and allergies) than the older individuals.

In a related study, we investigated blood parameters of people living in the same region (44). The results showed effects of both mobile phone use and mobile phone base station exposure, in combination with age and gender. Those more highly exposed had higher counts in certain white blood cells; i.e. basophiles and monocytes. Such higher levels are indicative of acute stress, or of the immune system battling a pathogen, infection or an inflammatory allergic reaction or chronic inflammation. Higher mobile phone exposures mostly affected lymphocytes, which underly the adaptive immune response, comprising T-cells and B-cells that are marshalled to fight pathogens and create antibodies, but which may be depleted after long-term stress. MPBS exposures contributed to absolute monocytes similar to the effects of smoking. Of concern, almost a quarter of those with high MPBS exposures had basophil counts above the clinical reference limits, while over half of those with heavy daily mobile phone use (4 to 6 hours) had lymphocyte counts above the limits, and most of these were under 30 years old.

Sensitive populations

The collections of health symptoms found in the above studies have been listed by WHO as symptoms associated with Electro-hypersensitivity Syndrome (EHS) (2005) (45). That is, people who experience these symptoms when exposed to mobile phones, modems, laptops, tablets, fitbits, baby monitors, all other wireless devices, Bluetooth devices, radar, satellite and mobile phone base stations (when close by or at higher power densities such as in rural regions) as well as many other sources of EMF used in everyday life. These people are therefore often unable to participate in normal life, and often lose their careers and relationships. The WHO has stated that there are currently no definitive diagnostic criteria for EHS. However, converging evidence from clinical, biological, and experimental studies support the recognition of EHS as a distinct, objectively identifiable, and well- characterized neurophysiological illness (46).

An Australian doctor published a series of case reports on neurological symptoms found from mobile phone use such as changes in C-fibers (pain fibers), and concluded that there is evidence that mobile phone use can cause symptoms in some people (47-51). Unfortunately, he was then dismissed from his position as medico for a telecommunications company.

EHS prevalence is high and seems to have increased. Our recent prevalence study showed that it is now reported at a rate of over 12% across the US, Canada and Australia. Moreover, there are high rates of co-prevalence of EHS with other inflammatory

conditions: chemical sensitivities, asthma conditions, autism spectrum disorders and fragrance sensitivity. In particular, reports of EHS were higher for males, 25-44 yrs old, who constitute a major component of the current workforce (52).

EHS has been around since the first wires were strung haphazardly across rooftops in London, crisscrossing the street in dense arrangements (53). However, EHS became notable in the modern era when PCs that also emitted chemical toxins from the hardware and plasticizers were first introduced into workplaces. Then EHS appeared in the hundreds, with the suspicion that some combination of chemical toxins and electromagnetic fields were the cause. However, this physical explanation was soon replaced with a psychosomatic explanation by industry-linked researchers, with the research money moving from the chemistry departments to the psychology departments (54).

A report was created at the time, summarizing the submissions of hundreds of people to a callout by the Swedish government, described how people's EHS symptoms occurred from a combination of EMF with computer exposures, mercury fillings, medical procedures and other environmental toxins and stressors (see Black on White (55)).

The current literature base on EHS is poor shape. EHS has been mostly tested in short-term laboratory provocation studies that average across everyone in a group, so that the data of sensitive persons (who are more responsive to EMF, including some of the control group members) are swamped out by the group averages, and are thus hidden in the statistics; e.g. *Changes varied strongly from subject to subject. Therefore, photic and microwave exposure did not cause statistically significant changes in the EEG activity level for the whole group. For some subjects, clear tendencies of changes in microwave on-off cycles were noticeable* (56).

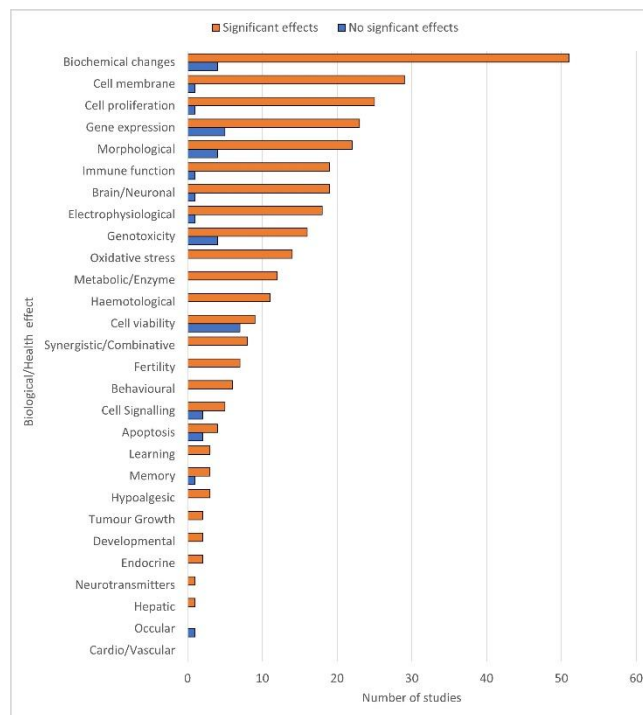
Poor subject selection, study design and analysis (57) have resulted in repeated provocation studies producing null or uncertain results, with a very high likelihood missing the important signals buried in the noise. These studies have been used to inform policy decisions to ignore this population in their great need for recognition and adjustments to be made (58). Doctors and independent medical researchers have created guidelines for dealing with person with EHS (59). Medical and health professionals are unaware of this condition and need urgent training and professional development in this area (60).

5G exposures

A recent series of case studies showing the effects of 5G exposures has been conducted in Sweden by Hardell and colleagues(61). Some of these are case studies with strong design that is used in experimental case studies, called an 'ABA' design. The evidence for the exposure causing the symptoms can be concluded, because when the exposure is given, the symptoms appear, then when it is

withdrawn, the symptoms disappear, and then when it is reintroduced, the symptoms reappear. This pattern occurred in real life in some of the Hardell studies (62, 63).

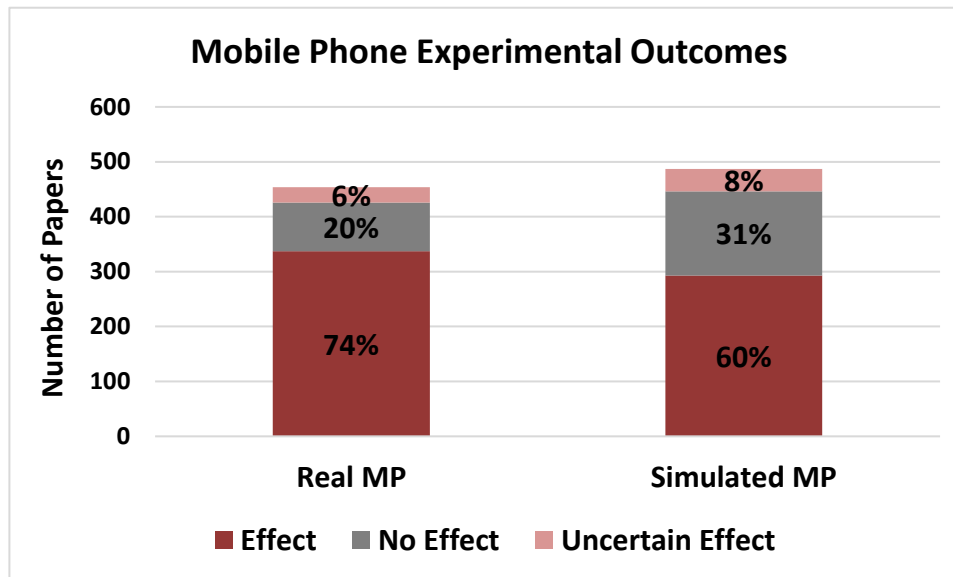
Our paper summarizing the literature base investigating millimeter waves (higher than 6Gigahertz) shows an array of health and biological effects, some with strong evidence. We concluded that while the science is still incomplete, that there is enough evidence for policy maker; i.e. there is enough smoke to suggest the risk of fire, and therefore there is an urgent need for protective policy.



Summary of health and bioeffects found from millimeter wave exposures

Factors influencing EMF effects

There are several important factors that create variation in the outcome of experiments. For example, experiments investigating the effects of mobile phones on biological and health outcomes can be influenced by whether the mobile phone used in the experiment is a real mobile phone sending real signals, or a simulation of a mobile phone created by a frequency generator. A real mobile phone is more likely to create visible effects, while a simulated signal is less likely (see below results, graphed from over 900 papers in ODEB). This is likely because real world devices contain characteristics not present in simulated signals, such as low frequency components and pulsing, spiking and modulations that constant variations to which the brain cannot adapt (64). These characteristics of signals are not factored into current safety guidelines of ICNIRP or the FCC.



Mobile phone and mobile tower experiments

Two prestigious institutions have conducted mobile phone studies in the recent past. The NTP study mimicked exposures to mobile phones, finding that the exposed male rats were more likely to develop malignant heart schwannomas. These rare nerve tumors have been previously linked to heavy cell phone use (36). The NTP study was peer reviewed with conclusions drawn that is provided “clear” evidence linking radiofrequency exposure to cancer (65, 66). The Ramazzini study (67) mimicked real word exposures to mobile phones base stations and found the same rare nerve tumors as the NTP study.

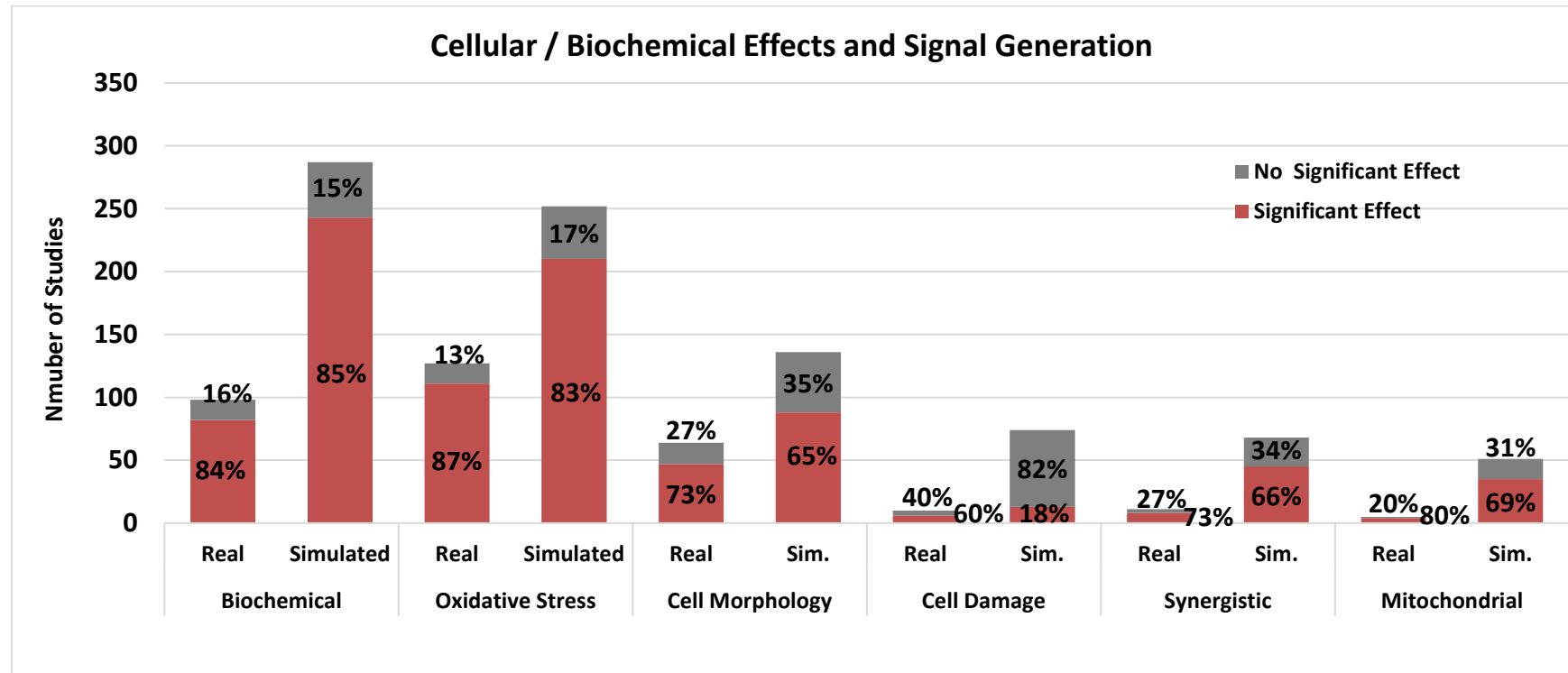
Summaries of factors influencing outcomes

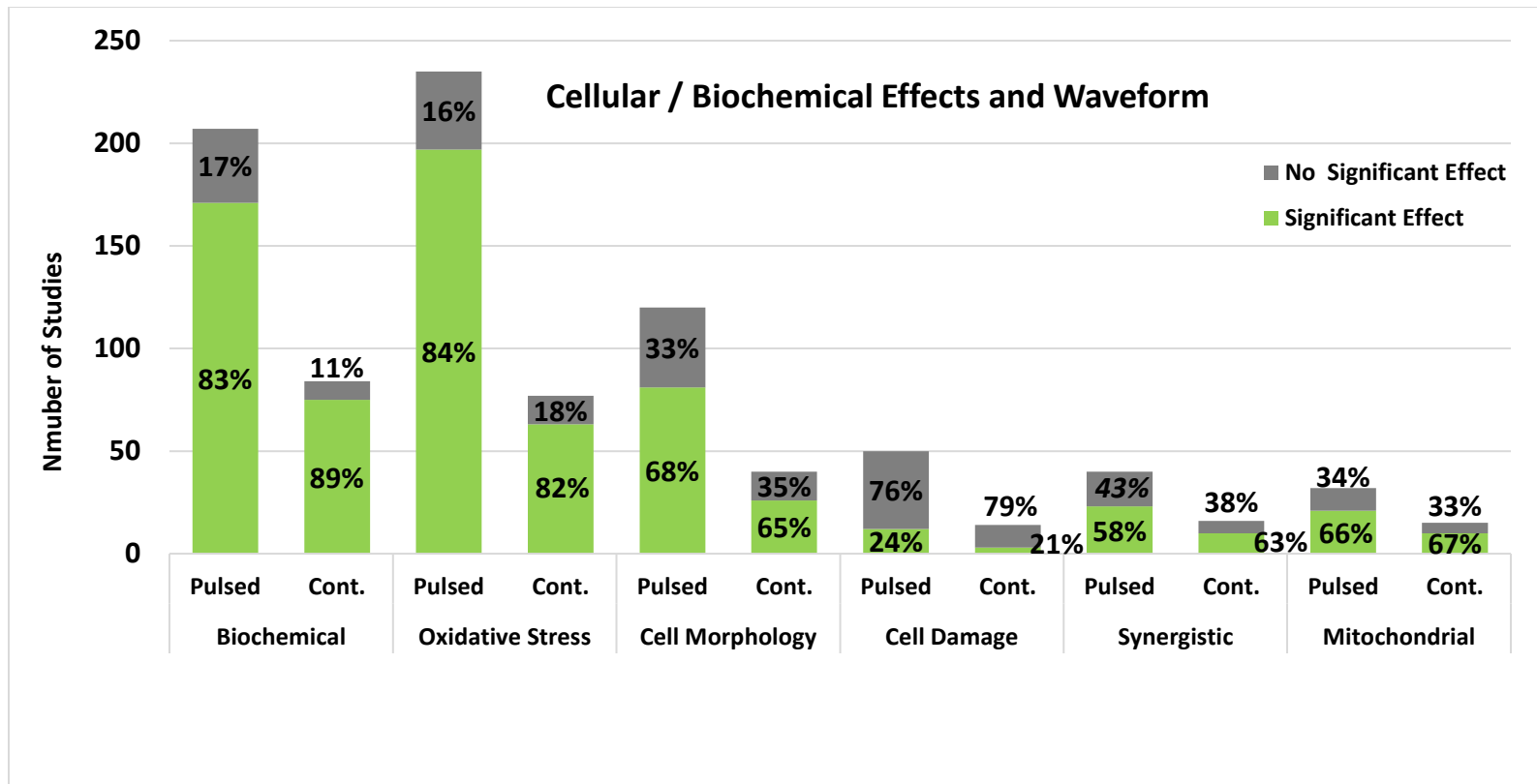
The effects of simulated versus real and pulsed versus continuous signals, as well as the effect of funding on experimental outcome for each of the main sets of outcomes are displayed in the sections below.

Overall, the results show that:

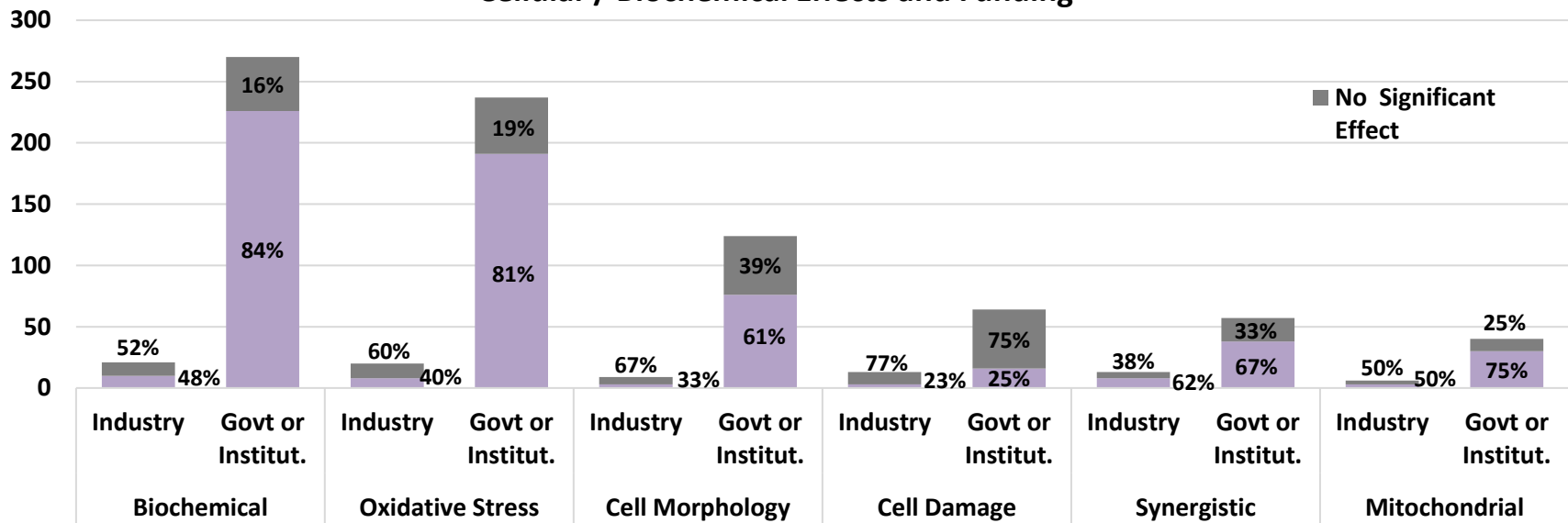
- More effects are found with real signals
- More effects are found with pulsed signals
- Funding determines outcomes, in that industry studies produce a greater proportion of null results than government / institutional studies.

Factors influencing Cellular / Biochemical outcomes

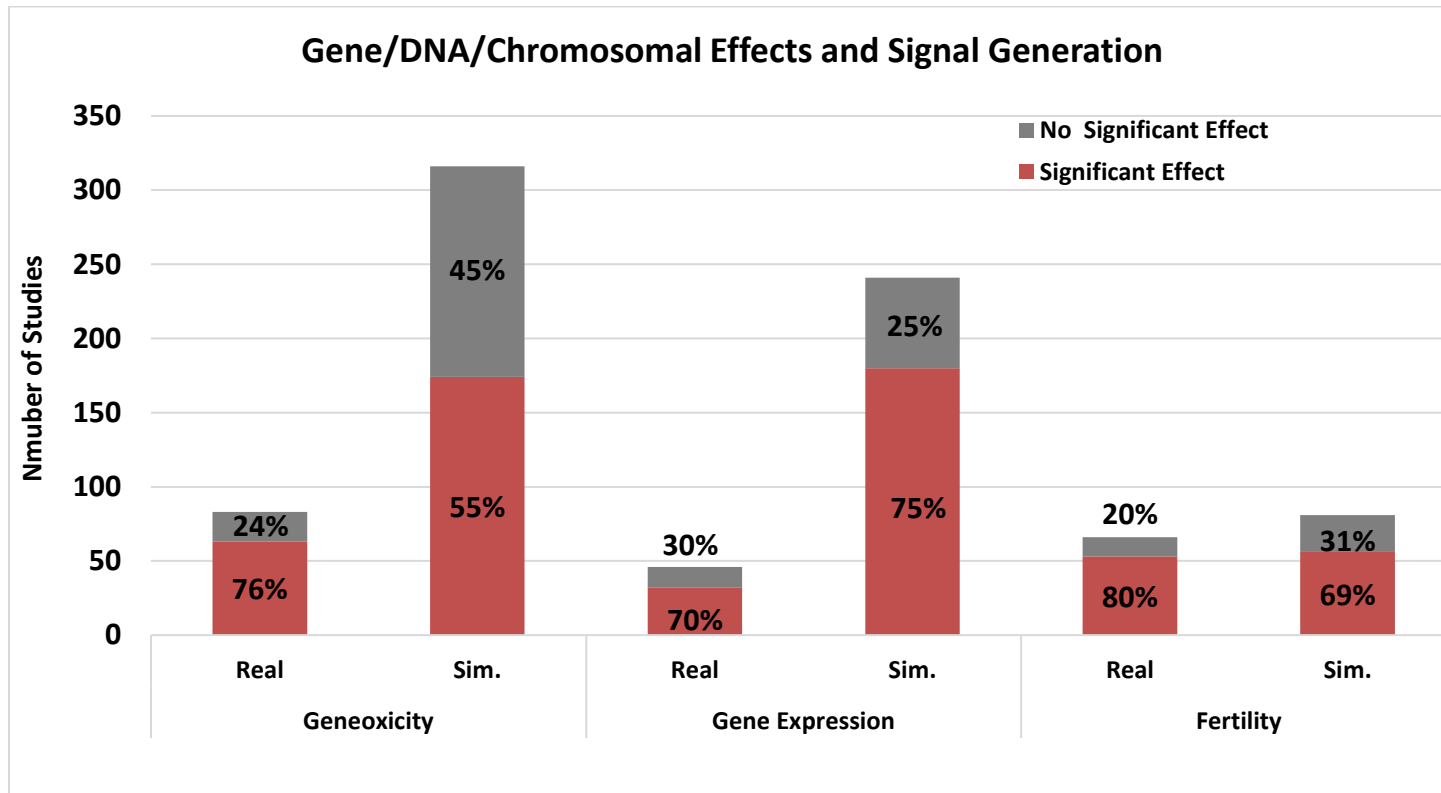




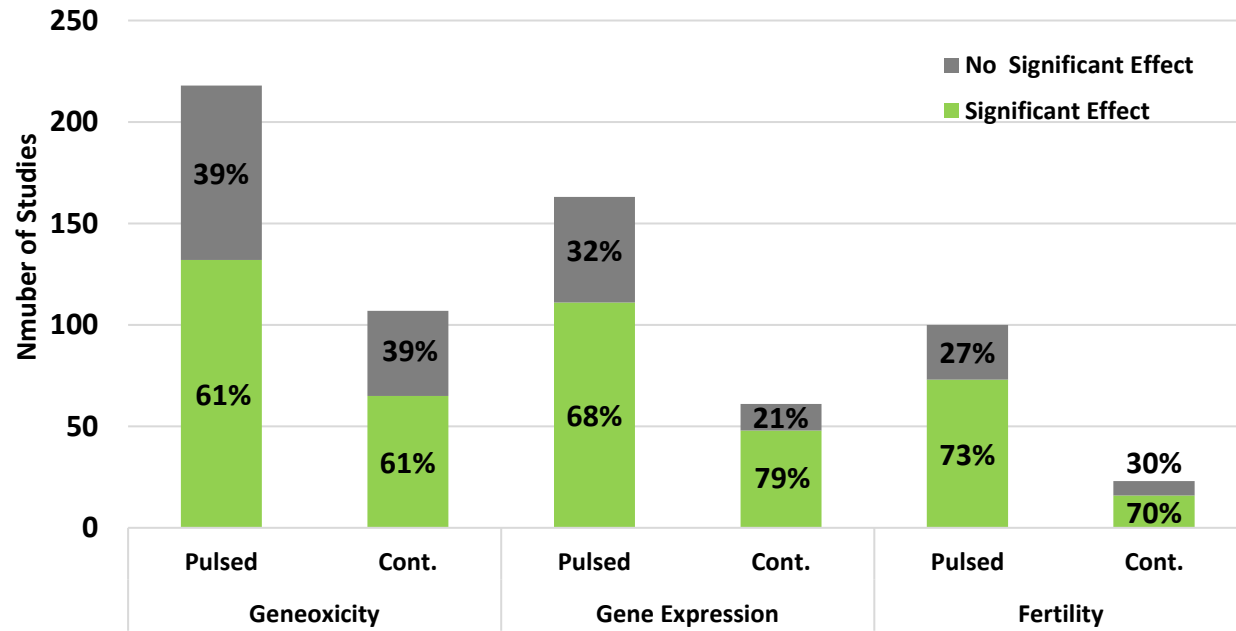
Cellular / Biochemical Effects and Funding



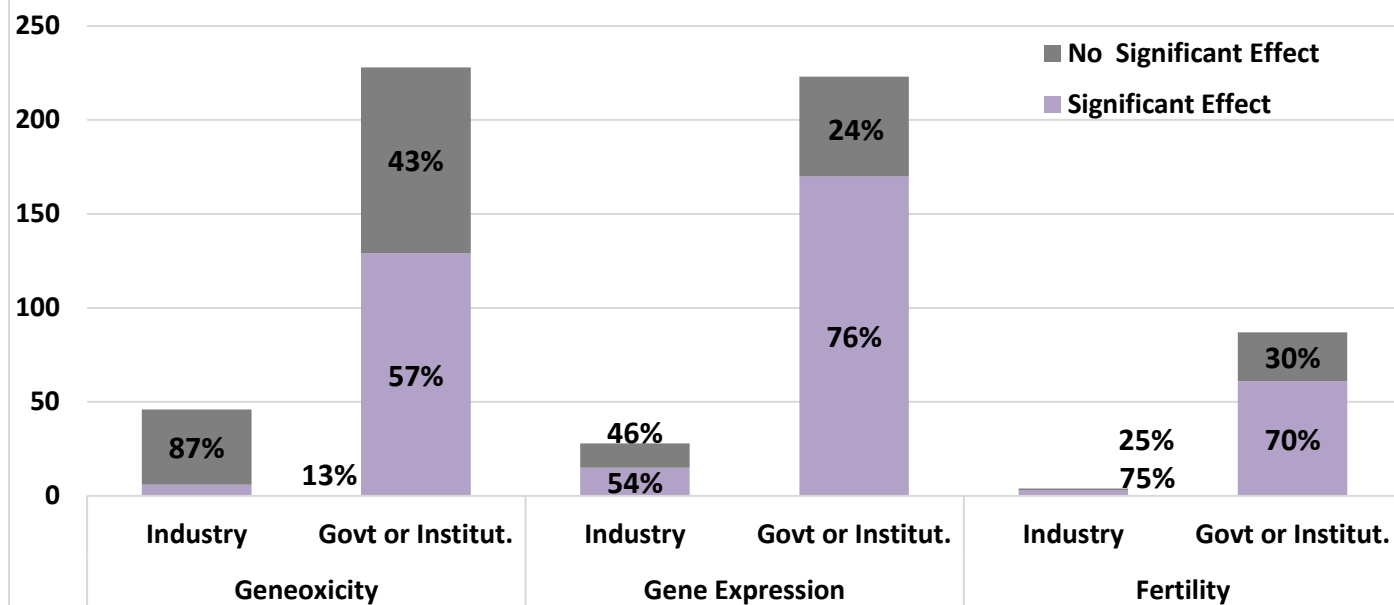
Factors influencing Genotoxicity and DNA Damage outcomes



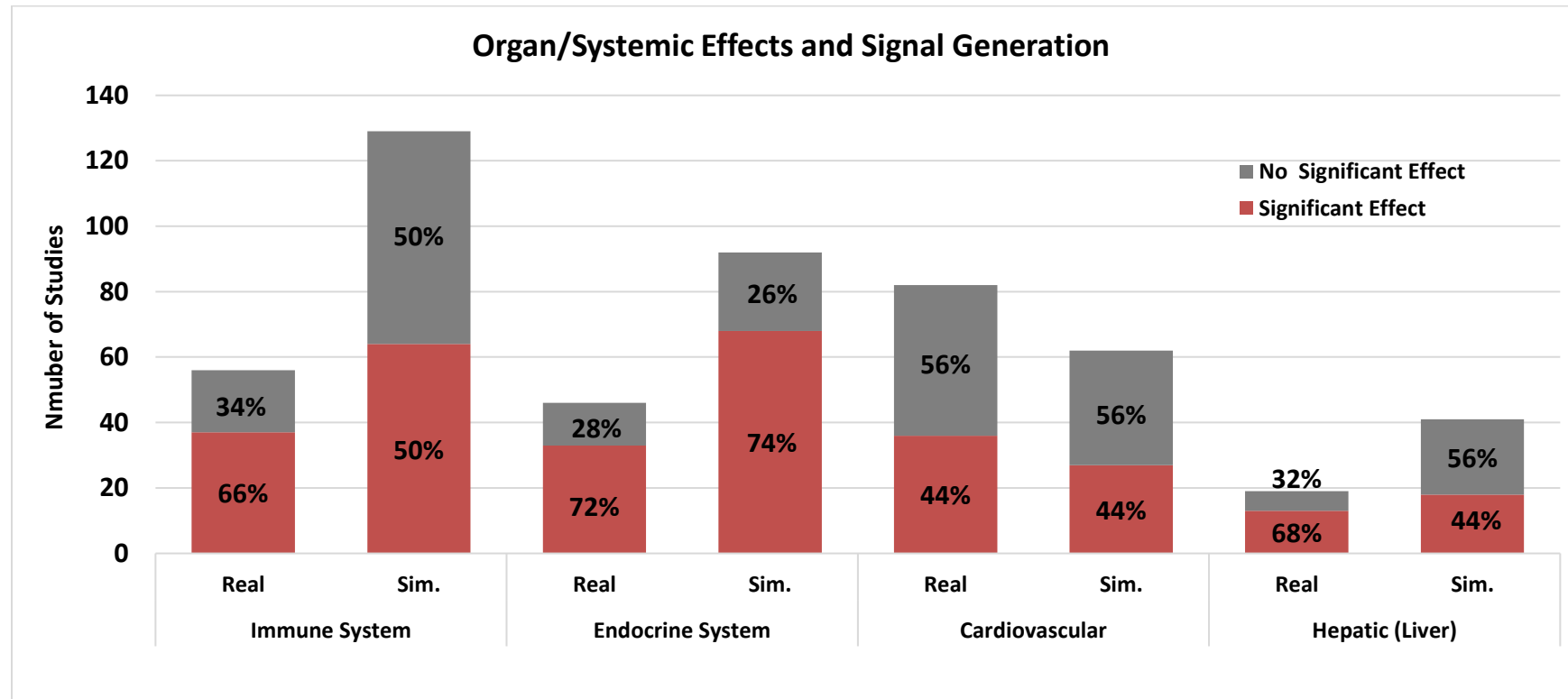
Gene/DNA/Chromosomal Effects and Waveform



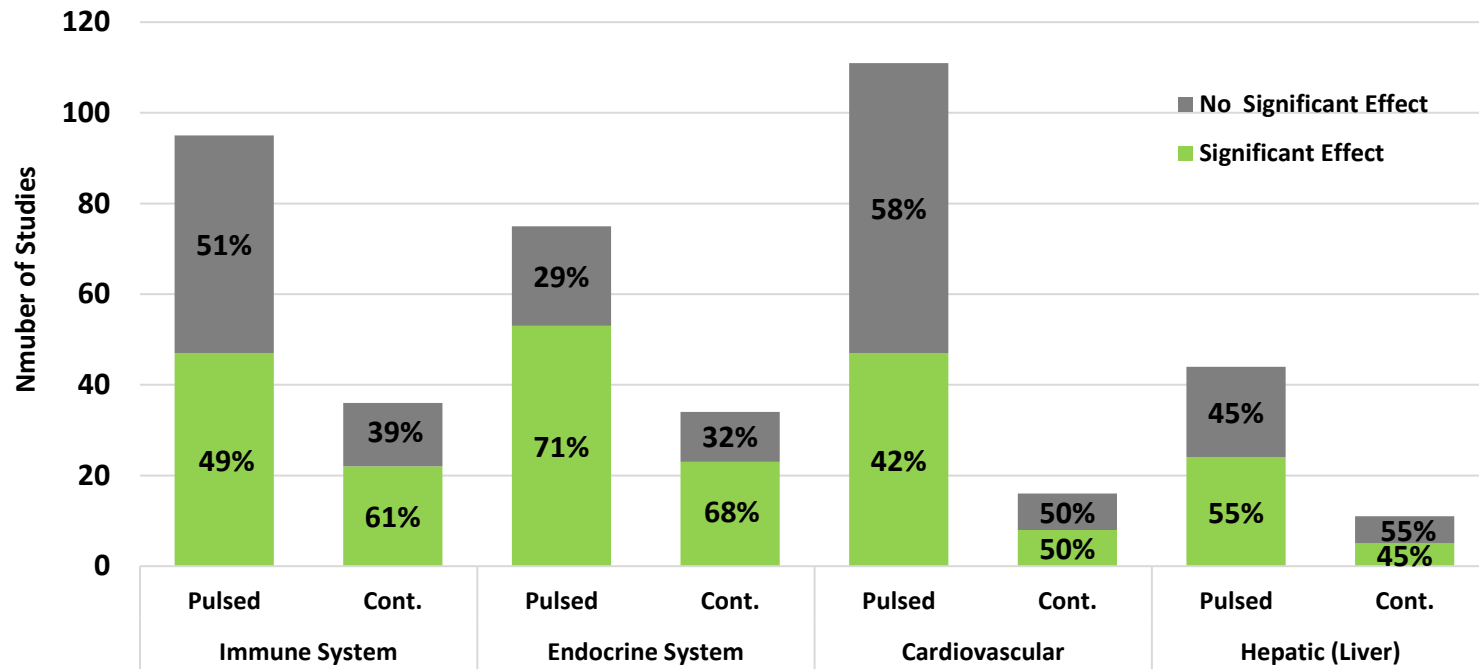
Gene/DNA/Chromosomal Effects and Funding



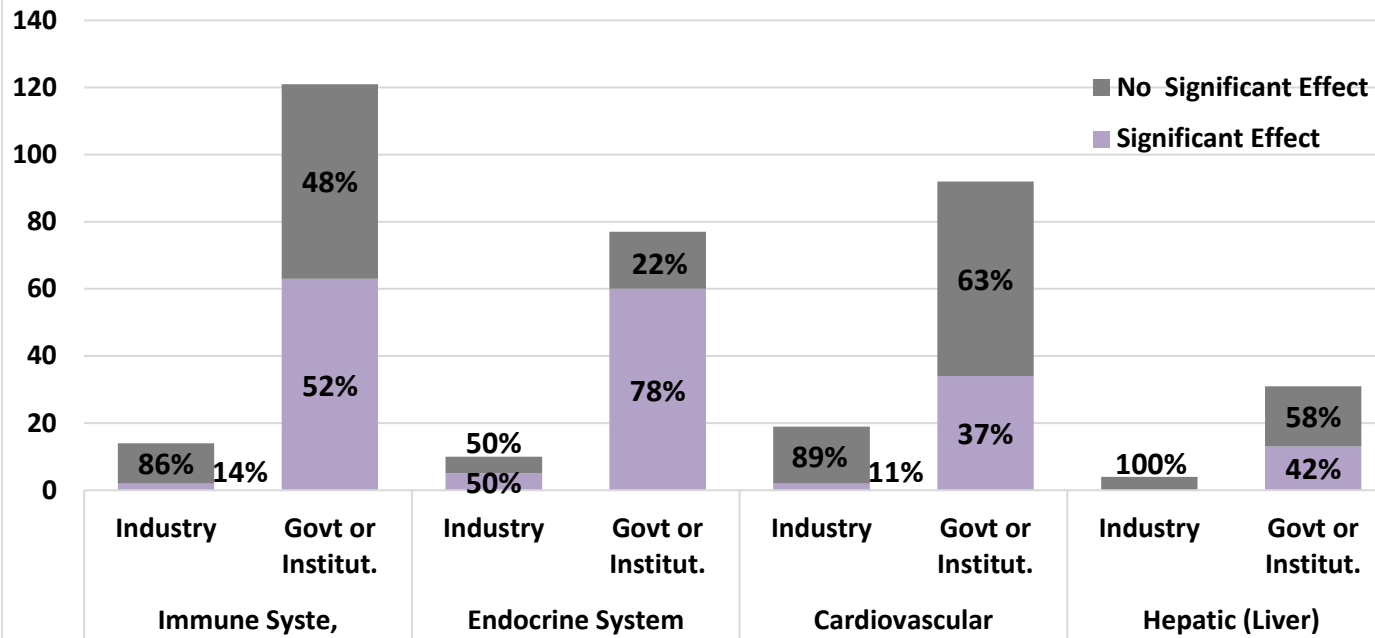
Factors influencing Body Organs and Systems outcomes



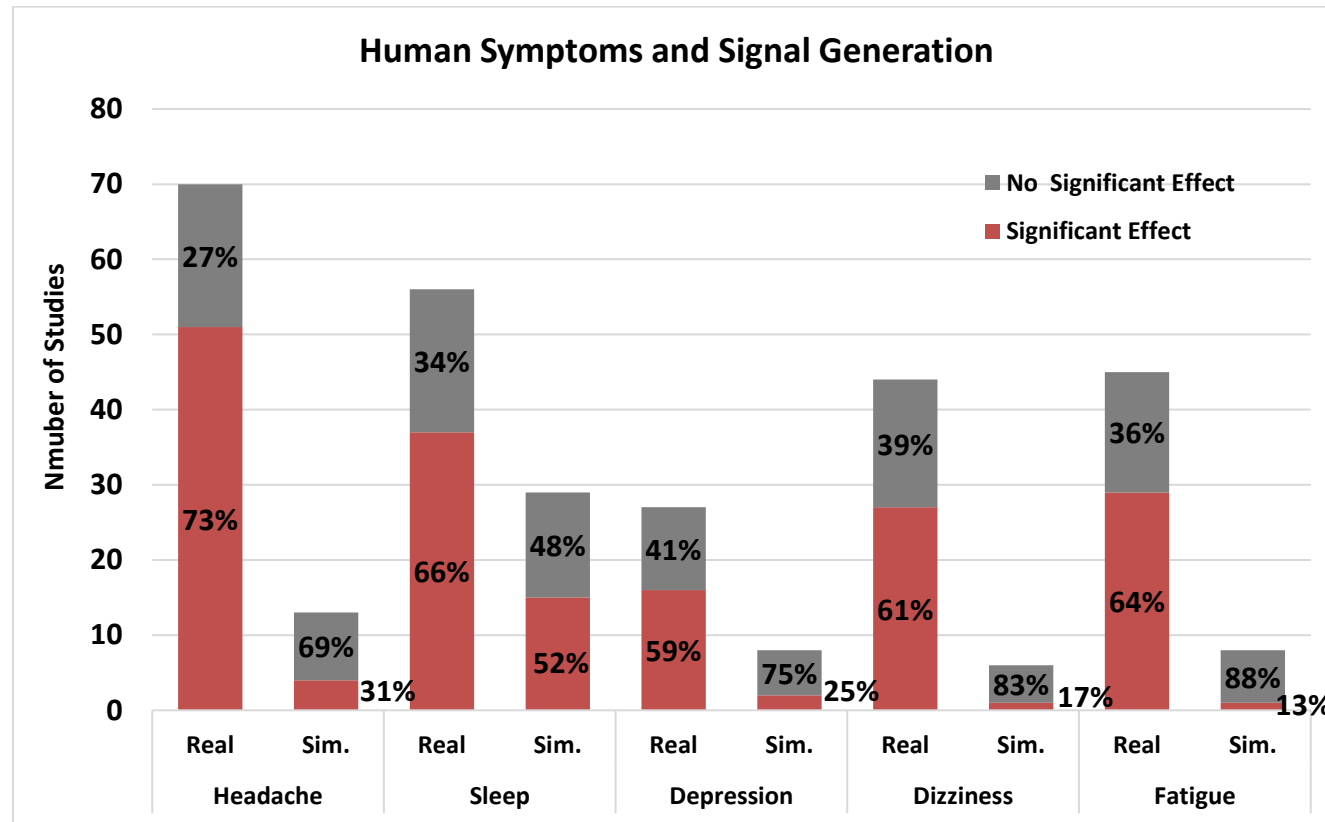
Organ/Systemic Effects and Waveform



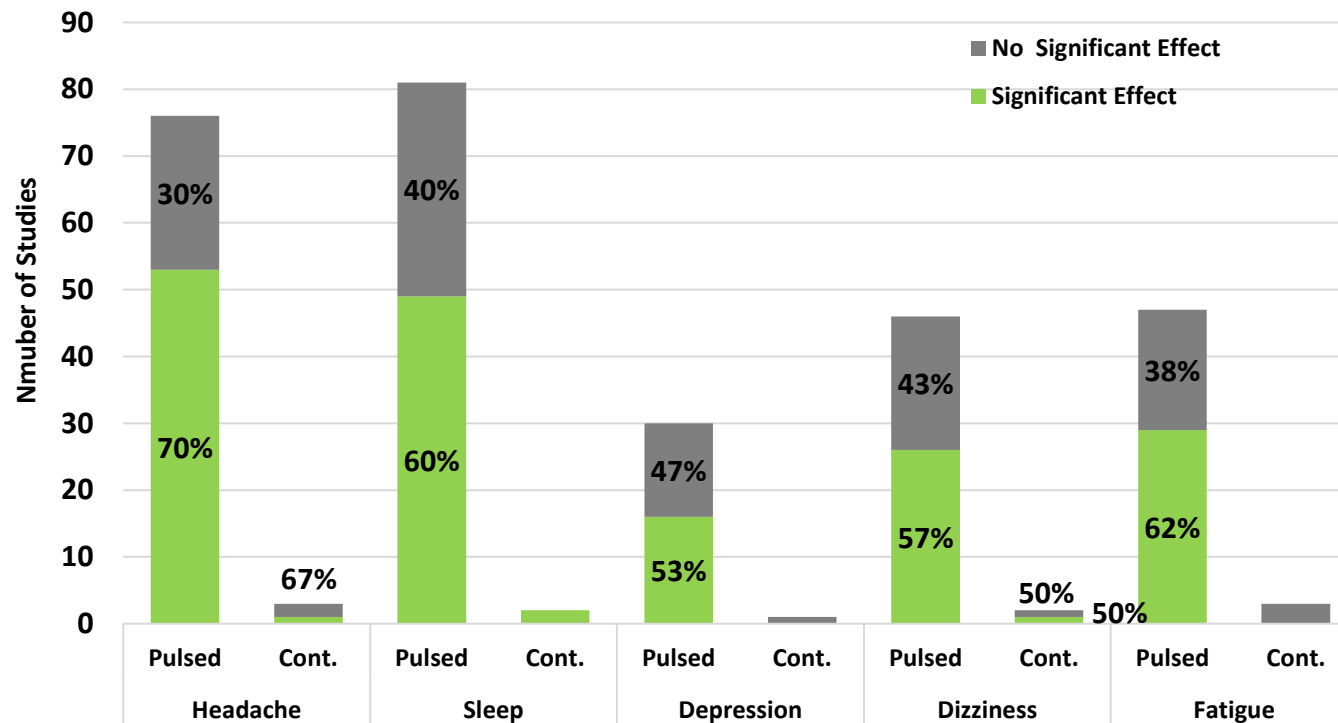
Organ/Systemic Effects and Funding



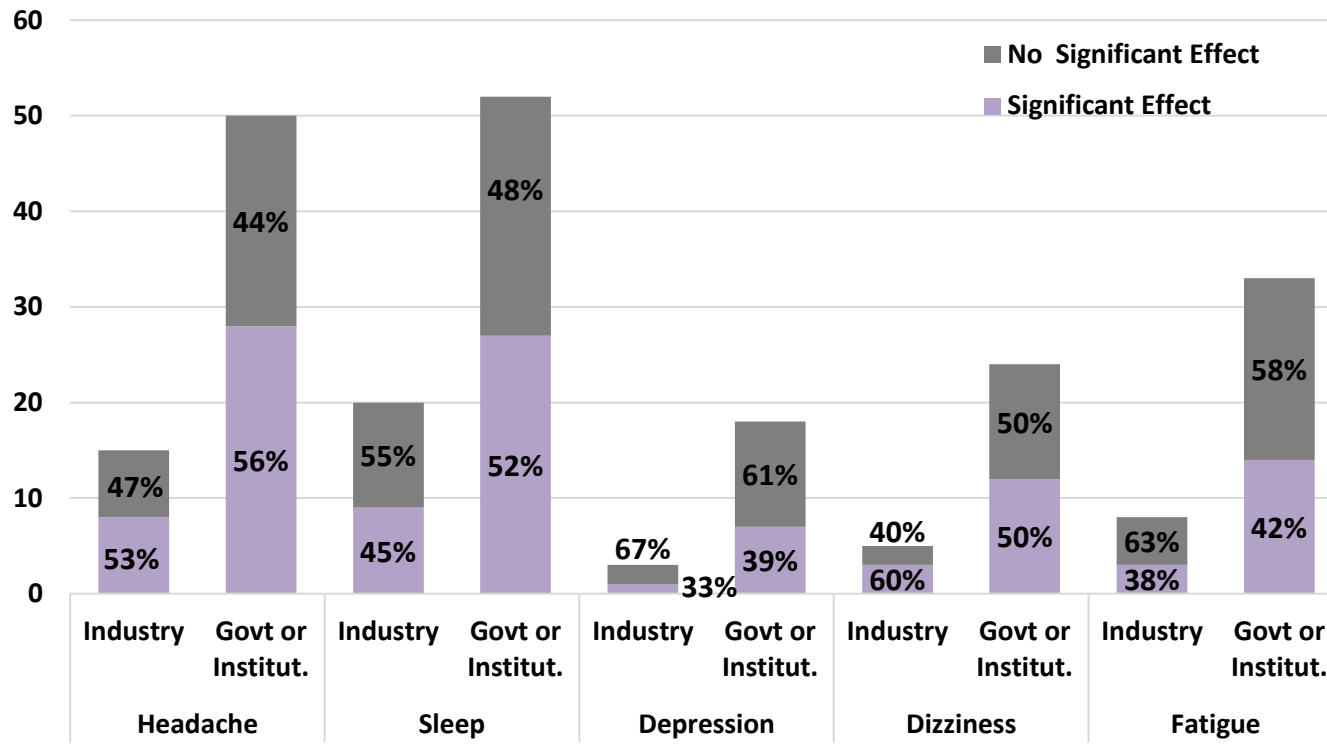
Factors influencing Human Symptom outcomes



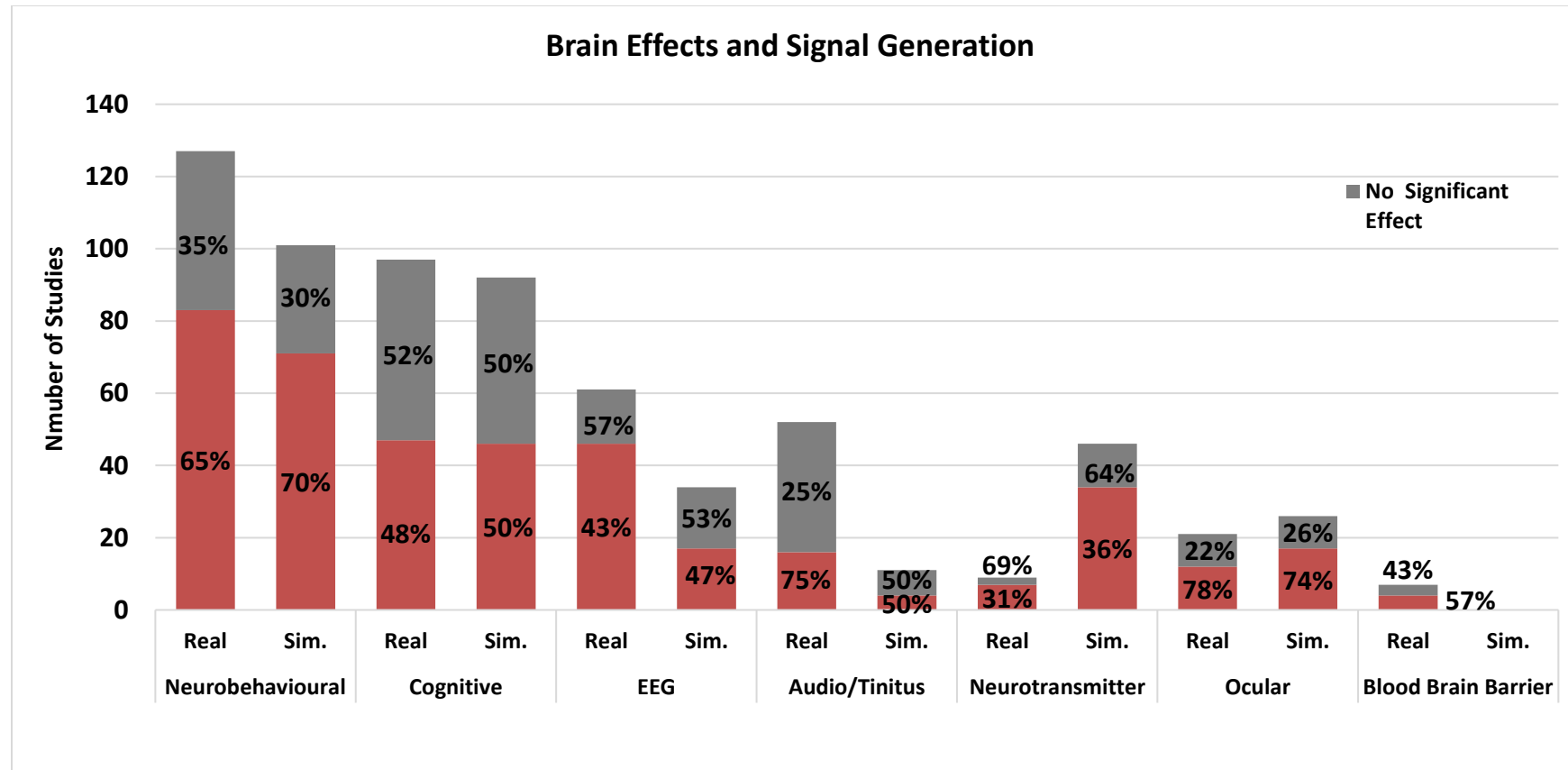
Human Symptoms and Waveform

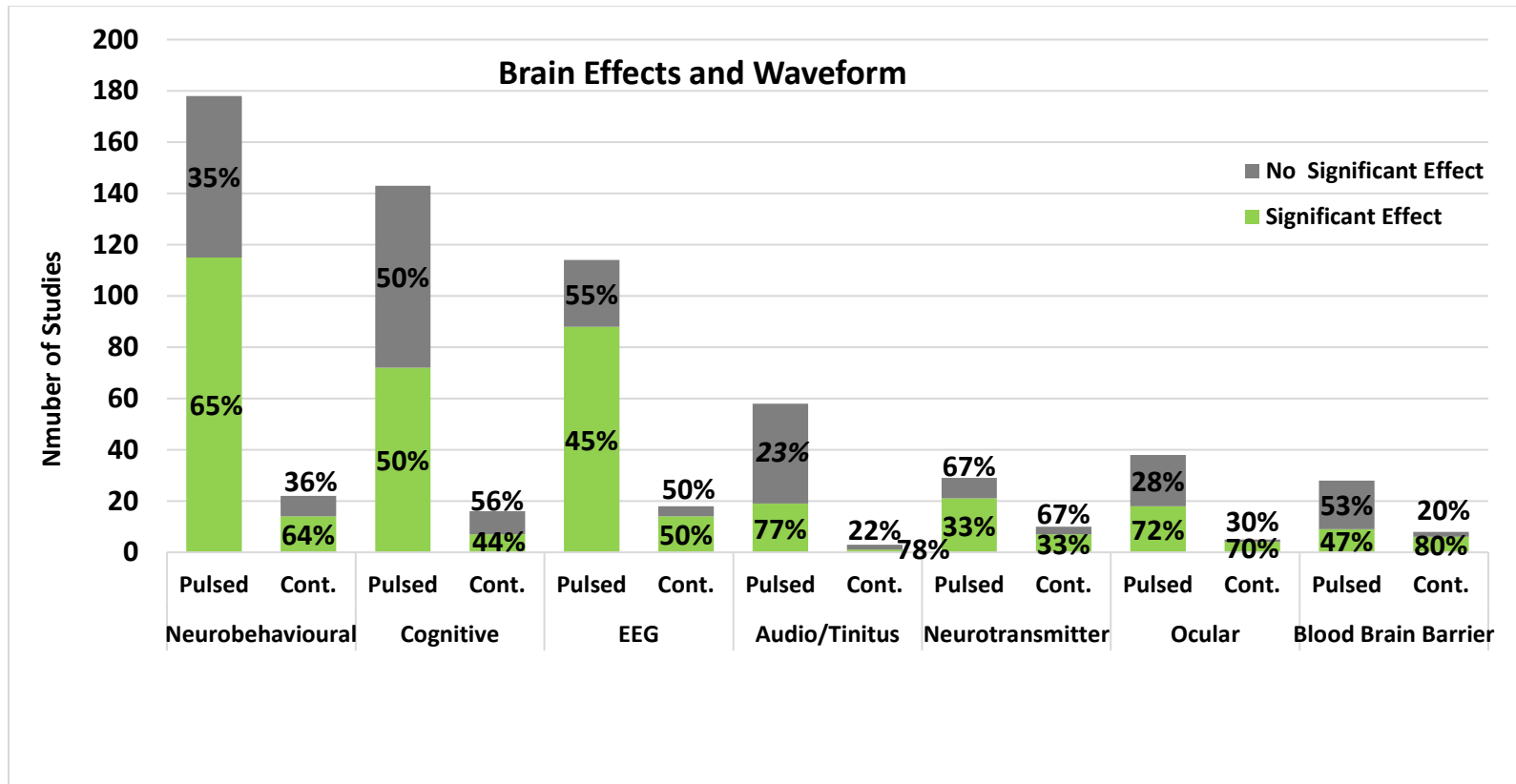


Human Symptoms and Funding

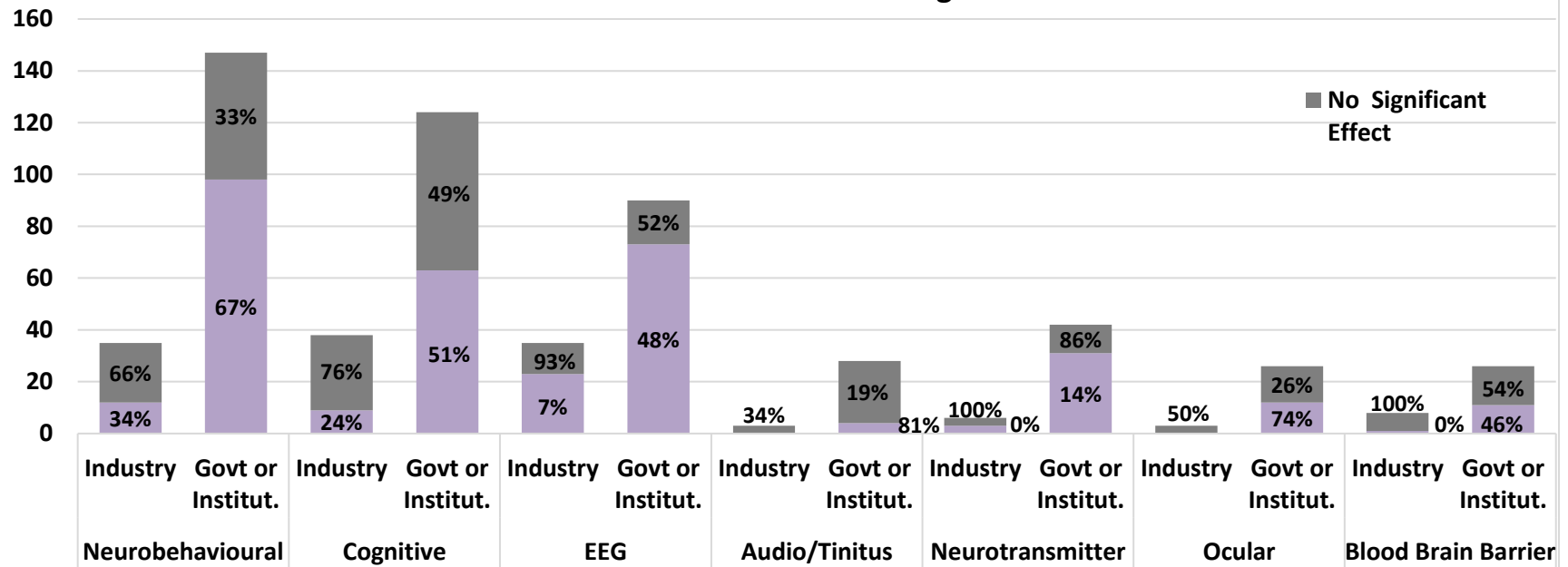


Factors influencing Brain Effect outcomes



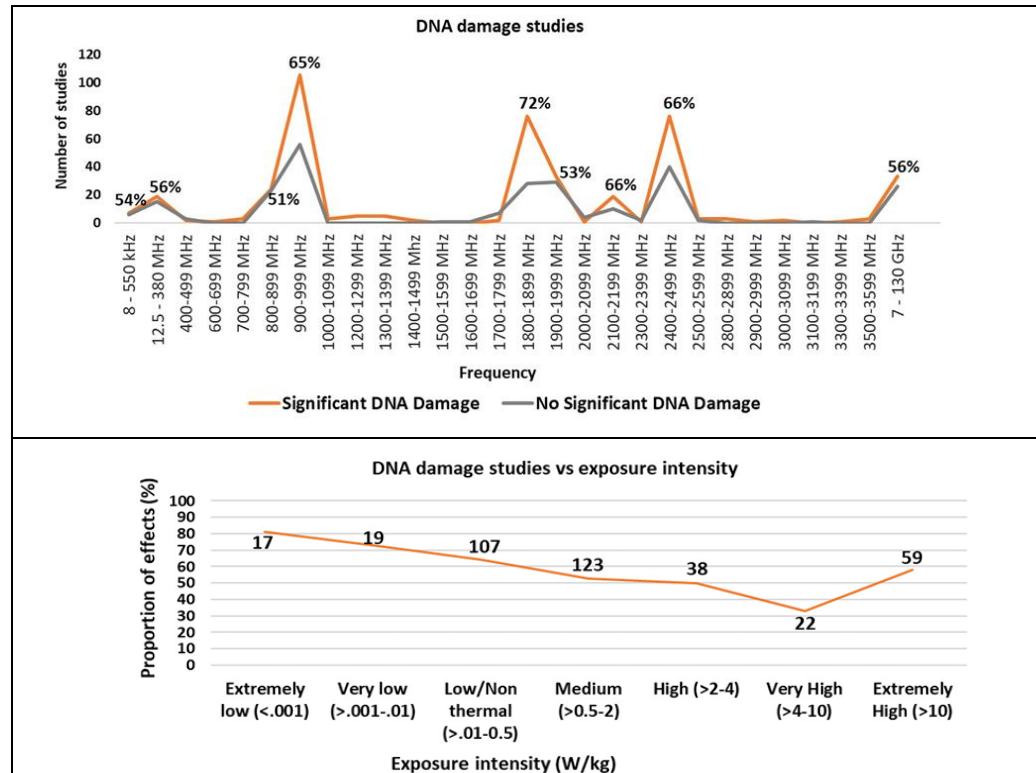


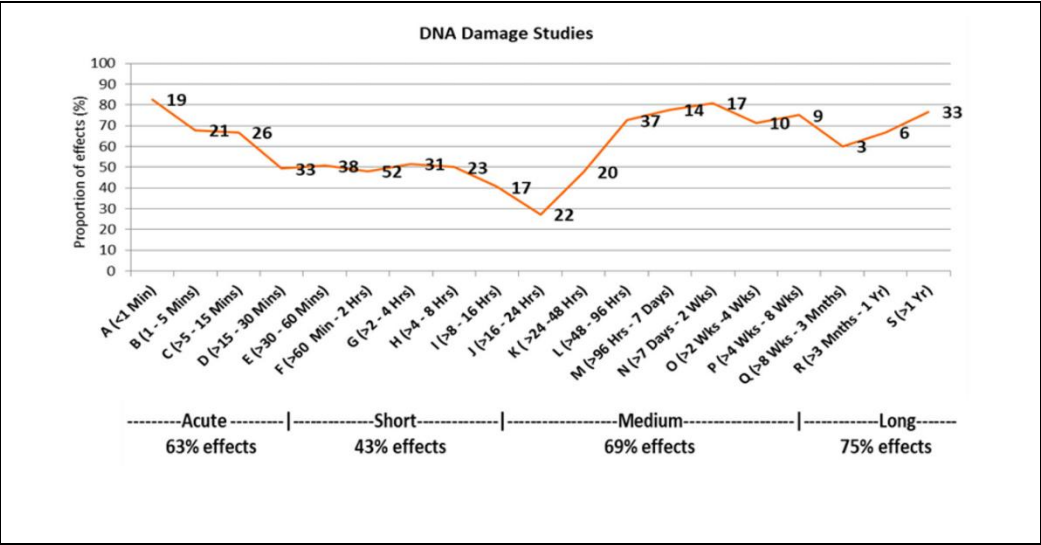
Brain Effects and Funding



Other factors influencing outcomes

There are other dimensions that are important for outcomes such as frequency, intensity and duration of exposures. Detailed exploration of these factors is beyond the scope of this report. However, the literature is clear that these dimensions need to be factored into considerations of health effects (and therefore into safety standards). Indeed, a recent scoping review paper looking at over 500 papers for genotoxicity/DNA damage effects, found that the effects change as frequency, duration and intensity change (see below, from (16) Figures 7 to 9 as well as complex combinations of these (not shown here; see original paper (16))).





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