Supplementary material for

Redefining electrosensitivity: A new literature-supported model

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Introduction

This appendix provides background material and literature support for the paper.

Life evolved in a relatively uncomplicated electromagnetic environment which included unpulsed emissions from the sun, the Earth's static magnetic field, the Schumann frequencies which encompass the planet and are caused by lightning, leading to, "a vertical current flow between the ground and the ionosphere of 1 - 3 x 10^-12 Amperes per square meter" (IMAGE NASA satellite program), and a small amount of ionising radiation that manages to penetrate the atmosphere and the Earth's magnetic field. The direction of human evolution relied on the first two of these: the Sun's warmth enabling life and its electromagnetic (EM) spectrum leading to the development of vision in that frequency range, and the geomagnetic field affecting the brain's alpha activity (Wang et al., 2019). It is not clear how necessary or beneficial the 7.8 Hz fundamental Schumann frequency is but it has been proposed as providing the synchronisation needed for intelligence (Cherry, 2003) and is apocryphally introduced in space-craft carrying humans in order to maintain their mental health. Ionising radiation can cause mutations, which can be damaging, but successful ones are also a necessary component of evolution.

Since the introduction of RFR-transmitting equipment in the early 1900s, each of numerous steps has added environmental and personal artificially generated RFR exposure[1] with new bands of radiofrequencies, moving up the spectrum to transmit increasingly higher frequency microwaves. In parallel, new modulation and transmission protocols have been introduced with each new 'Generation'. Frequencies used to transmit information, including voice, are digitally modulated; research indicates this increases bio-responses (Goodman, Greenebaum, & Marron, 1995) p.286. Bio-responses also depend on the state of the exposed cell (Goodman et al., 1995) .

5G will introduce millimetre (mm) wave transmissions to applications that (for the first time) intentionally expose populations routinely to such high frequencies in the near-field;[2] likewise for focused radiofrequency beams. Many countries have made bands of radiofrequencies in the 60 GHz region freely available, unlicensed. The most recent addition,

[1] For this paper, environmental exposure refers to those from remote sources such as routers and base-stations, while personal exposure refers to those from personal devices which the user can choose to turn off or go without

[2] Near-field distance can be approximated as the same as the wave-length in question

at the time of writing, was in mid-2019 by the Conference of Postal and Telecommunications Administrations, who approved the rollout of unlicensed 5G in Europe, using 59 - 71 GHz (Storm, 2019, Dec 20). Several countries had begun implementing this by April 2020.

Brief history of electrohypersensitivity

The existence of electromagnetic waves that later came to be called radio waves was first demonstrated by Hertz in 1887, with Marconi building the first commercial radio transmitting station in 1894, a mere one and quarter centuries ago. Early in the 1900s, once it was realised that high-powered radiofrequency exposure caused local or whole-body heating, it was used medically through diathermy to treat conditions such as arthritis, and to induce fever in order to stimulate the body's own healing mechanisms.

But by 1930, people working with microwave emitting equipment began reporting unwanted health symptoms, including headaches, to their employers. One example is General Electric, who instigated an investigation. It was found that complaints were generally related to those working near microwave transmitters. The complainants' temperature was elevated, up to a little over one degree Celsius.

With development of technology, especially radar, complaints of health problems increased. During WWII many people working near radar or with microwave transmitters complained it caused baldness and temporary sterility and made them feel over-heated. This was referred to colloquially as Microwave Sickness. Despite this, it was some time before Standards were introduced to prevent heat damage from these exposures in the general public and in those working near transmitting equipment.

In the meantime, technological development progressed and complaints, especially in office workers, increased. Several countries coined other syndrome names from the 1960s onwards. There was a rapid uptake of multiple electric devices in offices and homes, including televisions and then computer screens with cathode ray tubes.

The introduction of mobile phones began slowly. The first portable mobile phone was introduced in 1973, with popularity growing rapidly from the late 1990s once they were more generally affordable. A quarter of Australians had a mobile in 1998 and a third by 1999. 'Smart' phones were introduced only 13 years ago. Since then, a vast range of wireless transmitting devices has been added, and this is accelerating exponentially with the introduction and growth of the Internet of Things (IoT).[3]

Description of EHS

EHS has been described by the World Health Organisation (WHO) as comprising, "nervous system symptoms like headache, fatigue, stress, sleep disturbances, skin symptoms like prickling, burning sensations and rashes, pain and ache in muscles and many other health problems" (World Health Organisation, 2004).

Other symptoms include itch, dryness, and smarting of the eyes; motor function problems (e.g. trunk, limbs, joint pain or aches, numbness, weakness); cognitive challenges (e.g. memory impairment, lack of concentration, anxiety, depression). These symptoms are non-specific to EHS and are subjective (cannot be measured). However, others are objective, such

[3] IoT is the embedding of unique identifying transmitters in almost everything to enable automatic machine-to-machine transmission of user data. This can be used by the product's manufacturer for targeted marketing, but ultimately is intended to build the capabilities of machine-to-machine Artificial Intelligence.

as those impacting internal organs (e.g. heart palpitations and digestive problems) and resulting in typical markers for inflammation.

This wide range of symptoms, when resulting from exposure to electromagnetic fields, came to be known collectively as electromagnetic hypersensitivity, or electrohypersensitivity for short (EHS).

Aetiology of EHS and responses to it

Strongly polarised responses to the aetiology of EHS are on-going. On the one hand, there are EHS studies presenting objective evidence suggesting that direct effects of the exposure do occur and that some people are more vulnerable than others. Some of these are non-specific to EHS (Belpomme & Irigaray, 2020; de Luca et al., 2014; Irigaray, Caccamo, & Belpomme, 2018; Wood, Loughran, & Stough, 2006); these include inflammatory and disordered immune responses. Other vulnerabilities appear to be specific (de Luca et al., 2014; Luo et al., 2019), such as genetic propensity.

On the other hand, there are those who acknowledge the symptoms as real, but consider that they do not result directly from the interaction of RFR with the body; this includes the WHO and some scientists working in this area. Some of the latter group, which includes at least one national advisory body, refer to EHS in its entirety as a 'nocebo effect'.

These positions are becoming more entrenched. The WHO's 2020 web-page states that, "Governments should provide appropriately targeted and balanced information about potential health hazards of EMF to EHS individuals, health-care professionals and employers. The information should include a clear statement that no scientific basis currently exists for a connection between EHS and exposure to EMF" (World Health Organisation, 2020a). This has gone hand-in-hand with a 2020 update of International Classification of Diseases (ICD)[4] 10 Code W 90.0 which previously provided for adverse health outcomes from radiofrequency transmitting devices such as mobile phones. This is now Code W90.0XXA which only acknowledges "HIPPA-covered transactions" and "over-exposure". Confusingly, it can also be used for "overexposure to radioactive isotopes" despite this code being for "Exposure to radiofrequency: initial encounter" (World Health Organisation, 2020b). Radiofrequencies are not radioactive.

Inconsistent EHS research methods

EHS research results from similar studies have not always been consistent partly due to differences in methodology. For instance, neural function is affected by mobile phones, but results vary depending on exposure duration (Croft et al., 2002).

Some studies looking for physiological changes in real time have exposure periods that are too brief. One possible example examined cortisol, IgA and alpha amylase levels in saliva after four individual source exposures (e.g. WiFi, GSM) at 5 minutes each and no significant difference was found between EHS and control results (Andrianome, Yahia-Cherif, & Selmaoui, 2019).

On the other hand, another approach (Siqueira et al., 2016) reported significantly increased inflammatory cytokine profile in saliva ipsilateral to the side of usual device use when

[4] The International Code of Diseases is overseen by the WHO.

compared with saliva from the other side. This study provides helpful pointers concerning impacts of methodology on outcomes.

Results of somewhat longer exposures in other studies indicate that averaging the results of multiple participants hides individual, statistically significant, responses (Bolte et al., 2019; Wood et al., 2006).

There are many difficulties in choosing suitable exposure conditions for EHS studies. An important consideration is that EHS responses are not uniform; they are individual. This is generally observed by responders. At first EHS sufferers may have very limited conditions that trigger a response (which may only occur after more delay than is allowed for), while those who have had it for some years are often reluctant to take part in exposure studies.

Different sensitivities depend upon frequency band, modulation type, power intensity and possibly a greater impact in a real-life setting where there are assorted environmental RFR and other exposures which differs considerably to those trialled in laboratory studies. This list is not exhaustive but illustrates the sense of single-subject design in which the subject serves as their own control.

Objective bio-markers of EHS

A range of specialised and standard bio-marker tests have been identified for assessing the likely presence of EHS objectively (table 1 in main paper). Most recently, it has been found that those with EHS have lower cerebral pulsatility activity than non-EHS participants (Greco, 2020), confirming earlier indications (Irigaray, Lebar, & Belpomme, 2018). This applied particularly in the capsulothalamic area of the brain's temporal lobes. The authors consider that ultrasonic cerebral tomosphygmography and transcranial Doppler ultrasonography perhaps offer the best diagnostic tools to date.

Commonly found bio-effects of RFR exposure

The most frequently observed effects are altered enzyme activity/protein levels and protein damage (418), oxidative stress markers/increased ROS (346), assorted biochemical changes (331), cell irregularities/damage/morphological changes (187), neuro behavioural and cognitive effects (171), mutagenic and genotoxic DNA damage (154), and altered gene expression (144). The bracketed numbers indicate the number of times these effects were found in studies included in the ORSAA database by 2018 (Leach, Weller, & Redmayne, 2018). Many of these studies were in vitro or in vivo.

A review of effects of WiFi exposure indicated that, "[Voltage gated calcium channel] VGCC activation via EMF interaction with the VGCC voltage sensor seems to be the predominant mechanism of action of EMFs" (Pall, 2018).

Clearly bio-effects of RFR exposure in animals or in vitro are not 'nocebo', do not occur at the conscious level, and cannot be influenced psychologically. Effects of stress related to animals' test situations is commonly accounted for in methodology.

Some known impacts of RFR exposure are used therapeutically. Others can lead to acute physical symptoms or long-term disease. For instance, unresolved ROS load leads to oxidative stress, which in turn can cause inflammation in those with less than adequate self-healing or impaired immune/inflammatory systems may lead to somatic responses which could cause several of the EHS symptoms depending upon which tissues are affected. Ultimately, unresolved ROS has been linked to several diseases (Bandara & Weller, 2017; Umeno, Biju, & Yoshida, 2017).

It has also been proposed that damage to myelin sheathing from RFR exposure, may help explain EHS (Redmayne & Johansson, 2014). Such damage would leave myelinated neurons more vulnerable to further damage from exogenous fields. Post-ganglionic ANS neurons are not myelinated meaning they may be more vulnerable anyway.

EHS research evidence (Belpomme, Campagnac, & Irigaray, 2015; de Luca et al., 2014) and many other RFR exposure studies have found common indicators of inflammation (Leach et al., 2018).

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Positive action

Personal steps can be taken. Since much of the body's self-repair is done during sleep (Boeselt et al., 2019; Mourrain & Wang, 2019), a sensible measure is to minimise RFR exposure during the sleep period. A positive benefit of not having a switched-on phone by the bed is that the sleeper will not be woken by it. Research has shown that this is common even for children who have an active phone by the bed (Redmayne, Smith, & Abramson, 2013). The phone should not be carried in clothing or the hand. Further, it is suggested that a better balance in the ANS can be encouraged through certain breathing exercises (Gerritsen & Band, 2018).

The skin is our first line of defence from environmental threat. A response to RFR exposure that was observed 19 years ago is that mast cells rise to the skin surface (Johansson et al., 2001); activation of mast cells occurs as a defence response of the immune system (Chovatiya & Medzhitov, 2014). It will be interesting to see whether this type of response, and other dermal responses, increase in places where the high frequency, millimetre wave component of 5G is active, as generally the mm component will be absorbed entirely in the upper layers of the skin. Currently, many places advertising live 5G are only using the medium frequency band (around 3.5 GHz) supported by 4G and fibre. We recommend that Governments introduce protected areas with an absolute minimum of environmental RFR exposures. Internet can be maintained by supplying fibre and using wired computers.

Government auction and Telco introduction of devices transmitting radiofrequency bands higher than 10 GHz and new transmission protocols are unwise until and unless a body of relevant research fails to reveal biological hazards.

Government and medical support in moderating the range of personal and environmental RFR exposure is strongly recommended, particularly for those presenting with 'typical' signs and symptoms of EHS, in addition to those whose sudden onset disease may be a 'catastrophic' response to RFR exposure over the years.

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