The Public's Reactions to Precaution

On the Effects of Health Recommendations Regarding Wireless Communication Technologies

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Summary

When technological innovations become publicly available, it is often not entirely clear whether they might have negative effects, e.g. on their user's health. In that situation, calls for precaution are frequently voiced. Precautionary measures can take different forms, ranging from a complete ban over stricter limits or controls to merely telling users what they can do to decrease possible risks by themselves. The current work focusses on the latter form of precaution – 'precautionary recommendations' – and its effects on the recipients of the recommendations.

An innovation that has changed human life profoundly within the last 25 years is modern wireless communication technology. Mobile phones, laptops, tablets, and other wireless devices emit electromagnetic fields in the radiofrequency range (RF EMFs) that interact with the human body. Most health authorities worldwide agree in the assessment that there is 'no convincing evidence for detrimental health effects of RF EMFs'. However, some uncertainties remain. This is also reflected in the International Agency for Research on Cancer´s (IARC) assessment of RF EMFs from mobile phones as 'possibly carcinogenic'. Under these circumstances, many national health authorities give precautionary recommendations, e.g. to reduce personal exposure by using a headset for mobile phone calls. The main benefit of precautionary recommendations is that people would have been protected better in case it turned out that wireless communication devices had detrimental health effects after all. However, precautionary recommendations also involve costs: As part of the current work, a meta-analysis of all studies about the effect of precautionary recommendations on recipients' risk perception was conducted. The results show that precautionary recommendations increase risk perception of mobile phones and mobile phone base stations. Hence, whereas the main benefit of the recommendations might actually be non-existent, manifest costs exist.

However, the bearing and the implications of this increase in risk perception due to precautionary recommendations is quite unclear. The current work aimed to shed some light on this effect in order to delineate the costs of precautionary recommendations more precisely. Three research questions were posed:

(i) Who reacts with an increase in risk perception when receiving precautionary recommendations?

(ii) Can precautionary recommendations be amended so that they do not increase risk perception?

(iii) What are the implications of the increase in risk perception due to precautionary recommendations?

To investigate these questions, three experiments were conducted in which the participants were confronted with different texts that either did or did not contain various precautionary recommendations. After the participants read the texts, different variables were assessed that were statistically evaluated subsequently.

Regarding the first question, it was analysed whether precautionary recommendations effect people with different personalities in different ways. Trait anxiety emerged as the variable that interacted with the type of text people read. The current work indicates that precautionary recommendations selectively increase RF EMF risk perceptions of low-anxious people. However, the picture becomes more complex when risk perception is assessed with conditional risk perception questions. These questions referred to the hypothetical application of precautionary measures. Two different conditional questions were used in one of the studies: Risk perception under the condition that no precautions are taken and risk perception under the condition that precautions are taken. An important methodological finding of the current work is that the conditional measurement yields useful insights that go beyond those yielded by the traditional, unconditional measurement.

To answer the second research question, precautionary recommendations were amended in two ways: First, a motive for communicating precaution (i.e. providing measures to reduce exposure to those who are concerned) was explained. This explanation did not affect risk perception. Second, it was explained why the measures are effective in reducing personal exposure. Adding this explanation to the precautionary recommendation clearly increased recipients' risk perception under the condition that no precautions are taken. Thus, whereas one attempt to avoid the increase in risk perception in response to the recommendations had no effect, the other even increased risk perception.

In order to delineate the implications of the effect of precautionary recommendations on risk perception (third research question), two possible implications were analysed. First, although never empirically investigated, some scholars have claimed that precautionary recommendations raise fear and anxiety. Second, nocebo effects have been observed in response to alleged exposure to EMFs in some studies. Results showed that precautionary recommendations neither gave rise to an increased state anxiety, nor resulted in more nocebo responses to sham RF EMF exposure from an alleged WLAN antenna. The current work thus clearly delineates the boundaries of the costs of precautionary measures. The conclusion is drawn that the increase in risk perception, a variable that is generally an important predictor of health-related intentions and behaviour, is too small to have further effects. It remains an open question whether the results can be transferred to other possible risks.

Zusammenfassung

Kommen neue Technologien auf den Markt, ist oft nicht eindeutig geklärt, ob diese möglicherweise negative Effekte haben, zum Beispiel auf die Gesundheit ihrer Nutzer. Häufig werden dann Forderungen nach Vorsorge laut. Das Spektrum entsprechender Vorsorgemaßnahmen reicht von Moratorien über striktere Grenzwerte oder Kontrollen hin zu Empfehlungen, was Nutzer selbst tun können, um mögliche Risiken zu verringern. Derartige „Vorsorgeempfehlungen“ und ihre Effekte auf ihre Rezipienten stehen im Fokus der vorliegenden Arbeit.

Technologien zur drahtlosen Kommunikation haben unser Zusammenleben im Laufe der letzten 25 Jahre tiefgreifend verändert. Handys, Laptops, Tablets und andere drahtlose Geräte emittieren elektromagnetische Felder im Radiofrequenzbereich (RF EMF), die mit dem menschlichen Körper wechselwirken. Weltweit sind die meisten Gesundheitsbehörden der Auffassung, dass es keine hinreichenden Nachweise für schädliche Gesundheitseffekte von RF EMF gibt. Jedoch existieren noch wissenschaftliche Unsicherheiten. Dies spiegelt sich auch in der Bewertung der International Agency for Research on Cancer (IARC) wider: Die IARC bewertet RF EMF von Mobiltelefonen als „möglicherweise krebserregend“. Basierend auf dieser Sachlage empfehlen viele Strahlenschutzbehörden weltweit Vorsorge. Der wesentliche Nutzen solcher Empfehlungen besteht in einem besseren Gesundheitsschutz im Falle, dass tatsächlich gesundheitliche Risiken bestehen. Vorsorgeempfehlungen bringen jedoch auch Kosten mit sich: Im Rahmen der vorliegenden Arbeit wurde eine Meta-Analyse aller Studien zur Wirkung von Vorsorgeempfehlungen auf die Risikowahrnehmung ihrer Rezipienten durchgeführt. Dabei zeigte sich, dass die Risikowahrnehmung bezüglich Mobiltelefonen und Mobilfunk-Basisstationen durch die Empfehlungen steigt. Während der wesentliche Nutzen der Empfehlungen möglicherweise gar nicht existiert, gibt es damit offenkundig auch Kosten.

Unklar sind jedoch Tragweite und Auswirkungen der durch die Vorsorgeempfehlungen gestiegenen Risikowahrnehmung. Ziel der vorliegenden Arbeit war, diesen Effekt genauer zu beleuchten, um die mit ihm verbundenen Kosten besser eingrenzen zu können. Dazu wurden drei Forschungsfragen formuliert:

(i) Bei wem erhöht sich die Risikowahrnehmung durch die Rezeption von Vorsorgeempfehlungen?

(ii) Können Vorsorgeempfehlungen so verändert werden, dass sie die Risikowahrnehmung ihrer Rezipienten nicht mehr erhöhen?

(iii) Was sind die Auswirkungen der durch die Vorsorgeempfehlungen erhöhten Risikowahrnehmung?

Diese Fragen wurden im Rahmen von drei Experimenten untersucht. In den Experimenten lasen Probanden verschiedene Texte, die entweder Vorsorgeempfehlungen enthielten oder nicht. Anschließend wurden verschiedene Variablen erhoben und die Ergebnisse statistisch ausgewertet.

Bezogen auf die erste Forschungsfrage wurde untersucht, ob Vorsorgeempfehlungen auf Menschen mit unterschiedlichen Persönlichkeiten verschieden wirken. „Trait anxiety“ (generelle Ängstlichkeit) stellte sich als wichtige Variable heraus. Vorsorgeempfehlungen erhöhten speziell bei Menschen mit niedriger trait anxiety die Risikowahrnehmung bezüglich RF EMF von Mobiltelefonen. Einschränkend muss erwähnt werden, dass dieser Befund komplexer wird, wenn die Risikowahrnehmung bezogen auf bestimmte, situationale Bedingungen erhoben wird. In einer der durchgeführten Studien sollten die Probanden ihre Risikowahrnehmung unter zwei verschiedenen, hypothetischen Bedingungen einschätzen: einmal, wenn Vorsorge angewendet und einmal, wenn sie nicht angewendet wird. Ein wichtiger methodischer Befund der vorliegenden Arbeit ist, dass diese Art der Erfassung der Risikowahrnehmung zusätzliche, hilfreiche Erkenntnisse liefert.

In Bezug auf die zweite Forschungsfrage wurden Vorsorgeempfehlungen auf zwei verschiedene Arten ergänzt: Erstens wurde das Motiv dafür erklärt, Vorsorge zu kommunizieren (besorgten Menschen Mittel zur Expositionsreduktion an die Hand zu geben). Diese Erklärung des Motivs hatte keinen Effekt auf die Risikowahrnehmung. Zweitens wurde erklärt, warum die empfohlenen Maßnahmen die Exposition in effektiver Weise reduzieren. Diese Erklärung erhöhte die Risikowahrnehmung (unter der Bedingung eingeschätzt, dass keine Vorsorge getroffen wird) beträchtlich. Während eine der Ergänzungen also keine Wirkung hatte, bewirkte die andere gar eine zusätzliche Erhöhung der Risikowahrnehmung.

Im Rahmen der dritten Forschungsfrage wurden zwei mögliche Implikationen des Effekts von Vorsorgeempfehlungen auf die Risikowahrnehmung untersucht. Zum einen wurde die von renommierten Wissenschaftlern aufgestellte, jedoch nie überprüfte Annahme untersucht, dass Vorsorgeempfehlungen Ängste schüren. Zum anderen zeigen Studien, dass Probanden unter Scheinexposition mit EMF teilweise Symptome entwickeln (Nocebo-Effekt). In der vorliegenden Arbeit zeigte sich nach der Rezeption von Vorsorgeempfehlungen weder eine erhöhte state anxiety (momentane Ängstlichkeit), noch ein Nocebo-Effekt unter Scheinexposition von einer angeblichen WLAN-Antenne. Diesen Ergebnissen zufolge sind die mit Vorsorgeempfehlungen verbundenen Kosten also klar begrenzt. Risikowahrnehmung ist in der Gesundheitspsychologie als guter Prädiktor von Verhalten und Verhaltensintention bekannt. Aus den Ergebnissen der vorliegenden Arbeit wird die Schlussfolgerung gezogen, dass die mit der Rezeption von Vorsorgemaßnahmen verbundene Erhöhung der Risikowahrnehmung zu gering ausfällt, um weitere Effekte nach sich zu ziehen. Es bleibt offen, inwieweit sich die Ergebnisse dieser Arbeit auf andere mögliche Risiken übertragen lassen.

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Preface

Parts of this work contain content that has already been published in or submitted to scientific journals.

Chapter II section 3.1 and Chapter III section 3 contain content which forms part of a manuscript that has been submitted for publication as Boehmert, C., Freudenstein, F. & Wiedemann, P. (submitted). A Systematic Review of Health Risk Communication About EMFs from Wireless Technologies. A full version of this paper is included in Appendix D and its supplementary material in Appendix E.

Chapter V has been published as Boehmert, C., Wiedemann, P., Pye, J. & Croft, R. (2017). Improving Precautionary Communication in the EMF Field? The Effects of Precautionary Messages about Electromagnetic Fields from Mobile Phones and Base Stations Revisited: The Role of Recipient Characteristics. *Risk Analysis, 37(3),* 583-597, https://doi.org/10.1111/risa.12634.

Chapter VI has been published as Boehmert, C., Wiedemann, P. & Croft, R. (2016). Improving Precautionary Communication in the EMF Field? Effects of Making Messages Consistent and Explaining the Effectiveness of Precautions. *International Journal of Environmental Research and Public Health, 13(10)*, 992, https://doi.org/10.3390/ijerph13100992

Chapter VIII has been published as Boehmert, C., Verrender, A., Pauli, M. & Wiedemann, P. (2018). Does Precautionary Information About Electromagnetic Fields Trigger Nocebo Responses? An Experimental Risk Communication Study. *Environmental Health 17*:36, https://doi.org/10.1186/s12940-018-0377-y

For this reason, Chapters V, VI and VIII can also be read independently of the other chapters. However, this also means that some redundancies could not be avoided, especially in the introductory parts of the respective chapters.

A short remark has to be made concerning the use of central terms of this work. The terms ‘precautionary information’, ‘precautionary message’ and ‘precautionary recommendation’ all refer to the same entity in the current work. Still, they accentuate this entity in different ways. The use of the different terms mirrors the development of the author’s understanding of what is the most useful accentuation during four years of work. Because parts of the work are already published, the wording in these parts was not changed retrospectively. Another example is the use of the expressions ‘mobile communication technology’ and ‘wireless communication technology’. The latter was introduced because the study in Chapter VIII used a WLAN router, which is not a mobile technology. The reader is kindly asked to apologise these and other inconsistencies in the terminology.

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List of Abbreviations

ALARA	As low as reasonably achievable
ANSES	Agence nationale de sécurité sanitaire, de l'alimentation, de l'environnement, et du travail
ANOVA	Analysis of Variance
AR-PANSA	Australian Radiation Protection and Nuclear Safety Authority
BAG	Bundesamt für Gesundheit
BS	Base Station
BfS	Bundesamt für Strahlenschutz
CI	Confidence Interval
CR1	Conditional Risk Perception if precautions are not taken
CR2	Conditional Risk Perception if precautions are taken
DoH	English Department of Health
EIRP	Equivalent Isotropic Radiated Power
EMF(s)	Electromagnetic Field(s)
GHz	Gigahertz
GSM	Global System for Mobile Communications
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institution of Electrical and Electronic Engineers
IEI-EMF	Idiopathic Environmental Intolerance attributed to Electromagnetic Fields
kHz	Kilohertz
LAN	Local Area Network
LED	Light-Emitting Diode
LMR	Linear Multiple Regressions
LTE	Long Term Evolution
MHz	Megahertz
MP	Mobile Phone
PMT	Protection Motivation Theory
RF EMFs	Radiofrequency Electromagnetic Field(s)
SA	State Anxiety
SAR	Specific Absorption Rate
SCE-NIHR	Scientific Committee on Emerging and Newly Identified Health Risks
SDS-17	Social Desirability Scale-17
SPSS	Statistical Package for Social Sciences
SSA	Somatosensory Amplification
SSAS	Somatosensory Amplification Scale
STAI	State Trait Anxiety Inventory
TV	Television
UMTS	Universal Mobile Telecommunications System
UR	Unconditional Risk Perception

WBGU	Wissenschaftlicher Beirat der Bundesregierung Globale Umwelt-veränderungen
WLAN	Wireless Local Area Networks
WHO	World Health Organization
ZPFI	Z-Score of Personal Fear of Invalidity
ZPNS	Z-Score of Personal Need for Structure
ZTA	Z-Score of Trait Anxiety

Chapter I

Wireless Communication Technology, Electromagnetic Fields and Health

1 Introduction to Wireless Communication and Electromagnetic Fields

Wireless communication technology is omnipresent in the world of today. Already in 2014 the number of mobile communication devices exceeded the number of humans on the planet (Boren, 2014). Wireless communication technologies include mobile phones and mobile phone base stations, WLAN compatible end devices (such as computers, smartphones, tablets, watches, smart home devices connected to the internet of things etc.) and WLAN routers, Bluetooth devices, smart meters, and cordless phones. These technologies are usually able to both send information and to receive information. Television and radio program can also be transmitted wirelessly, most baby monitors work without a wire. These technologies serve unidirectional communication purposes, with a transmitter on the one end and a receiver on the other.

How does wireless communication work? The information from the sender is transmitted via electromagnetic waves to the receiver. Other expressions are electromagnetic fields (EMFs) or electromagnetic radiation. The whole electromagnetic spectrum that also includes frequencies that are not used for wireless communication, like visible light, UV radiation or X-rays, is depicted in Figure 1. Different types of wireless communication devices operate in different frequency bands, but all of them operate within the radiofrequency range. This range comprises all frequencies between 3 kilohertz (kHz) and 300 Gigahertz (GHz) (Wood, 2017b), equalling $3 * 10^3$ Hertz and $3 * 10^{11}$ Hertz, respectively, with 1 Hertz being one repetition of the wave in one second. For the current thesis, only radiofrequency electromagnetic fields (RF EMFs) are of interest, and within the radiofrequency range, only a number of frequency bands is actually used for wireless communication purposes from 'modern technologies' (e.g. mobile telephony, wireless local area networks (WLAN)).

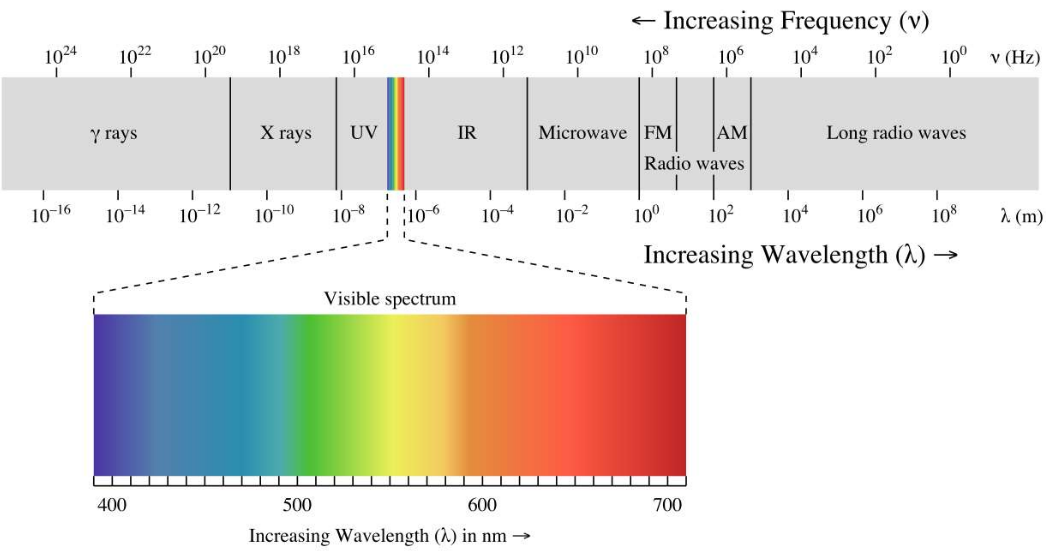

Figure 1. The electromagnetic spectrum. Image source: Wikimedia Commons/ Philip Ronan, CC BY-SA 3.0. Note. UV = Ultraviolet, IR = Infrared, FM = frequency modulated, AM = amplitude modulated, Hz = Hertz, m = metre, nm = nanometre.

To give an example, WLANs can be operated in the frequency bands between 2400 and 2483,5 Megahertz (MHz), 5150 and 5350 MHz, 5470 and 5725 MHz and also at 17,1 to 17,3 GHz in Germany (Bundesnetzagentur, 2016). Put simply, in a common setting at home, a signal arrives via cable, is demodulated with a modem and emitted in the form of an EMF in the above frequency bands by the antenna of a WLAN router. This signal is then received by the antenna of an end device (e.g. a laptop), which in turn can send a signal that is received by the router, subsequently modulated by the modem and then sent via cable. It is important to note that in the example, both the router and the end device transmit and receive. Albeit the communication between mobile phones and mobile phone base stations uses different frequencies, their way of functioning is essentially the same.

Electromagnetic waves emanate wherever an electric current exists, i.e. wherever there is a difference in charge. They are made up of two components, an electric field and a magnetic field, which are coupled (i.e. the ratio of the magnitude of the electric field to the magnetic field has a fixed value) in vacuum after a few wavelengths from the propagating source (e.g. the antenna, Wood & Roy, 2017). The electric field is measured in volt per metre (V/m) and the magnetic field is measured in ampere per metre (A/m). The power density of an electromagnetic wave is the product of the electric and the magnetic field and has the unit Watts per metre squared (W/m^2).

The radiofrequency range lies within the range of non-ionising radiation. In contrast to ionising radiation (like X-rays or gamma-rays), non-ionising radiation does not have enough energy to ionise molecules, which is the mechanism of damage of ionising radiation. Instead, radiofrequency radiation has a thermal effect on tissues that it penetrates, i.e. it results in tissue warming. How much EMFs warm tissues depends on the power density, the frequency and the constituency of the tissue itself.

2 Do electromagnetic fields have detrimental health effects?

2.1 International standards

Over the past decades, a lot of research has been done to clarify how RF EMFs interact with the body. It is important to differentiate between different types of interactions, i.e. between (non-harmful) biological effects and detrimental health effects. Above frequencies of approximately 5 to 10 MHz (to date, all modern wireless communication technologies use frequencies above this frequency band) the dominant and well-known mechanism by which RF EMFs cause biological effects is the heating of tissue (Foster, 2017b). This heating effect is referred to as the thermal effect in the literature.

It is still under debate whether besides the thermal effect, nonthermal biological effects exist, i.e. if RF EMFs have biological effects that are not caused ‘indirectly’ through an increase in tissue temperature. Several mechanisms have been proposed for such nonthermal effects. To date, researchers have not been able to consistently show nonthermal effects (Wood, 2017a). For radiation protection, however, it is in the first place of minor importance whether the detrimental effects are thermal or nonthermal (Foster, 2017b). The major international scientific bodies recommending exposure standards for health protection are the International Commission for Non-Ionizing Radiation Protection (ICNIRP) and the Institution of Electrical and Electronic Engineers (IEEE, US-based). These exposure standards have been implemented in the laws of many countries (see Missling, Riel, Wuschek, Reidenbach, & Weiskopf, 2015 and Stam, 2017 for overviews). For the frequency range used for wireless communication, the differences between the standards set by the two organisations are minor (Wood, 2017b), so that only the ICNIRP standards will be described briefly in the following. ICNIRP (1998) has recommended two standards: (1) basic restrictions and (2) reference levels. The basic restrictions refer to the amount of energy that is absorbed by the body (resulting in tissue heating). The unit of energy absorption is the SAR (specific absorption rate) which is measured in watts per kilogram (W/kg). Reviewing the available scientific evidence, ICNIRP (1998, 2009) sees converging evidence from animal studies, epidemiological studies and human volunteer studies that detrimental health effects do not occur when the whole body is exposed to SAR values lower than 4 W/kg. Below this value, the corresponding increase in body temperature in a 30 minute exposure period is below 1 degree Celsius. Stemming from the 4 W/kg threshold, ICNIRP introduced a safety factor of 10 for occupational exposure (0,4 W/kg whole body exposure) and an additional safety factor of 5 for public exposure (0,08 W/kg whole body exposure). These whole body exposure standards are relevant for RF EMFs from sources that are far away from the body (so-called far-field), i.e. at least more than one wavelength away (e.g. mobile phone base stations). Because the whole body SAR cannot be measured, reference levels are provided that specify limits for the strength of an electromagnetic field outside of the body. The reference levels are supposed to ensure that the basic restrictions are met.

The whole body SAR is less relevant for RF EMF sources that are used in close proximity (near-field) to the body (e.g. mobile phones). These sources expose specific parts of the body to stronger electric and magnetic fields than other parts. Because the overall impact of locally induced heat is not as high as that of a heating of the whole body (at least at power densities below those causing local burns of tissue), the basic restrictions for the local SAR (head and trunk) are considerably higher: 10 W/kg for occupational exposure and 2 W/kg for public exposure (ICNIRP, 1998). For near-field wireless devices, product standards ensure that these restrictions are met (for the standards in Europe, see European Norm EN SN 50360+A1:2012, CENELEC, 2012).

To conclude, above a certain threshold, the thermal effect of RF EMFs is detrimental to health. Standard setting organisations have implemented high safety margins below these detrimental exposure levels in their recommendations for exposure limits. These recommendations have been implemented in national laws and regulations in many countries and are thus widely assumed to provide sufficient protection (see Chapter III section 2.3 and Missling et al., 2015; Stam, 2017 for an overview and information on countries that did not implement the ICNIRP limits). However, the recommended restrictions have been contested by various sources. An overview of the assessments of various scientific committees is given in the next section.

2.2 Differing risk assessments: IARC and other scientific bodies

Nearly all international organisations that have reviewed and evaluated the new evidence have concluded that the existing recommendations and the derived limits adequately protect public health (e.g. ARPANSA, 2014, ICNIRP, 2009; SCENIHR, 2015; SSM's Scientific Council on Electromagnetic Fields, 2016). The prominent exception is the International Agency for Research on Cancer (IARC). IARC has 'put a question mark' behind the safety of the existing limits by classifying RF EMFS of mobile phones as a 2B 'possible carcinogen' to humans. However, IARC emphasises that the evidence for an increase in glioma and acoustic neuroma (two types of brain tumours) among users of mobile phones was limited and that the evidence for an increase in other cancers was inadequate (Baan et al., 2011). Also, this classification was made for mobile phones only, not for any other source of RF EMFs. Moreover, it is important to note that the IARC's aim is to identify hazards (for a differentiation of hazard and risk, see Chapter II section 1). This basically means that IARC only evaluated the potential of mobile phone EMFs to cause certain types of cancer and did not come to the conclusion that it is impossible. IARC does not evaluate the risk and how high it could be in specific exposure scenarios.

In general, there have been significant advances in the science since the introduction of the ICNIRP guidelines in 1998 (ARPANSA, 2014). A great number of studies has been conducted and the study quality has been improved over the years (e.g. the characterisation of exposure is now more reliable in many studies). Furthermore, the more time has passed since the introduction of mobile phones without an increase e.g. in cancer incidence rates, the less likely a severe effect of RF EMFs becomes. This has led authors to conclude that for instance, regarding mobile phones, 'the trend in the accumulating evidence is increasingly against the hypothesis that mobile phone use can cause brain tumours in adults' (Swerdlow et al. 2011).

However, as the IARC classification shows, some scientific uncertainties prevail. These pertain especially to long-term exposures for more than 15 years, and to possible effects on children (WHO, 2010; 2014).

Chapter II

Risk Perception, Risk Communication and Wireless Communication Technologies

1 Risk

What is risk? Different disciplines have different concepts of risk and hence give different answers to this question (see Renn, 1992, p. 57, 2007, p. 25 for overviews). While it is not the scope of this monograph to give an overview of these differing conceptualisations, a definition that is broadly agreed on among scientists shall be provided as well as some differentiations that are useful in relation to the topic of this thesis. Risk is first of all about potential events that might happen in the future (Holzheu & Wiedemann, 1993, p. 10). Furthermore, most definitions of risk agree that these events have to be associated with negative outcomes (as e.g. in Renn, 2007, p. 21). An important distinction has to be made between positivistic and constructivist approaches to risk. Positivistic approaches see risk as a characteristic of the outside world and 'a physically given attribute of hazardous technologies' (Bradbury, 1989, p. 381). Constructivist approaches see risk as an entity that is constructed by humans and thus the result of perceptual and judgmental processes (Holzheu & Wiedemann, 1993, p. 11). This perspective implies that risk assessment can never be independent of the assessor (Bradbury, 1989), be it an expert or a non-expert. However, choosing one of these opposing positions and ignoring the other is not useful. Rather a position in between the two should be able to more adequately explain social responses to risk (Renn, 1992, pp. 54–55). In this vein, Aven (2016, p. 60) sees the objective side of risk as existing in 'broad inter-subjectivity'. According to him, the subjective component is introduced when risk is assessed by individuals and the uncertainty of the occurrence of damage is quantified beyond the inter-subjective agreement of 'being unknown'. This is the point, when individual knowledge and assumptions come into play and risk becomes subjective (Aven, 2016) or 'constructed'.

Another key distinction has to be made between the concepts of hazard and risk. Hazard can be defined as the 'inherent property of an agent or situation having the potential to cause adverse effects when an organism, system or (sub)population is exposed to that agent' (IPCS, 2004, p. 12). Risk can be defined as 'the probability of an adverse effect in an organism, system, or (sub)population caused under specified circumstances by exposure to an agent' (IPCS, 2004, p. 12). The concept of risk is thus much more sophisticated as that of hazard, and the communication of risk is more informative but also more demanding for communicators and recipients alike. Thus, the conditions for successful communication are much more complex in risk communication (Scheer & Ulbig, 2009, p. 11). This distinction is important for the current work because precautionary measures (see Chapter III) aim at reducing exposure, although it is still unclear if RF EMFs pose a risk in the situations in which the exposure reduction is recommended (e.g. when making a phone call). This is because, as was outlined in Chapter I, it is uncertain if they are a hazard at all.

2 Risk Perception

For people who are unfamiliar with the literature, the term risk perception can be misleading, because risk cannot be 'perceived' in the sense of a sensory perception (Sjöberg, 2000c, p. 408). Instead, risk perception is a matter of attitudes and expectations (Sjöberg, 2000c, p. 407). These are formed more or less intuitively (more in lay people, less in experts; Slovic, 1987, p. 280). They are based on (or constructed on) subjective (prior) experiences, sensory perceptions, mediated information, psychological mechanisms and interest-driven assessments (Renn, 2007, p. 77). The formation of the perception of a risk is as such comparable to the formation of other attitudes (Sjöberg, 2000c). In other words, if we consider something a risk is thus a question principally comparable to if we consider something to be nice or boring.

A very influential approach in risk perception research is the so-called psychometric paradigm in which researchers have used psychological methods (i.e. questionnaires) to assess lay risk perceptions. The current thesis follows this research tradition. Therefore, this approach will be described more thoroughly than other influential approaches like cultural theory (Douglas & Wildavsky, 1982) and the social attribution of risk framework (Kasperson et al., 1988; Pidgeon, Slovic, & Kasperson, 2003), which will briefly be introduced at the end of this section. Research within the Psychometric Paradigm focusses on individual risk perceptions. The roots of the approach date back to the late 1960s. Back then, experts and the public had different positions concerning the acceptability of certain technologies. The question was, how these differences could be explained. A related question underlying this research agenda was why some hazards with a low probability of damage (e.g. airplane travel) were judged as more dangerous than others with much higher probability, e.g. car travel (cf. Weber & Ancker, 2010)? And finally, why do people think that risks in modern western societies are now greater than ever before, although life expectancy is higher than ever before (cf. Lübbe, 1993; Renn, 2014)?

Psychometric risk perception research started with the works of Starr (1969) and his successors (Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Slovic, 1987). They found that in contrast to classical quantitative risk assessment, the public focussed more on qualitative aspects of risk issues. In the paradigm, risk perception is equated to 'intuitive risk judgments' that are made by the majority of citizens (Slovic, 1987, p. 280). The general methodological approach within this paradigm is to ask subjects to characterise a set of hazards on a range of criteria, such as controllability or voluntariness of exposure. In a second step, the mean ratings on these criteria are related to the mean risk perception for each hazard. This procedure results in a 'profile' that is characteristic for each hazard. In subsequent factor analyses, main factors that predict lay risk perception were identified: A 'dread risk' factor that is defined by the perception of controllability, voluntariness, dread, catastrophic potential, fatal consequences, and an inequitable distribution of risks and benefits (Slovic, 1987, p. 283). The second factor was labelled 'unknown risk'. Hazards with a high factor loading on this factor are perceived as 'unobservable, unknown, new, and delayed in their manifestation of harm'. In various studies, especially the dread factor was shown to have a close relation to risk perception (Mullet, Duquesnoy, Raiff, Fahrasmane, & Namur, 1993; Slovic, 1987; Teigen, Brun, & Slovic, 1988).

Within the methodological frame that investigates individual risk perception by means of questionnaires, other factors that are important in individual risk judgments have been identified. For instance, it is important for whom a risk is judged. People generally assess risks for themselves as lower than for others, which has been labelled as risk denial (Sjöberg, 2000b, p. 2). Furthermore, other factors influencing risk perception were identified, e.g. a factor termed 'unnatural and immoral risk' (Sjöberg, 2000b). The concept of 'tampering with nature' (Sjöberg, 2000a) is especially relevant in the context of new technologies. Of special importance is also the connection of risk perception with two other concepts, namely benefit perception and trust. Benefit perception has been shown to inversely correlate with risk perception (Alhakami & Slovic, 1994; Frewer, Howard, & Shepherd, 1998; Sokolowska & Sleboda, 2015). Another important factor related to risk perception is trust (see Earle, 2010 for a review and theoretical differentiation of the construct). Trust in managing authorities is strongly correlated with risk perception for unknown hazards and uncorrelated to risk perception for well-known hazards (Siegrist & Cvetkovich, 2000).

An important shift within the paradigm is a stronger emphasis on affective components in risk judgments. Whereas an affective connotation always existed implicitly within the psychometric paradigm (Cousin, 2008, p. 20), most prominently in the dread factor, the importance of affective and emotional processes in risk judgment has been strengthened later on (see the 'risk-as-feelings'-approach, Loewenstein, Weber, Hsee, & Welch, 2001 and the 'affect heuristic', Finucane, Alhakami, Slovic, & Johnson, 2000, see also Slovic & Peters, 2006). Affective components, i.e. a feeling of vulnerability, have been shown to be an especially good predictor for preventive behaviour (Dillard, Ferrer, Ubel, & Fagerlin, 2012). The importance of concurrent emotions and mood for risk perception has also been asserted (Hogarth, Portell, Cuxart, & Kolev, 2011). The psychometric paradigm has also been criticised on various grounds. For instance, for unknown hazards, the questionnaire-based measurement was subjected to produce attitudes and perceptions rather than to measure them (Fischhoff, Slovic, & Lichtenstein, 1979, see also section 2.1 in the current chapter for the related issue of 'switching risks'). It was further criticised that psychometric studies have related risk characteristics and risk perception on the level of sample means and that the explanatory power of the risk characteristics was much lower on the level of individual data (Bronfman, Cifuentes, deKay, & Willis, 2007; Marris, Langford, Saunderson, & O'Riordan, 1997; Siegrist, Keller, & Kiers, 2005; Sjöberg, 2000b).

Cultural theory, introduced by Douglas and Wildavsky (1982) takes a genuinely societal perspective on risk perception and focusses on its determination by cultural worldviews. The aim of this theory is to classify societal reactions to risk in 'cultural prototypes' (Renn, 2007, p. 56). The theory identifies four different cultural worldviews: fatalists, individualists, hierarchists, and egalitarians. These differ in their perception of risk as well as in their risk-taking behaviour. Cultural theory has especially been criticised for lacking empirical evidence (Lee, 1998, pp. 91–92). Kahan, Slovic, Braman, and Gastil (2010) integrate cultural theory and the psychometric paradigm in a common framework called 'cultural cognition'. In this framework, 'the impact of cultural worldviews is not an alternative to, but rather a vital component of the various psychological and social mechanisms that have been shown to determine perceptions of risk' (Kahan et al., 2010, p. 193).

An influential theoretical framework that has been proposed in order to integrate the findings from the psychometric paradigm and cultural theory as well as from other disciplines (e.g. media research) is the social amplification of risk framework (SARF, e.g. Kasperson et al., 1988; Pidgeon et al., 2003). The aim of the framework is to explain the dynamics of risk on the societal level, i.e. in which ways hazard characteristics interact with psychological, social, institutional, and cultural processes. A major aspect of the analyses within the framework is (as already indicated by the name of the framework) why some risks are attenuated (i.e. experts judge the risk to be higher than the public does) and some risks are amplified (i.e. the public judges the risk to be higher than experts do). The framework was fruitful in that it gave rise to many empirical investigations (see e.g. Pidgeon et al., 2003). However, it is a broad framework that conceptually links different approaches and not a theory that can be tested by formulating falsifiable hypotheses (af Wahlberg, 2001).

To conclude, risk perception is a complex construct that is influenced by a multitude of parameters. As such, it cannot easily be explained. On the one hand, approaches with a narrower focus on certain aspects can be criticised to ignore other important aspects. For instance, the psychometric paradigm focusses on individual aspects and can be criticised to ignore socio-cultural aspects involved in risk perception. On the other hand, integrative approaches like the social amplification of risk framework lack specificity and falsifiability.

Despite these inadequacies, risk perception research has fostered the understanding of public reactions to risk at great length. For instance, the qualitative risk factors identified in the psychometric paradigm offer an explanation of why some risks that are perceived as relatively harmless by experts cause the greatest resistance among the public (Renn, 2007, p. 79). Moreover, risk perception research has implications on policy-making: Factors like the voluntariness of exposure, an important factor in lay risk perception, need to be considered by policy-makers (Renn, 2007, p. 87). Being aware of the public's under- and overestimation of certain risks can help policy-makers anticipate public reactions and act proactively, e.g. with an adequate risk communication strategy.

The aim of the current section was to give an overview of the main approaches to risk perception and their potential to explain differing views on risk issues. It does not lie within the scope of the current work to give an in-depth analysis of the strengths and weaknesses of each approach. The next section summarises the findings of psychometric risk perception studies regarding radiofrequency electromagnetic fields used in wireless communication.

2.1 Risk Perception Regarding Radiofrequency Electromagnetic Fields

Many studies have investigated risk perception of EMFs. The scope of this section is to give a concise overview of public risk perception and not to provide a systematic review of the literature as is done for risk communication about RF EMFs (see section 3.1 in the current chapter). Three restrictions are implemented:

(1) Only relatively new studies are considered (i.e. studies published in 2000 or later),

(2) only relatively large studies with a sample size of N > 1000 are considered,

(3) only quantitative studies are reported.

These restraints are implemented in order to keep the chapter brief while conveying a realistic picture of public risk perception. The third restraint is made in line with the notion that qualitative research is mainly explorative and hypothesis-generating (Johnson & Onwuegbuzie, 2016, p. 18). Therefore, interesting studies like the one by Dohle, Keller, and Siegrist (2012) that investigated people's free associations to mobile phone base stations will not be discussed here.

Some studies focussed exclusively on EMF risk perception, while others also measure risk perception regarding other hazards and thus allow for a comparison of risk perceptions regarding various hazards. As can be seen in Table 1, the means of risk perception for EMFs lie generally around the scale midpoint and are higher for base stations than for mobile phones (Siegrist, Earle, Gutscher, & Keller, 2005; White, Eiser, Harris, & Pahl, 2007). The proportion of concerned people lies between around slightly below 20 and slightly above 40% (see Table 1). A large part of this between study variation is probably due to methodological differences (e.g. question wording, see column 'type of RP measurement' in Table 1). Repeated measurements with the same methodology in Germany have yielded very consistent results over the course of 11 years (Infas Institut, 2003; 2004, 2005, 2006, 2010; LINK Institut, 2013).

Moreover, risk perception of base stations was consistently higher than of mobile phones. Interestingly, WLAN risk perception was not assessed in any of the studies.

The Special Eurobarometers for EMFs (TNS Opinion & Social, 2007, TNS Opinion & Social, 2010) also revealed cultural differences. In southern Europe, risk perception was higher than in most middle and northern European countries. For instance, the percentage of concerned citizens in Greece and Italy (both 81%) was much higher than in Germany or the Netherland (29 and 24%, respectively), according to the Eurobarometer 2010. Interestingly, risk perception was also high among a sample of high school teenagers in Turkey (Hassoy et al., 2013).

In general, these percentages are quite high and stand in contrast to ownership and usage patterns of RF EMF communication technology. So is it possible that all of the above-mentioned studies actually overestimate the 'true' concerns of the population? There are several perspectives on the issue that can help to make this seeming contradiction understandable:

1. Risk benefit pay-offs

Presumably, the experienced benefits simply outweigh the concerns people have. Results from a Swiss study provide some support for this explanation (Siegrist, Earle et al., 2005). However, risk perceptions and benefit perceptions are inversely correlated (Alhakami & Slovic, 1994; Frewer et al., 1998; Sokolowska & Sleboda, 2015), which suggests that if benefits were not that high, risk perceptions would be even higher.

Table 1. Overview of Studies Assessing Risk Perception of Radiofrequency Electromagnetic Fields

Study	N	Sample type	Country	Assessment Procedure	Type of RP measure	At risk	Percentage of people that perceives a risk					
							MP	BS	WLAN	EMF in general	HVPL	other EMF
Blettner et al., 2009	27376	GP	GER	Mail survey	Worry	n.s.	n.a.	**19**	n.a.	n.a.	n.a.	n.a.
TNS Opinion & Social, 2007	28584	GP	EU	Face-to-face interview	Concern	n.s.	n.a.	n.a.	n.a.	**48**	n.a.	n.a.
TNS Opinion & Social, 2010	26602	GP	EU	Face-to-face interview	Concern	n.s.	n.a.	n.a.	n.a.	**46**	n.a.	n.a.
Hassoy, Durusoy, & Karababa, 2013	2240	High school students	TUR	Questionnaire	Risk	Public	**40**	n.a.	n.a.	n.a.	n.a.	n.a.
Infas Institut, 2010	2502	GP	GER	Telephone interview	Worries	n.s.	**20**	**28**	n.a.	n.a.	**19**	**14-25**
Kowall et al., 2012	3253	GP	GER	Questionnaire	Concern	n.s.	**13**	**20**	n.a.	n.a.	**16**	**8-11**
LINK Institut, 2013	2500	GP	GER	Telephone interview	Worry	n.s.	**18**	**27**	n.a.	n.a.	**20**	**10-23**
Siegrist, Earle et al., 2005	1015	GP	SUI	Telephone interview	Risk	Public	**2.93**[a]	**3.26**[a]	n.a.	n.a.	**3.64**[a]	**2.17-2.65**[a]
White et al., 2007	1320	GP	UK	Mail survey	Likelihood	Various	**2.46 (s)**[b]**; 2.99 (o); 4.27 (c)**	**3.23 (s)**[b]**; 3.35 (o); 4.09 (c)**	n.a.	n.a.	n.a.	n.a.
Wiedemann, P. & Freudenstein, F., 2014	3097	GP	8 European Countries	Online survey	Concern	n.s.	**38**	n.a.	n.a.	n.a.	n.a.	n.a.

Note. N = Sample size; MP = Mobile phone; BS = Base station; WLAN = Wireless local area network; HVPL = High-voltage power lines; GP = General Population; n.s. = not specified; n.a. = not assessed. [a] Means on scale from 1 to 5; [b] Means on scale from 0 to 6, risk judged for s = self, o = similar other, c = children.

2. Comparison to risk perception of other hazards

Many surveys not only assessed risk perception regarding RF EMF communication technology, but additionally risk perception of other hazards. The percentages of people who are concerned about mobile phones and base stations is generally much lower than the percentage for other hazards. In Germany, for instance, the proportion of the concerned is constantly above 50% regarding genetically modified food and air pollution (Infas Institut, 2005, Infas Institut, 2006, Infas Institut, 2010; LINK Institut, 2013). Thus, relative to the perception of other hazards, risk perception regarding RF EMF technologies is rather low.

3. Risk perception in questionnaires vs. in everyday life

Qualitative research has raised the question how well risk perception measured by closed survey questions (i.e. questions with a predefined answering range, e.g. from '1 = not at all concerned' to '5 = very concerned') correspond to people's 'real' risk perceptions (Gaskell, Hohl, & Gerber, 2016; Zwick, 2005). Technological risks, such as RF EMFs emitted by communication technologies have been termed 'switching risks' (Zwick, 2005), because they can be activated by external cues like media reports, conversations – or questionnaires. In contrast to 'pervasive risks', such as traffic accidents or financial risks, 'switching risks' are not the risks that people mention by themselves when simply asked to talk about risks (Zwick, 2005). The pervasive risks, so the conclusion, thus have a higher importance in people's everyday life.

Wiedemann, Freudenstein, Böhmert, Wiart, and Croft (2017) have investigated the pertinence of RF EMF risks in people's daily lives. In their sample from various European countries, 43% were concerned according to a closed question. The authors additionally asked participants how often they thought and talked about potential RF EMF health risks in their daily lives. The lower part of Figure 2 shows that of those indicating concern on the closed question, only 29% thought (or thought and talked) about the risk 'often' or 'very often' in their everyday life. This number is equivalent to 13% of the whole sample. These findings have been replicated in an Australian sample, in which 54% were concerned according to the standard (closed) survey question and 11% were both concerned according to that question and thought often about the issue in their everyday life (Boehmert, Freudenstein, Croft, & Wiedemann, 2017). Because these findings are still based on survey answers, the approach is not a remedy for all potential problems stemming from the assessment with quantitative surveys (for an overview of these problems, see Schwarz, 1999). However, the proposed methodology allows for a further distinction of potential target groups that might have to be addressed differently in risk communication.

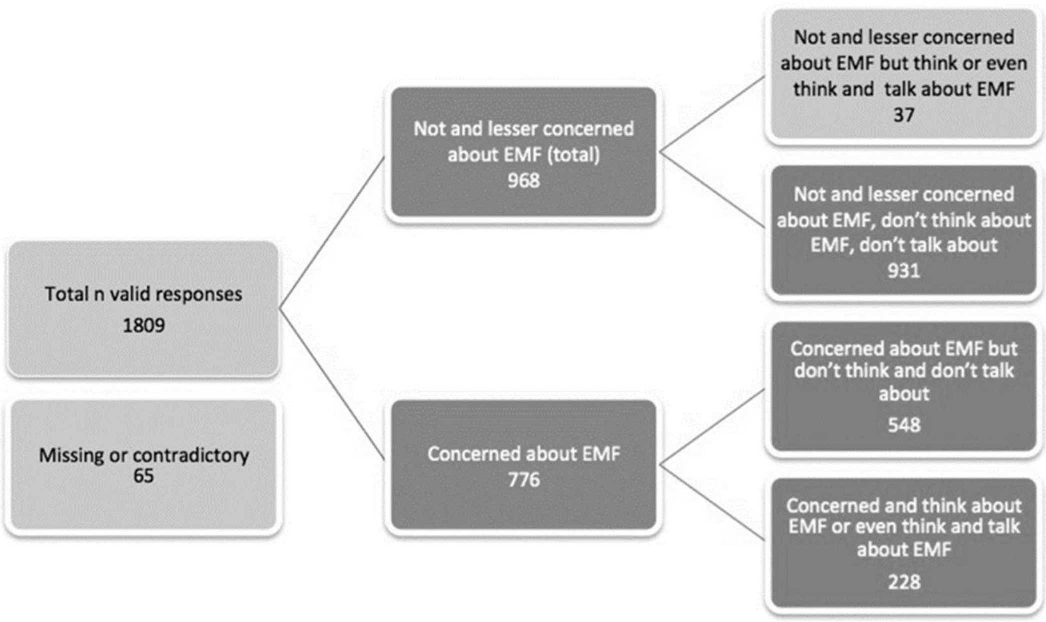

Figure 2. Absolute frequencies of concerned people according to the closed question and of people that think (and talk) about potential health risks of RF EMFs in their everyday life. Adapted from Wiedemann, Freudenstein et al. (2017).

4. Profile: Not dreaded, but unknown

According to the psychometric paradigm, there are two broad factors on which the characteristics of hazards as perceived by laymen can be classified: An agent is judged as riskier if it is perceived to a high degree as (1) unknown and (2) if it is dreaded. Bronfman and Cifuentes (2003) assessed 54 hazards in a study following the traditional psychometric paradigm. One of the hazards was 'cell phone transmission antennas'. While this hazard had an moderate factor loading on the 'dread factor' (comparable to e.g. surgery or commercial aviation), it had the second highest loading on the 'unknown factor' (only genetic engineering had a higher loading). This finding suggests that in the case of RF EMFs, people's risk perception is rather based on their lack of knowledge and not on their fear of this potential hazard. This difference might not be adequately reflected in the quantitative assessments discussed above. However, more research would help to clarify this last point.

To conclude, studies have shown that public risk perception regarding RF EMFs emitted by mobile communication technologies are not negligible. The relatively high numbers of concerned in quantitative surveys have been put into perspective by comparative, quantitative and qualitative research, however.

3 Risk Communication

Risk communication means communication about risks. Those who communicate risks in general do this with one of three principal goals: (a) advance/change knowledge and/or attitudes, (b) modify risk-relevant behaviour or (c) facilitate conflict resolution (Rohrmann, 1992). Of course, a combination of these goals can also be aimed at. For instance, it can be the goal to increase smokers' risk perception regarding cigarette smoke in order to make them quit smoking. In his 1995 review of 20 years of risk communication practice, Baruch Fischhoff lists eight different stages through which risk management and communication went over that period of time (Fischhoff, 1995). These stages are summarised in Table 2.

Table 2. Stages in the Development of Risk Communication According to Fischhoff, 1995

1.	All we have to do is get the numbers right.
2.	All we have to do is tell them the numbers.
3.	All we have to do is explain what we mean by the numbers.
4.	All we have to do is show them that they've accepted similar risks in the past.
5.	All we have to do is show them that it's a good deal for them.
6.	All we have to do is treat them nice.
7.	All we have to do is make them partners.
8.	All of the above.

Adapted from Fischhoff (1995).

Each of the stages is characterised by 'a focal communication strategy which practitioners hope will do the trick' (Fischhoff, 1995, p. 137). While the first stage is characterised by a lack of communication, stages two to five refer to the 1970s when risk communication broadly focussed on changing public views and foster technology acceptance under the premise of a 'public […] ignorant of the scientific 'truth'' (Frewer, 2004, p. 392). The industry tried to employ the early findings of risk perception research in order to calm public fears and resistance and 'to get their facilities sited on time and on budget' (Löfstedt, 2015, p. 677). However, the public remained hostile and risk communicators had to learn that it is not enough to educate the public (Fischhoff, 1995; Löfstedt, 2015, p. 677). A definition that has overcome these early, insufficient views of risk communication, has been broad forward by the US National Research Council (1989):

> Risk communication is an interactive process of exchange of information and opinion among individuals, groups, and institutions. It involves multiple messages about the nature of risk and other messages, not strictly about risk, that express concerns, opinions, or reactions to risk messages or to legal and institutional arrangements for risk management.

The definition emphasises the bidirectionality of risk communication, thereby opposing former views of risk communication as a process of education by means of various strategies (see stages one to five in Table 2). Interestingly, the very same shift from a unidirectional to a bidirectional, or from a deficit model (the knowledge of the public being deficient) to a dialogue model, or from public understanding of science ('PUS', Royal Society, 1985) to public engagement with science and technology ('PEST', Science, 2003) also manifested itself in the general field of science communication (cf. Schäfer, 2008; Weingart, 2005). However, it appears that the shift took place a bit earlier in the field of risk communication. With this shift towards participatory communication formats, is research that analyses the effects of 'simple', isolated risk messages[1], such as risk

[1] According to NRC (1989), a risk message is a 'written, verbal, or visual statement containing information about risk; may or may not include advice about risk reduction behavior; a formal risk message is a

comparisons, now futile? Certainly not, adequate risk messages are an integral part of risk communication, no matter if the communication process is uni- or bidirectional. Moreover, as Lee (1998, pp. 93–94) already argued, formats and situations in which the communication is primarily unidirectional continue to exist e.g. in the form of films or leaflets. In other formats nowadays, having more direct ways to interact (e.g. in online social networks or with videos embedded on online platforms), the recipient can still choose to interact or not to interact (and thus leaving the communication unidirectional). The German Commission for Risk argues normatively that risk communication should always comprise three types of interactions: one-way communication, dialogue and participation (Risikokommission, 2003, p. 53). Finally, a quick look at Fischhoff's stages in Table 2 confirms this view – the last stage includes all the earlier stages and does not replace them. The current thesis stands in a tradition of an analysis of the effects of (unidirectional) risk messages. Aim of such studies is to provide an evidence base for risk communication (cf. Fischhoff, Brewer, & Downs, 2011).

Empirical research on the effects of risk messages has been prosperous over the past four decades. For instance, the NRA's work on risk communication (1989) and Baruch Fischhoff's 1995 publication have both been cited more than 1200 times on google scholar (date of search: 18 March, 2018). Empirical risk communication research has provided recommendations for communication practice concerning various aspects (see Fischhoff et al., 2011 for a practice oriented overview): Conveying quantitative information (Fagerlin & Peters, 2011) including especially probability information (Visschers, Meertens, Passchier, & Vries, 2009; Zipkin et al., 2014, 2014) and graphical communication formats (Ancker, Senathirajah, Kukafka, & Starren, 2006; Zipkin et al., 2014), qualitative information (Downs & Fischhoff, 2011; Zipkin et al., 2014), readability, comprehension and usability (Neuhauser & Paul, 2011). Risk message formats often interact with recipient characteristics, e.g. with numeracy (Fagerlin & Peters, 2011; Peters, 2008), health literacy (Wolf, 2011), or attentional processes (Covey, 2014).

Progress can especially be observed in the field of medical risk communication. The understanding of risks by professionals in the medical system has been shown to be flawed (Gigerenzer, Gaissmaier, Kurz-Milcke, Schwartz, & Woloshin, 2007), resulting in an inadequate communication of the risks. Various formats have been developed and successfully tested to overcome these problems in the field of clinician-patient communication (e.g. Gigerenzer & Hoffrage, 1995, Gigerenzer et al., 2007, see also Woloshin & Schwartz, 2011).

It is beyond the scope of the current thesis to give a systematic overview over the risk communication literature as a whole. Instead, the specific literature on communication about potential RF EMF risks is reviewed in the next section.

structured written, audio, or visual package developed with the express purpose of presenting information about risk.'

3.1 Risk Communication About Radiofrequency Electromagnetic Fields[2]

Many guidelines have been published on risk communication in general. However, a closer look reveals that they are rather built on general assumptions and not on systematic research. Evidence-based risk communication – like in the field of clinician-patient-communication – is the exception rather than the rule (Fischhoff et al., 2011). For RF EMFs in wireless communication, no systematic review has thus far covered the literature on risk communication. Within the framework of the current monograph, a systematic literature review was conducted. This review can be found in Appendix D.

In the systematic literature search, 26 articles were identified that provided new empirical data on RF EMF risk communication and sufficed basic criteria of methodological reporting. Most of the identified studies were experiments, but there were also three survey studies and two qualitative studies that met the applied inclusion criteria (see Appendix D for details). Subsequently, the quality of the included literature is described first, followed by a list of the study topics that were identified. Afterwards, the findings are summarised for each topic. Detailed descriptions of each study can be found in Appendix E3.

3.1.1 Study Quality Assessment

As shown in Figure 3, the experimental studies performed well against some of the criteria and rather bad against others. In contrast to experiments in e.g. medical research, the studies reviewed here were not at risk for blinding of outcome assessment or allocation concealment (one could also argue that these criteria are not useful in evaluating research in which the experimental manipulation immediately follows the allocation and in which outcome measures are self-reported). Bias of selective reporting was assessed by comparing the measures mentioned in the method section with the measures reported in the results section. About half of the studies did not report results for at least one measure used in the study according to the method section. Risk of bias introduced by inadequate blinding of personnel and random sequence generation was largely unclear due to insufficient reporting. Only 22% of the experimental studies and none of the survey studies reported power calculations. The two qualitative studies performed rather well against Mayring's quality criteria (Mayring, 2016). One of the studies (Collins, 2010) partly lacked justification of its research methodology. The three survey studies' (Barnett, Timotijevic, Shepherd, & Senior, 2007; Ruddat, Sautter, Renn, Pfenning, & Ulmer, 2010; Wiedemann, Boerner, & Repacholi, 2014) performance against the TSE was mixed to bad. Detailed assessments of the study quality can be found in Appendices E4 to E6.

[2] This chapter contains parts of a review article by Boehmert, Freudenstein, and Wiedemann (submitted). The complete article can be found in Appendix D. For the sake of readability, the two studies reported in Chapter V and Chapter VI, which the review article also covers, were excluded here.

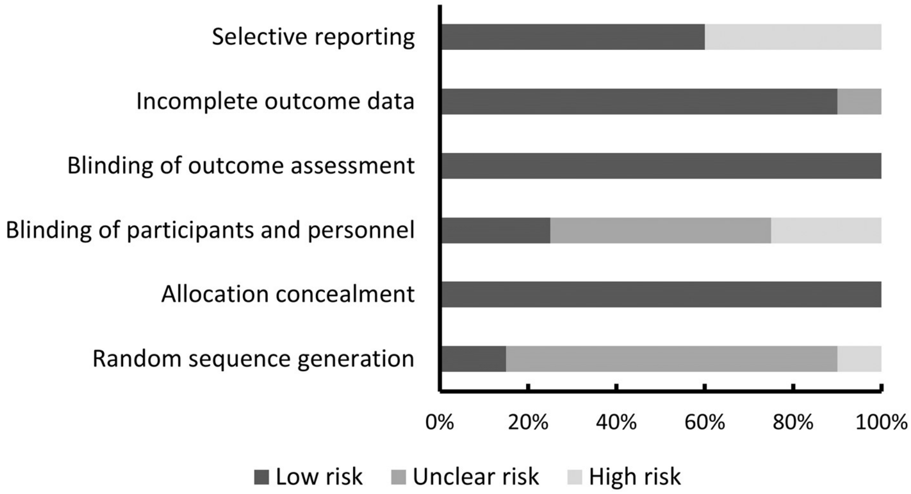

Figure 3. Risk of bias in the 20 experimental studies.

3.1.2 Study Categorisation by Content

During the course of the review, we identified nine different aspects of RF EMF risk communication that studies had been focussing on, i.e.

1. Comprehensibility of information (4 studies)
2. Information on existence of the risk (2)
3. Information about uncertainty (3)
4. Information focussed on different health effects (3)
5. Information about the source of the information (2)
6. Information about individual risk and exposure aspects (5)
7. Information about precautionary measures (12, see section 3 in Chapter III)
8. Effects of television reports and audio-visual advertisements (4)
9. Miscellaneous (2)

While some of the reviewed studies address one aspect only, others address multiple aspects. The results section will be structured in accordance with the nine identified aspects. An overwhelming majority of the studies used textual risk communication stimuli. If not otherwise specified, the communication material used in the studies were texts. If not otherwise mentioned, all results reported were statistically significant.

3.1.3 Summary of study results

Comprehensibility of Information (4 studies)

Two out of two studies report that information containing less technical terms, intended to be understood easily, is in fact understood better by the recipients (Cousin & Siegrist, 2011; Nielsen et al., 2010). Importantly, the indicators for understanding differed between the two studies, with one study reporting an increase in 'objective' understanding (i.e. increased knowledge) and one study reporting an increase in the subjectively rated comprehensibility. A third study (Ruddat et al., 2010) points at the possibility of attitude-congruent judgments of comprehensibility, while a fourth (Wiedemann et al., 2014) documents the difficulties in the understanding of the International Agency for Research on Cancer's classification of mobile phone RF EMFs as 'possibly carcinogenic'. Additionally, the understanding of this term is shaped by prior risk perception. Those who already see a risk assign a higher probability to the term possibly (Wiedemann et al., 2014).

2. Information on Existence of the Risk (2 studies)

The two studies in this section show that that if it is a communicator's aim to convince people that there are no health effects, this aim is not easily achievable (Hartung, Schulz, & Keller, 2013; Siegrist, Cousin, & Frei, 2008). Especially participants with an already high risk perception seem to be a group that cannot easily be targeted. These participants said their risk perception further increased in response to an all-clear message (Hartung et al., 2013). A message stating that a health effect was found in a study was judged to be more credible than a message about a study that did not find a health effect (Siegrist et al., 2008). As for comprehensibility, the judgement of credibility is influenced by prior risk perception. Those who already have a moderate or high risk perception find the study that found a health effect more credible. This was not the case for people with low prior risk perception.

3. Information About Uncertainty (3 studies)

Effects of information about scientific uncertainty have been studied in three experiments (Wiedemann & Schütz, 2005, studies 1 and 2, Wiedemann, Thalmann, Grutsch, & Schütz, 2006) and one survey study that assessed lay understanding of expressions of uncertainty (Wiedemann et al., 2014). The three experimental studies do not indicate an important effect of information about uncertainty (Wiedemann & Schütz, 2005, studies 1 and 2, Wiedemann, Thalmann et al., 2006). However, all three studies manipulated uncertainty solely with one single sentence (which was, on top, the very same sentence in all studies). Uncertainties might affect recipients if communicated in different ways. The survey study (Wiedemann et al., 2014) showed that recipients' understanding of terms expressing uncertainty of potential adverse effects vary widely.

4. Information Focussed on Different Health Effects (3 studies)

The discourse about possible RF EMF health risks often focusses on possible cancer risks. However, other endpoints haven been and still are discussed. Two experimental studies systematically varied the negative outcome focussed by the risk message (Siegrist et al., 2008; Thalmann & Wiedemann, 2006). It has been assumed that compared to information about relatively 'harmless' outcomes, information about 'severe' outcomes induces a higher degree of emotionality (Thalmann & Wiedemann, 2006). Therefore, a study reporting on the effects of an emotionally charged newspaper article is also included in this paragraph (Cousin, Dohle, & Siegrist, 2011).

Recipients recognise the emotional character of risk information (Cousin et al., 2011). However, in all three studies risk perception was not affected by texts that manipulated the health outcome and were supposed to give rise to emotions (Cousin et al., 2011; Siegrist et al., 2008; Thalmann & Wiedemann, 2006). Because affective and emotional processes are known to be an important aspect of risk perception (see e.g. 'risks as feelings' perspective, Loewenstein et al., 2001 or the 'affect heuristic', Finucane et al., 2000), it seems unlikely that they do not contribute to RF EMF risk perception. Instead, it seems more likely that simply focussing on a different outcome does not change affective or emotional responses.

5. Information About Source of the Information (3 studies)

Three out of three studies did not find an effect of a variation of the source of information on risk/ safety perception (Cousin & Siegrist, 2011; Hartung et al., 2013; Wiedemann, Schütz, & Clauberg, 2008). However, the source of information might exert a more complex influence on recipients. In this context, Cousin and Siegrist (2011) discuss that their experimental approach might have oversimplified real-life conditions.

6. Information About Individual Risk and Exposure Aspects (5 studies)

Two out of two studies found information about individual risk and exposure to increase participants' knowledge about RF EMF exposure issues, which, however, is not a surprising result (Claassen, van Dongen, & Timmermans, 2015; Cousin & Siegrist, 2011). Moreover, there is evidence for an increase in risk perception due to the provision of such information. This effect could be due to a better understanding of the contribution of the distance-exposure relationship and of the contribution of various EMF sources to personal exposure (Cousin & Siegrist, 2011; Nielsen et al., 2010). Studies specifically report higher risk perceptions for mobile phone EMFs. In contrast, risk perception of base station EMFs decreased in two studies (Cousin et al., 2011; Cousin & Siegrist, 2011) and was not reported in one other study (Nielsen et al., 2010). One study did not find an effect on risk perception (Claassen et al., 2015). This might have been due to its low statistical power. However, the explanations of the distance-exposure relationship were combined with other technical information in all of these studies, which leaves some uncertainty with regard to what exactly caused the change in risk perception. Combining the findings on knowledge and risk perception, it seems plausible that participants gained new insights about RF EMFs and adjusted their risk perceptions accordingly.

7. Information About Precautionary Measures (14 studies)

This section of the original article is part of the current work in Chapter III section 3.

8. Effects of Television Reports and Audio-Visual Advertisements (4 studies)

Three out of four studies found increased risk perception regarding EMFs in response to short video clips suggesting a health effect (Bräscher, Raymaekers, van den Bergh, & Witthöft, 2017; Köteles, Tarján, & Berkes, 2016; Witthöft et al., 2017). In the fourth study (Witthöft & Rubin, 2013), no main effect was found, but an interaction between the experimental condition and state anxiety. It can thus reasonably be assumed that video clips that (strongly) suggest health effects of EMFs elevate peoples' risk perceptions, a finding that does not surprise much. There is mixed evidence for the moderating influence of personality variables. Whether the changes in risk perception are persistent, has not yet been investigated. The findings on symptom perception and the intensity of tactile perceptions have been discussed as indicators of the potential role of media reports in the development of idiopathic environmental intolerance. Although this is plausible, more research is needed to provide further evidence regarding this hypothesis.

9. Miscellaneous (2 studies)

Two studies could not be subsumed under one of the eight identified topics (Collins, 2010; Wiedemann & Schütz, 2008). A description of their findings can be found in Appendix D.

3.1.4 Conclusions for the Current Monograph

For the current monograph, these studies are important, because they focus on several topics of great relevance in the communication about RF EMFs and health. Generic issues like the comprehensibility of information need to be considered in the context of communicating precautionary recommendations as well. How aspects of individual exposure are communicated is also a question when giving precautionary recommendations that aim at reducing individual exposure. It is relevant that while information about aspects of individual exposure increases knowledge about exposure patterns, there is also an indication that it increases risk perception. A potential way of communicating individual exposure patterns within precautionary recommendations is tested in Chapter IV. Interestingly, information about the source of the information and information about remaining scientific uncertainties both did not have an effect on the recipients' risk perceptions. Therefore, the current monograph does not focus on these aspects. Finally, the results of the literature review emphasised the importance of the topic of the current thesis: With 12 studies the field of precautionary recommendations was a clear focus of RF EMF risk communication research.

An important methodological consideration derived from the literature review concerns the study of interactions of message type and recipient characteristics. The interaction effects of message type and prior attitudes (i.e. risk perception) reported in some of the above studies highlight the importance of designing studies so that such interaction effects can be assessed. A potential deficit of all of the above studies that tested the influence of prior attitudes on message reception is that they did not use continuous attitude variables but divided their participants into groups (i.e. for example groups with high, moderate and low prior risk perception in Siegrist et al., 2008). This procedure results in a loss of potentially meaningful variance. The studies reported in Chapter V and Chapter VII analyse the interaction of personality variables with different messages. They overcome the problem of loss of variance by using continuous recipient variables.

Chapter III introduces the precautionary principle, followed by an overview of the application of the principle in the case of RF EMFs. Finally, the part of the literature review on the effects of precautionary recommendations that has been omitted in the current section, forms the concluding part of Chapter III and leads to the development of the research questions in Chapter IV.

Chapter III

The Precautionary Principle and its Application to Electromagnetic Fields

1 The Precautionary Principle

There are various definitions of the term ‘precaution’, and the denominations and connotations of translations of precaution in different languages also differ widely. For the case of EMFs, the latter has been pointed out by radiation protection agencies (WHO, 2012, p. 10). As for the term ‘precaution’ itself, there are also many different understandings of the so-called precautionary principle. Indeed, a main problem of the principle is ‘the extreme number of definitions and interpretations’ (Aven, 2011). More than 20 definitions have been mentioned in 1999 already (Sandin, 1999). Section 1.1 of the current chapter is supposed to give an overview of the precautionary principle and of key issues that are frequently debated when the principle is brought up.

1.1 An Approximation to the Principle

The precautionary principle is a strategy of risk management in the face of uncertainty (Klinke & Renn, 2001, p. 167). In a nutshell, the principle states that under uncertainty, it is generally ‘better to be safe than sorry’, meaning that erroneously deciding e.g. against the implementation of a new and harmless technology is better than erroneously deciding to implement a dangerous one. It is a decision rule that, broadly spoken, favours false positives over false negatives. The principle ensures that uncertainties are taken into account and prevents situations in which ‘undue importance is attached to known and probable (and typically short-term) benefits, relative to the associated disadvantages, if these are less certain and likely to manifest themselves only in the long term’ (Health Council of the Netherlands, 2008, p. 21).

With regard to decisions that are taken, the concept of precaution is similar to the concept of prevention (Stirling & Tickner, 2004, pp. 184–186). In both cases, the intention is to avoid potential harm. A key feature of precaution is that this avoidance takes place early (Weed, 2004, p. 316), even earlier than in the case of prevention. Primary prevention, the earliest form of prevention (and thus the closest to precaution), targets the roots of a risk, e.g. preventing people from starting to smoke in order to reduce their risk of lung cancer (Stirling & Tickner, 2004). Although there is uncertainty on the individual level in this example (it is unclear whether a specific person will develop lung cancer due to smoking), there is little uncertainty that on the population level smoking increases the risk of lung cancer. In contrast to this, precaution is the use of preventive action under uncertainty if there is a risk on the population level, i.e. under circumstances with less evidence for the connection of a certain agent (e.g. EMFs) to adverse effects (Weed, 2004). In other words, it is the use of preventive measures when it is (still) unclear if a certain agent is a hazard at all.

The principle has been criticised on many grounds. It goes beyond the scope of the current thesis to provide an overview of the different positions. Rather, after giving a brief overview of the nature of the principle, approaches to the key questions revolving around the principle are presented. The reader is referred to various sources, e.g. Morris (2000), Mossmann and Marchant (2002), Sunstein (2005), Majone (2002), and Peterson (2006) for critical positions towards the principle and to Sandin, Peterson, Hansson, Rudén, and Juthe (2002) and Stirling (2007) for a defence.

According to Renn (2008) the most widely used formulation of the precautionary principle is the one used in the 'Rio Declaration on the Environment and Development':

> 'In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.' (Rio Declaration, Principle 15, United Nations, 1992)

Other formulations will not be discussed in detail here (the reader is kindly referred to Sandin, 1999). The formulation in the Rio Declaration shall be used to exemplify the four dimensions of the precautionary principle that Sandin (1999) has distilled out of the commonalities of the various formulations of the principle:

(1) A threat dimension: The Rio declaration speaks specifically of threats of serious or irreversible damage.
(2) An uncertainty dimension: Uncertainty is described as a lack of full scientific certainty in the definition above.
(3) An action dimension: Cost-effective measures shall not be postponed according to the Rio declaration, i.e. they should be taken.
(4) A command dimension: The principle is prescriptive in that it demands action (3) in case (1) and (2) exist. Dimensions three and four have also been termed the 'remedy part' of the precautionary principle (Manson, 2002).

The command dimension gives the reader an impression of the nature of the precautionary principle, which is essentially an 'ethical principle' (Aven, 2011). It is as such a principle that is thought to guide actions in general, i.e. in all situations to which (1) and (2) apply. At this point, two heavily debated issues become obvious. Firstly, the many definitions of the principle differ in regard to their specifications of the threat dimension and the uncertainty dimension. Secondly, for each potential hazard, be it e.g. nanotechnology, aluminium in antiperspirants, or EMFs emitted by mobile communication technologies, proponents and opponents of the principle can argue whether the threat and the uncertainty are *large enough* to warrant invoking the principle. The first question under constant debate is thus: When should the precautionary principle be invoked?

1.2 When Should the Precautionary Principle Be Invoked?

Regarding the threat dimension, a wide range of criteria for a judgment of the seriousness of a threat can be applied. These range from very specific criteria such as the disruption of a specific biological process in an organism to broad criteria such as injury or mortality, or general criteria like ubiquity or irreversibility (Renn et al., 2009, pp. 32–33). An integral part of the judgment of seriousness is the decision about what should be protected, which is an ethical question. The application of the precautionary principle thus always implies a value judgment (Aven, 2011). The fact that basically everything in the future is uncertain to some extent (from a strict standpoint, even the sun might not rise tomorrow), and hence full scientific certainty will never exist, has led critics of the principle to complain that it is arbitrary (e.g. Mossmann & Marchant, 2002). Indeed, regarding the uncertainty dimension, in order to not become arbitrary in the application of the principle, the plausibility of an effect is often formulated as a precondition (see e.g. Health Council of the Netherlands, 2008, p. 17). According to the Dutch Health Council, an effect 'may be considered plausible if at least some recognised experts in the field have concerns'

(Health Council of the Netherlands, 2008, p. 17). It catches the eye easily that this precondition can lead to debates about the expertise of scientists involved in the debate over a risk.

Beyond the point of plausibility, attempts have been made to systemise different types of uncertainties and link them to the application of the precautionary principle. The classification by Stirling and Gee (2002) is depicted in Figure 4 (see also Stirling, 2008). Because their terminology conflicts with other definitions of e.g. the term 'risk' (Aven, 2011), the terminology shall not be important for the current work. What is of importance, is the differentiation of two types of knowledge that either can exist or not exist: Knowledge about the probability of occurrence of an outcome and the knowledge about the outcome itself. Regarding the former, there can either be some basis for the estimation of a probability of occurrence or no basis. The latter can be well-defined (e.g. major outcomes of smoking include lung cancer and oesophageal cancer) or poorly-defined (e.g. there are large uncertainties with regard to the consequences of the predicted rise of the sea level due to the melting poles). Stirling and Gee (2002) link precaution mainly to situations in which uncertainties exist for both the probabilities and the outcomes.

Knowledge about likelihoods	Knowledge about outcomes	
	Outcomes well defined	Outcomes poorly defined
Some basis for probabilities	**Risk**	**Ambiguity**
No basis for probabilities	**Uncertainty**	**Ignorance**

Figure 4. Four types of uncertainty depending on knowledge about outcomes and probabilities. Adapted from Stirling & Gee 2002.

For Aven (2011), it is the potential for negative surprises that characterises uncertainties that are linked to the precautionary principle. He offers a somewhat different classification scheme, in which he relates scientific uncertainties to the cause-effect relationship. This scheme distinguishes between situations in which an accurate prediction model (which is inherently based on knowledge about cause-effect relationships) exists, and cases where there is no such model. Precautionary approaches can be invoked in cases where no such model exists.

Weed (2004) analysed the relation between uncertainties, causality and precaution. He provides a good picture of how a broad application of the precautionary principle would change health risk assessment. In his analysis, he focuses on evidential criteria typically used to establish causality in epidemiological research. From a practical standpoint, Weed argues, precaution comes down to lowering the criteria that justify preventive action. These evidential criteria are for instance 'Hill's criteria of causality' (Hill, 1965) or the convention to interpret a p-value smaller than .05 as 'statistically significant' (and not one that is e.g. smaller than .10).

To conclude, judgments regarding the threat dimension are ethical judgments (Aven, 2011). The uncertainty dimension has usefully been systemised and related especially to cases in which uncertainties exist about probabilities *and* outcomes (Stirling & Gee, 2002) and to the absence of predicting models (Aven, 2011). In the absence of these conditions, other approaches to risk management are of greater importance. While these authors stay on more general grounds, the analysis of Weed (2004) shows that for the concrete application of the precautionary principle for a potential risk (e.g. EMFs), the questions whether and when potential risks are considered as existing, likely or maybe existing, plausible or implausible come down to an appraisal of research paradigms and methods.

1.3 How Should Precaution Be Implemented?

The second question under debate is: How should precaution be implemented? And related to this: Which precautionary measures should be implemented? In general, the implementation of precautionary measures is specific to the potential risk at hand. Potential and applied precautionary measures for the case of RF EMFs in mobile communication are discussed in sections 2.2 and 2.3 of this chapter, respectively. In the current section, the general guidance on characteristics of precautionary measures provided by the European Commission (EC, 2000) is described in order to convey an overview of the issues that need to be considered when implementing precaution. The EC highlights that 'reliance on the precautionary principle is no excuse for derogating from the general principles of risk assessment'. According to the EC (2000), precautionary measures should be

1. proportional to the chosen level of protection, i.e. precautionary measures should be tailored to the chosen level of protection;
2. non-discriminatory in their application, i.e. comparable situations or hazards should not be treated differently;
3. consistent with similar measures already taken, i.e. comparable to these measures;
4. based on an examination of the benefits and costs of action or lack of action, i.e. overall costs and benefits for the community, in both short and long term;
5. subject to review, i.e. precautionary measures should be maintained as long as scientific evidence is inconclusive or incomplete, and the risk is still considered too high to be imposed on society;
6. capable of assigning responsibility for producing the scientific evidence; i.e. the burden of proof may be placed on producer, manufacturer or importer, but this has to be decided on a case-by-case basis.

For the current thesis, especially the fourth point is of interest. The EC highlights that the examination should include an economic cost-benefit analysis where appropriate, however, the analysis 'is wider in scope and includes non-economic considerations' (European Commission, 2000). Among the non-economic factors, the EC lists acceptability of action or inaction to the public. Section 3 of the current chapter outlines the cost-factor that is important for the current thesis, Chapter IV builds empirical hypotheses on the basis of cost and benefit reasoning.

2 The Precautionary Principle and Electromagnetic Fields

2.1 RF EMFs in Wireless Communication – a Case for the Precautionary Principle?

Invoking the precautionary principle in the case of RF EMFs and possible health effects means to take precautionary actions for exposure levels that are below the limit values that have been established by ICNIRP (1998) and that most countries worldwide have adopted in their legislations. As outlined earlier, ICNIRP (1998, 2009) came to the assessment that there is no conclusive evidence for adverse health effects below the ICNIRP limits. Still, a precautionary stance has been recommended by some expert committees, must notably by the British 'Independent Expert Group on Mobile Phones' (IEGMP, 2000). Moreover, the IARC (Baan et al., 2011) has classified RF EMFs from mobile phones as 'possibly carcinogenic' (it is important to note that this assessment was not made for other sources of RF EMFs, such as wireless local area networks (WLAN) or mobile phone base stations). While the IARC assessment itself stresses scientific uncertainties, further uncertainty is introduced by the fact that IARC and ICNIRP, both agencies related to the WHO, come to different assessments. In its current research agenda, the WHO highlights two areas of uncertainties – potential long-term effects and potential effects on children, who might be more susceptible to RF EMFs than adults (WHO, 2010; 2014). Thus, there are uncertainties in risk assessments that, principally, warrant a precautionary approach. However, it has to be kept in mind that resources (time, money, labour) are always limited and precautionary approaches cannot be pursued for every potential hazard and it is common sense that resources should be allocated to potentially large threats rather than to potentially small threats. (Potential) risks thus need to be classified and compared against each other before decisions on precaution can be made.

To this end, in 1998, the German Advisory Council on Global Change (WBGU, 2000) developed a classification scheme of risks. The names for the different classes of risks were derived from Greek mythology (e.g. Sword of Damocles, Pandora's Box etc.). The WBGU (2000) mentions RF EMFs in mobile telecommunication as the prototype example of a 'medusa risk'. The medusa risk class is characterised by a high potential for public outrage and mobilisation albeit the probability of occurrence and extent of potential damage are rather low. From the elaborations, it becomes clear that the WBGU considers the extent of damage to society as a whole and not on an individual level. The WBGU makes out psychological explanations for the public outrage. According to Klinke and Renn (2001), discursive risk management approaches that target public outrage should be used for medusa type risks. A precautionary approach should only play a subordinate role.

Figure 5 depicts the WBGU assessment of the EMF risk potential. It is relatively safe to assume that after twenty years in which media coverage about RF EMFs and health steadily declined (cf. the development of journal articles about the media coverage in Chapman & Wutzke, 1997; Claassen, Smid, Woudenberg, & Timmermans, 2012; Elvers, Jandrig, Grummich, & Tannert, 2009; Litmanen & Tuikkanen, 2008; Martha, Coulon, Souville, & Griffet, 2006; Vasterman, Scholten, & Ruigrok, 2008) the WBGU's assessment of the mobilisation potential would be somewhat lower nowadays. Some shifts regarding the other dimensions are also likely. However, as outlined before, major scientific bodies still see some uncertainties persisting.

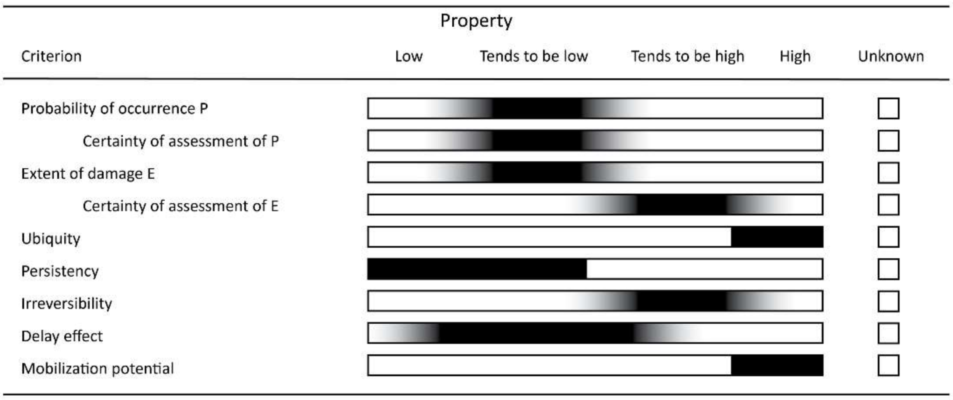

Figure 5. Assessment of the risk potential of electromagnetic fields by the German Advisory Council on Global Change (WBGU 1998).

Different stakeholders, like the industry and environmental activists, have taken the expected stance regarding the issue (Klinke & Renn, 2001). Whereas activists advocate a precautionary approach (e.g. Bioinitiative Working Group, 2012), the industry is against precautions (e.g. Dolan & Rowley, 2009). The WHO has meanwhile denied responsibility for EMF precautions and stresses that the WHO's goals are limited to prevention and that precautionary policies would lie within the responsibility of national health authorities (WHO, 2012, p. 9). Hence, national health authorities play a key role in the implementation of precautionary measures. In the next section, the range of potential precautionary measures in the case of RF EMFs shall be explored, followed by an assessment of the precautionary measures that are in place in different countries.

2.2 Potential Precautionary Measures

Wiedemann, Mertens, Schütz, Hennings, and Kallfass (2001) have offered a classification of potentially applicable precautionary measures regarding RF EMFs and health (see Figure 6, see also Wiedemann, 2010). Their approach divides precautionary measures into three domains:

1. Health-related measures
2. Process-related measures
3. Research-related measures

First of all, it seems obvious that this classification has been developed inductively, in an attempt to systemise existing precautionary measures in the EMF case. This is indicated by the lack of mutual exclusiveness of the three domains. For instance, research is itself a process and research is also health-related in the case of epidemiological and toxicological studies about potential health effects from RF EMFs. An important difference between the three domains is the aim that is pursued.

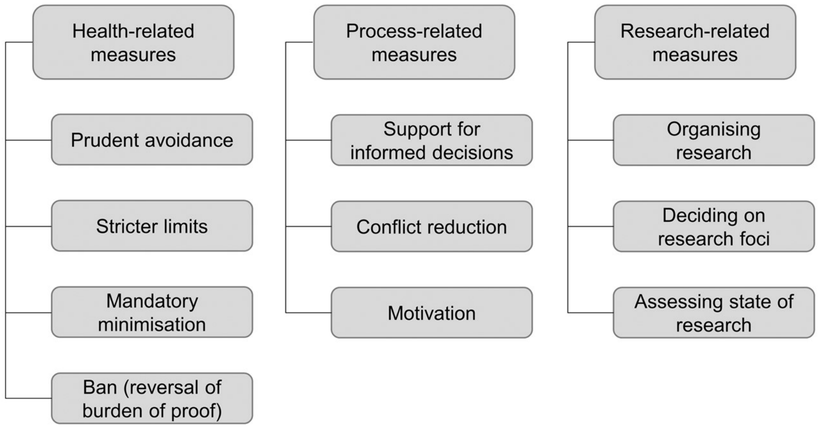

Figure 6. Overview of potential precautionary measures, adapted and translated from Wiedemann et al. 2001.

Research-related measures aim at minimising uncertainties regarding potential health effects. Consequently, research has the aim of making precaution superfluous. If research leads to the conclusion that a health effect exists, precaution will be substituted by prevention or other risk management options. Conversely, if the conclusion is that health effects do not exist (and that the remaining uncertainties are negligible), then precaution will simply not be necessary any longer[3]. Research-related measures can therefore be seen as 'indirect' precautionary measures that do not directly serve to prevent potential negative health outcomes.

The process-related measure 'conflict reduction' does not contribute to health protection and thus cannot be regarded as a precautionary measure in the original sense according to Wiedemann et al. (2001, p. 94). Another process-related measure is 'motivation'. It refers to motivating the industry towards a more precautionary approach. This is also not an immediate, direct precautionary measure because it actually tries to make the industry implement health-related measures. The measure 'support for informed decisions' refers mainly to the information about measures to reduce individual exposure and will be discussed below.

Health-related measures aim at preserving public health. Every measure in this domain aims at a minimisation of exposure. Because it is uncertain whether RF EMFs emitted by wireless devices are a hazard to human health at all, the term 'health-related' might better be replaced by the term 'exposure reduction measures'. The most drastic intervention would be a ban of RF EMF technology, a more lenient alternative would be to set stricter exposure limits. In the classification by Wiedemann et al. (2001), 'mandatory minimisation' refers to other reduction measures that would be implemented in law, but which do not set definite exposure limits for all exposure situations. Mandatory minimisation includes policy approaches like 'ALARA' (as low as reasonably achievable). ALARA is a 'flexible methodology expressing the […] precautionary principle' (Health Council of the

[3] However, precaution is in its core a careful 'general normative guide' for treating uncertainty that assigns 'the benefit of doubt to the protection of human health and the environment, rather than to competing organizational or economic interests' (Stirling, 2007, p. 312, see also European Commission, 2000). Hence, the conclusion that precaution is not needed any longer will under most circumstances not arrive very quickly.

Netherlands, 2008, p. 132). The concept originated and is most strongly applied in the field of protection against potential health effects of low-level ionising radiation (Health Council of the Netherlands, 2008). ‘Prudent avoidance’ is the most lenient approach among the health-related measures. This approach emphasises the safety of the existing exposure limits. Consequently, in contrast to the ‘ALARA’ approach, minimisation is not enforced in law, which can be understood as the main difference between ‘ALARA’ and prudent avoidance according to Wiedemann et al. (2001).

Prudent avoidance favours the application of low-cost measures that do not entail other negative consequences (Wiedemann et al., 2001, p. 45). A negative consequence in this sense could be, for instance, reduced network availability or capacity. The concept was proposed in the late 1980s for risk management of low frequency magnetic fields emitted by high voltage power lines (Nair, Morgan, & Florig, 1989). In this context, prudent avoidance encompasses two types of measures (Nuttall, Flanagan, & Melik, 2017). The first type, siting measures, refers to siting power lines in an appropriate distance to places where people reside. The second type, design measures, refers to measures that reduce emissions by power lines and also by electrical household appliances. For both types of sources, the magnetic field (as well as the electric field) is an unwanted by-product. In contrast to this, in wireless communication devices, the EMF is the essential part that enables the transmission of the communication. Moreover, the interaction between technology that is usually close to its user (e.g. mobile phone, computer with WLAN) and distant technology (e.g. mobile phone base station, WLAN router) has to be optimised to reduce exposure to the population. Multiple exposure sources that operate close to the body (e.g. smartphones, tablets, smart watches etc.) have added complexity to the user’s exposure and altered the exposed body regions (SCENIHR, 2015, p. 13).

However, the mobile phone remains the main source of exposure in particular for brain tissue, because it is usually used close to the head when making phone calls (SCENIHR, 2015, p. 13). Moreover, for many people, the mobile phone is responsible for a larger share of personal exposure than mobile phone base stations (Bolte & Eikelboom, 2012; Neubauer et al., 2007). This exposure pattern is counterintuitive for many people (Cousin & Siegrist, 2010a): If a mobile phone base station is removed from an area, then mobile phones will have to emit a stronger signal to reach the next base station. Removing a base station can hence increase the overall exposure of residents of this area significantly. Thus, individual, behavioural measures applied by the users themselves when using their phones (or other wireless devices) have a high exposure reduction potential. In that sense, Wiedemann et al. (2001) also mention information measures as part of the prudent avoidance concept. The underlying idea is that informing people about measures to reduce their exposure, that is about precautionary measures, will also lead to reduced exposures if people actually apply the measures.

The aims of informing about precautionary measures can thus be on different levels (this is also reflected in Figure 6). On the one hand, people are informed so that they can make their own, ‘informed decision’ (in the sense of a process-related measure according to Wiedemann et al., 2001). On the other hand, information about precautionary measures can also be seen as a measure to reduce public exposure. Interestingly, in practice, precaution has also been implemented with yet another aim, i.e. the intention to reduce public outrage and concerns in the EMF debate (Vecchia & Foster, 2002 and UK Department of Health, 2004, cited in Timotijevic & Barnett 2006).

Looking at how possible risks stemming from RF EMFs are handled by national radiation health authorities, it can be observed that the classification provided by Wiedemann et al. (2001) fits well to how risks are managed today. Especially stricter exposure limits and foremost precautionary recommendations are the precautionary measures that are applied (see the next section). However, the boundaries between some forms of precaution are not clear-cut.

2.3 Precautionary Measures in Practice

This section's function is to give the reader an overview of what precautionary measures are generally applied by national health authorities for the case of RF EMFs. Its scope is not to give an in-depth description of the measures used in each country. Regarding exposure, most European countries have not implemented stricter limits than the reference limits recommended by ICNIRP (for an overview, see Stam, 2017). Other countries even have more lenient limits in place (e.g. Austria) while in yet another group of countries (e.g. the Netherlands and the United Kingdom) no regulation by law exists and mobile communication companies have committed themselves to respect the ICNIRP limits instead (Stam, 2017). However, while the wireless technologies in question have not been banned in any country, there are a few countries that have set stricter limits for public exposure than recommended by ICNIRP (1998, 2009) on precautionary grounds. Belgium, China, Italy, Lithuania and Russia are among these countries, for instance (Missling et al., 2015). Some countries, e.g. Croatia, Slovenia or Switzerland, also have set lower limits for special 'areas of sensitive use' only, e.g. for places like kindergardens, schools or hospitals (Missling et al., 2015; Stam, 2017). The stricter limits refer to the emissions of stationary RF EMF-emitting devices and not to mobile devices, for which stricter limits on the grounds of precaution do not exist.

The most frequent precautionary measure for possible risks from RF EMFs is giving precautionary recommendations. The National Institute for Public Health and the Environment, RIVM, (2017) has counted that in 20 out of 35 analysed countries, precautionary recommendations are given by health authorities. This shows the practical importance of this type of precautionary measure in comparison with the other options identified by Wiedemann et al. (2001). For example, the German Bundesamt für Strahlenschutz (BfS) recommends to reduce exposure to RF EMFs from mobile phones by (a) using a landline phone if available, (b) keeping calls with the mobile phone short, (c) not making phone calls under bad reception conditions, (d) using a mobile phone with a low SAR-value, (e) using a headset to make phone calls and (f) writing text messages instead of making phone calls (Bundesamt für Strahlenschutz, n.d.a). For smartphones and tablets, they recommend some additional precautionary measures: (g) only surfing on the internet or check emails when reception is good or when connected to a WLAN, (h) only checking emails manually, (i) not downloading emails while talking on the phone, (j) assuring that the minimum distance is complied with when carrying the smartphone on the body, (k) taking care of a sufficient distance from the body when surfing on the internet. In addition, the BfS also stresses that exposure minimisation is 'especially important' for children (Bundesamt für Strahlenschutz, n.d.b). Although most other national health authorities do not inform about precautionary measures as extensively as the BfS, the recommendations are in principle more or less the same (see e.g. those in Australia[4], Austria[5], England[6], France[7]). This information enables people to reduce their exposure to RF EMFs on their own. However, the recommendations have also been shown to have other effects on message recipients (e.g. on risk perception). The effects of precautionary recommendations are the core topic of the current monograph. Studies that investigated these effects will be described in the subsequent section.

3 Effects of Precautionary Recommendations About RF EMFs in Wireless Communication[8]

As described in Chapter II section 3.1.2, a total of twelve empirical studies that contained analyses of the effects of precautionary information were identified. When compared to the other investigated aspects, the mere number of studies underscores the importance the research community gave to this aspect. The goal of the current section is to summarise and combine the evidence that the twelve studies provide. Because of the high number of studies dealing with the issue, a meta-analytical approach was chosen. In a first step, the studies' eligibility for the meta-analysis was checked.

3.1 Meta-Analysis

3.1.1 Selection According to Methodological Criteria

Only experimental studies with at least one group that received precautionary recommendations and at least one control group without these recommendations are considered. Two studies were excluded because they were not experiments (Barnett et al., 2007; Timotijevic & Barnett, 2006) and two studies were excluded because they had no control groups without precautionary information (Barnett, Timotijevic, Vassallo, & Shepherd, 2008 and Chandran & Menon, 2004, study 2).

3.1.2 Selection According to a Definition of 'Precautionary Recommendation'

In order to define the term precautionary recommendation in this meta-analysis, we provide a differentiation between precaution and protection on the one hand and refer to speech act theory (Searle, 2012) on the other hand. Two conditions needed to be fulfilled. Firstly, we only consider communication to be about precaution if it was stated that there is 'no conclusive evidence' or that 'no scientific proof' exists or a similar statement

[4] https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/reducing-exposure-to-mobile-phones
[5] https://www.bmgf.gv.at/cms/home/attachments/1/9/2/CH1238/CMS1202111739767/handy_folder_20170727.pdf
[6] https://www.gov.uk/government/publications/radio-waves-reducing-exposure/radio-waves-reducing-exposure-from-mobile-phones
[7] https://www.anses.fr/fr/content/radiofr%C3%A9quences-t%C3%A9l%C3%A9phonie-mobile-et-technologies-sans-fil
[8] This chapter contains modified parts of the article Boehmert et al. (submitted). The complete article can be found in Appendix D.

clarifying that harmful effects of RF EMFs have not (yet) been proven. If recommendations are given without this piece of information, then we consider it a recommendation of protective measures and not as precaution. Secondly, the precautionary character of the information had to be stated explicitly and/or the speech act of the statement had to be a recommendation/advice (cf. Searle, 2012). For example, the speech act of 'in order to minimise personal exposure, we strongly encourage people to use a headset while talking on the phone' is a recommendation while it is not a recommendation in 'in order to minimise personal exposure, a headset can be used while talking on the phone'. It is important to note that for our selection, the source of information (e.g. an activist group, a governmental agency etc.) and the addressee (e.g. the public, risk regulators etc.) of the recommendation are not relevant.

Of the identified studies, we excluded two studies (Kim, Kim, & Niederdeppe, 2015; Niederdeppe et al., 2014; Nielsen et al., 2010) from the subsequent analyses, as they did not contain any information that health effects have not been proven. The studies not selected for the meta-analysis are summarised at the end of this section.

3.1.3 Choice of Comparison Groups

To minimise performance bias (i.e. bias due to other differences than the precautionary recommendation), we only compared groups where the precautionary recommendation was the only difference between the two groups. For instance, in Cousin and Siegrist (2011), there was one group that read a booklet with precautionary recommendations, one group that read the same booklet with the only difference that it did not contain the recommendations and another group that also received the recommendations but that was additionally informed that the source of the information were the Swiss mobile communication providers. We only compared the first two groups to avoid any confounding.

This rationale led us to include more than one group comparison in studies with a complete factorial design (4 group comparisons in Claassen et al., 2015 and in Wiedemann et al., 2013, 2 group comparisons in Wiedemann & Schütz, 2005, study 1 and in Wiedemann & Schütz, 2005, study 2). Wiedemann et al. (2013) conducted the exact same experiment with eight different samples in eight different countries. We combined these samples for the meta-analysis.

3.1.4 Choice of Dependent Variables

All of the included studies used multiple dependent variables. Three studies assessed mobile phone risk perception and base station risk perception separately (Claassen et al., 2015; Cousin & Siegrist, 2011; Wiedemann et al., 2013), and four studies general EMF risk perception (Claassen et al., 2015, Wiedemann & Schütz, 2005, studies 1 and 2, and Wiedemann, Thalmann et al., 2006). All dependent variables were single item measurements. It is important to note that the wording of the items differed between studies. For instance, regarding general EMF risk perception, Wiedemann and Schütz (2005) speak of 'electrosmog' while Claassen et al. (2015) use the expression 'electromagnetic radiation'. As mentioned earlier, we termed variables as risk perception that were termed differently in the original study. For instance, Cousin and Siegrist (2011) use the expression 'health concerns'. The study by Wiedemann et al. (2008) was excluded from the meta-analysis because it did not assess risk perception as a dependent variable.

3.1.5 Data Analysis

A separate meta-analysis was conducted for each of the dependent variables mobile phone risk perception, base station risk perception and general EMF risk perception. In all studies, post-test values of the groups with precautionary recommendations and post-test values of the groups without precautionary recommendations were compared. For each comparison, 'Hedges g', which is a sample size corrected version of the standardised mean difference (Hedges & Olkin, 1985), was calculated as a measure of effect size in a spreadsheet. Inverse variance weights were calculated in the same spreadsheet. Means, standard deviations and sample sizes of the respective groups were requested from study authors if they had not been reported in the articles. Mean effect size calculation and moderator analysis were conducted using SPSS 24 and David Wilson's meta-analysis macro for SPSS (the macro can be downloaded on http://mason.gmu.edu/~dwilsonb/ma.html). The random effects model coefficients are reported.

3.1.6 Results

Forrest plots of the effect sizes of all included studies are shown in Figure 7 for mobile phone risk perception, in Figure 8 for base station risk perception and in Figure 9 for general EMF risk perception. Mean effect sizes were small but significant for mobile phone risk perception ($n = 9$, Mean Hedges' $g = .14$, 95% CI (.003, .27)) and for base station risk perception (Mean Hedges' $g = .18$, 95% CI (0.11, 0.25)) and small but not significant for general EMF risk perception (Mean Hedges' $g = .15$, 95% CI (-0.04, 0.34)). There was considerable variation between the studies regarding mobile phone and general EMF risk perception (Homogeneity statistic $Q = 20.13$, $p < .01$ for mobile phone risk perception; $Q = 7.34$, $p = .50$ for base station risk perception; $Q = 16.97$, $p = .049$ for general EMF risk perception). An analysis of a potential moderating variable that accounted in part for this variation goes beyond the scope of the current chapter but can be found in the full paper in Appendix D. An analysis of the funnel plots for all three dependent variables showed some variation between the effect sizes of studies with smaller standard errors. There was no sign of the typical pattern of publication bias (i.e. large effect sizes of studies with large standard error, no effect among studies with small standard error; cf. Hartung & Knapp, 2008, pp. 172–175).

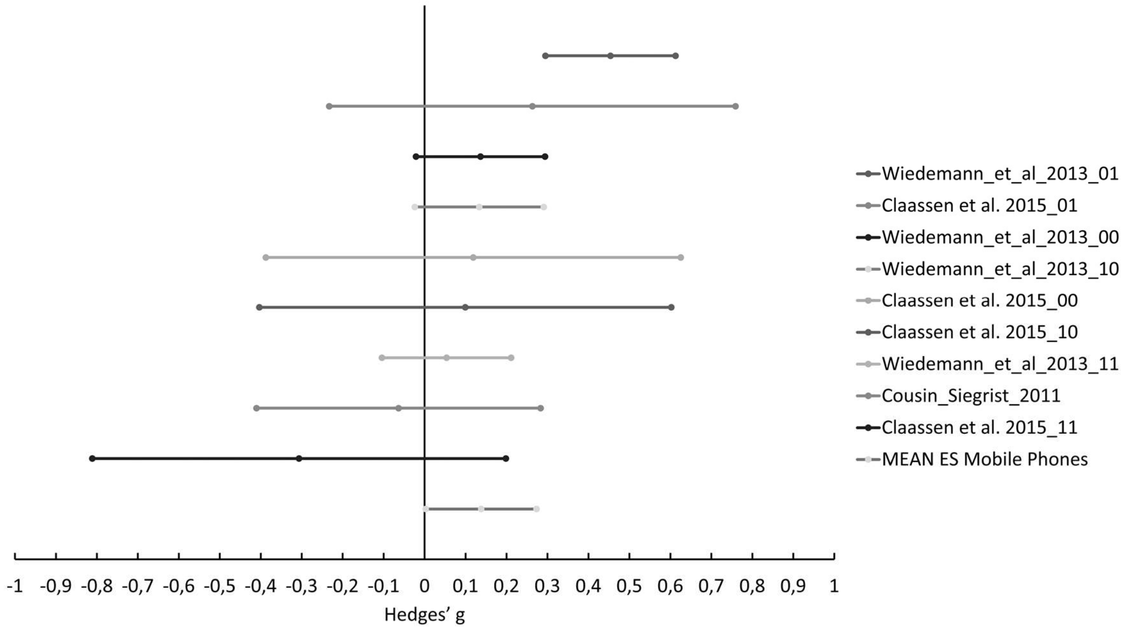

Figure 7. Forrest plot of effect sizes (Hedges' g) of precautionary recommendations on mobile phone risk perception. Note. Explanation of suffices. Claassen et al. 2015 first number: 1 = exposure-distance information included (0 = not included). Second number: 1 = exposure management options included (0 = not included). Wiedemann et al. 2013 first number: 1 = risk framing, 0 = safety framing. Second number: 1 = base station text first, 0 = mobile phone text first.

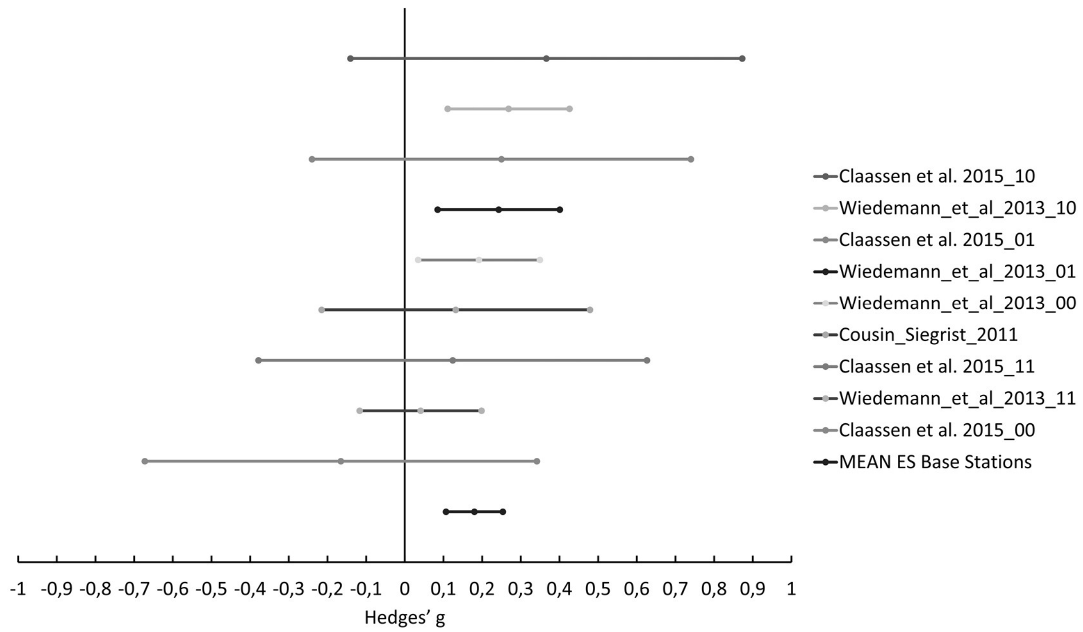

Figure 8. Forrest plot of effect sizes (Hedges' g) of precautionary recommendations on base station risk perception. Note. Explanation of suffices. Claassen et al. 2015 first number: 1 = exposure-distance information included (0 = not included). Second number: 1 = exposure management options included (0 = not included). Wiedemann et al. 2013 first number: 1 = risk framing, 0 = safety framing. Second number: 1 = base station text first, 0 = mobile phone text first.

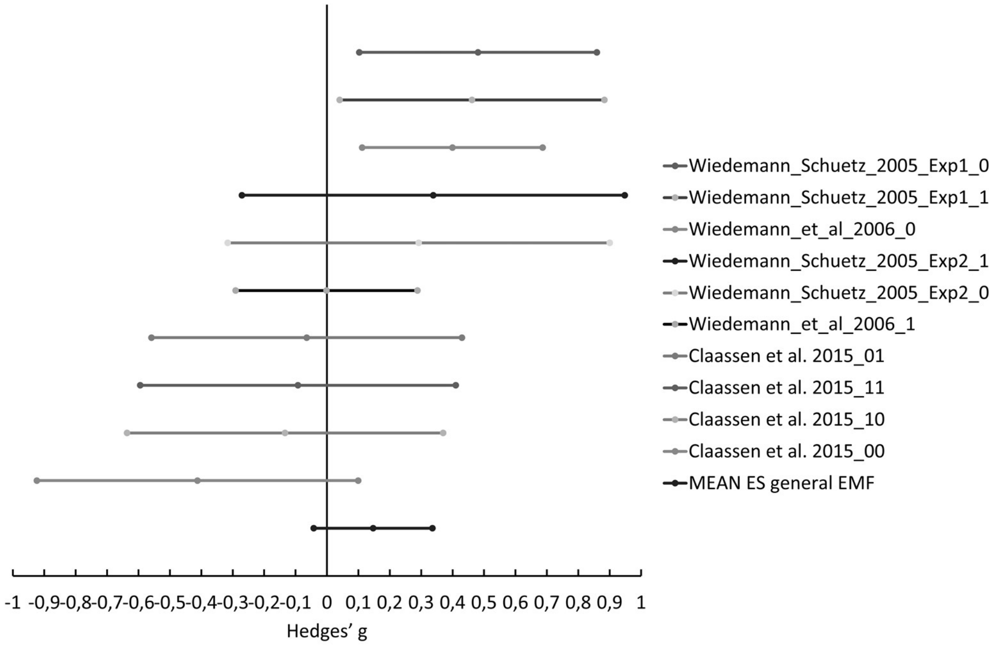

Figure 9. Forrest plot of effect sizes (Hedges' g) of precautionary recommendations on general EMF risk perception. Note. Explanation of suffices. Claassen et al. 2015 first number: 1 = exposure-distance information included (0 = not included). Second number: 1 = exposure management options included (0 = not included). Wiedemann & Schütz 2005, studies 1 and 2: 1 = uncertainty information included, 0 = uncertainty information not included).

3.2 Other Dependent Variables

Some of the studies in the meta-analyses also reported results for other dependent variables. Cousin and Siegrist (2011) report that after receiving precautionary information, more participants tended to change their mobile phone usage within the next two weeks then after the reception of a booklet without precautionary recommendations (54% vs. 35%).

Two of the studies analysed the effects on trust in public health protection. One found a detrimental effect on trust (Wiedemann & Schütz, 2005), while one did not find an effect (Wiedemann, Thalmann et al., 2006).

3.3 Studies not Included in the Meta-Analysis

3.3.1 Effect of Precautionary/Protective Information vs. no Information

Barnett et al. (2007) conducted a survey among the British general population. The survey 'explored public responses to a leaflet issued by the Department of Health (DoH) in 2000' that contained precautionary recommendations regarding the use of mobile phones. Data were assessed by means of face-to-face interviews in November 2004. Recognition rate of the recommendations in the leaflets were below one third. On a measure of self-perceived change, the percentage of participants saying the precautionary recommendations by the DoH increased their risk perceptions was higher (between 40% and 50% for each precautionary measure) than the percentage saying it decreased their risk perception (between 20% and 30% for each precautionary measure). However, inferential statistics regarding this difference were not provided.

In an experiment with 15 groups, 8 groups received information about ‘Another study [linking] cell phone use to an increased risk of cancer’ (Niederdeppe et al., 2014). The other 7 groups only received information about another hazard or were control groups). Of these eight groups, four received additional exposure reduction information (by use of a hands-free headset). In a multiple regression analysis, this information did neither have an effect on cancer prevention fatalism (i.e. the belief that nothing can be done to prevent cancer), nor on cancer information overload (i.e. the feeling of being overwhelmed by the volume of cancer information). For the same dataset, an effect of exposure reduction information on self-efficacy regarding the precautionary behaviour was reported (Kim et al., 2015).

Nielsen et al. (2010) assigned their participants to one of three groups: One received short facts about RF EMFs used in mobile communication, a second one received extensive technical information and a third group received information about how to reduce personal exposure to RF EMFs from mobile phones. The information about options of personal exposure reduction was evaluated more positively than the other two information types in terms of trustworthiness and usefulness. Compared to the group that received the short facts, a higher percentage of participants in the exposure reduction condition had an increased risk perception about mobile phone use after reading the message and showed less acceptance for the placement of a base station in the vicinity of their homes. Behavioural intentions regarding the application of precautionary measures did not differ between the groups.

Wiedemann et al. (2008) investigated the effects of information about a precautionary SAR value (‘Blue Angel’, introduced in Germany in 2002, see also section ‘Information about the source of information’). Safety perception of four different SAR values (0.16 W/kg, 0.59W/kg, 1,14 W/kg, and 1.63 W/kg) served as the dependent variable. The authors did not find differences between participants that either received only basic information about the SAR value or received additional information about the ‘Blue Angel’).

3.3.2 Framing Precautionary Recommendations

In an experiment by Barnett et al. (2008), all groups received precautionary information regarding mobile telephony. The framing of the precautionary information was varied in a 2 × 2 design, with the first factor pertaining to message framing (risks vs. risks and benefits) and the second factor pertaining to the reason for providing the information (scientific uncertainties vs. public concern). With a smaller sample, that study replicated results of their own research group (Barnett et al., 2007) in terms of the effect of precautionary information. No effects of the experimental variation were found. However, assuming an effect size of $f = .05$ which would be in line with other effect sizes reported in this area, the study was underpowered with a statistical power of $1\text{-}\beta = .10$ for a main effect in a 2 × 2 ANOVA.

Chandran and Menon (2004) conducted an experiment with 64 students. All participants read a text that stressed the risk of cancer due to mobile phone use. In a 2 × 2 experimental design, the temporal framing of this text (day vs. year) was varied, as well as the type of precautionary measures described afterwards (easy to implement (e.g. use of hands-free device) vs. hard to implement (e.g. using phones as little as possible in a car)). Risk perception was greater in response to the day framing, but the type of precautions mentioned had no main effect on risk perception. There was an interactional effect of temporal framing and type of precaution on behavioural intention to inform oneself about the risk. While in the day frame the type of precautions did not make a difference, in the year frame participants who had read the easy to implement precautions indicated higher intentions to inform themselves about the risk.

3.4 Influence of Recipient Variables

Timotijevic and Barnett (2006) conducted a study with 9 focus groups. In an initial discussion, a very low awareness of the British government's precautionary approach became apparent throughout all focus groups. Subsequently, the researchers introduced the governmental approach to the groups. The authors speak of a 'complex picture' and report that already concerned participants tended to have concerns about the precautions, whereas '[f]or those people less attentive to possible health risks […] precaution did seem to provide some reassurance.'

Wiedemann et al. (2008) did not find differences in safety perceptions in reaction to information about a precautionary SAR value between people with low prior risk perception, high prior risk perception and unsure people.

3.5 Summary

In sum, the meta-analysis shows that there is an effect of precautionary recommendations on mobile phone and base station risk perception. For general EMF risk perception, the effect is not significant. The effect on mobile phone and base station risk perception can thus be regarded as solid. Some studies also investigated effects of precautionary recommendations on variables other than risk perception. One study reported more precautionary behaviour in response to the recommendations. The evidence regarding the effect on trust in public health protection is inconclusive. The findings are inconclusive with regard to framing effects and further research is warranted.

The fact that there is a well replicated effect of a communication pattern that is used by many national health authorities warrants an in-depth investigation of this effect. The research questions for this in-depth analysis will be developed in the next chapter.

Chapter IV

Knowledge Gaps and Research Questions

As outlined in the previous section, precautionary recommendations increase risk perceptions among the recipients of the recommendations. There are several questions of interest that arise around this effect and that have not been answered yet. National health authorities have been communicating precaution since the public rise of mobile communication technologies (Burgess, 2002) and are continuing to communicate it nowadays (Stam, 2017). It is relatively safe to assume that, considering the current state of scientific knowledge about potential health effects, most authorities would like to avoid fuelling public concerns.

As formulated by the European Commission (2000), the costs and benefits of precautionary actions (in this case of communicating precautionary recommendations) should be weighed against each other and compared with those of other actions (in this case the option of not communicating precautionary recommendations). The European Commission stresses that such an ‘Examination of the pros and cons cannot be reduced to an economic cost-benefit analysis. It is wider in scope and includes non-economic considerations.’ The terms ‘cost’ and ‘benefit’ hence have to be understood in a broad sense in the following, and not in the narrow sense of an economic cost-benefit analysis. The costs and benefits mentioned here do not have a common unit and it is thus very difficult to compare them. However, while the current work points out the need for such a comparison, it is not its scope to suggest how this comparison could be done. Instead, the current work’s aim is to draw a clearer, more detailed picture of the costs themselves.

In spite of newly gained scientific knowledge over the past 15 years, there are still no established and accepted findings indicating health effects below the current exposure limits. Due to the research efforts, uncertainties regarding potential health effects are now smaller than before (see e.g. Swerdlow, Feychting, Green, Kheifets, & Savitz, 2011 regarding reduced uncertainties for a possible relation between mobile phone use and brain cancer). The most important benefit of precautionary recommendations is that those individuals that implement precautions in response to the recommendations will have been exposed less in case detrimental health effects that are not yet known exist after all[9]. However, with diminishing uncertainties, this benefit becomes smaller. In plain words: Every new study that does not show a health effect of RF EMFs used in wireless communication diminishes the benefits of giving precautionary recommendations and also diminishes the potential costs of not giving the recommendations.

A cost of recommending precaution is the increase in risk perception among the public (again, this evaluation depends on the specific goal of the communicator). The question is thus, if health authorities will come to an evaluation where the pendulum will swing to the other side and the negative effect of precautionary recommendations will outweigh the potential benefits in case a risk existed, because the likelihood of its existence is so small. In this case, according to the European Commission’s (2000) rationale of weighing costs and benefits of different alternatives, it would be logical for health authorities to stop recommending precaution. Goal of the current monograph is to provide deeper insights into the effects of precautionary recommendations. These insights can help health

[9] This is the benefit for society at large. Other benefits exist on other levels, e.g. health authorities benefit from recommending precaution: In case that health effects occur, they will not be criticised for giving false all-clear messages. Also, they may not be sued.

authorities in deciding whether they want to communicate precautionary recommendations, and if so, how they can communicate these. To this end, three research questions are formulated:

Research Question 1: Who reacts with an increase in risk perception when receiving precautionary recommendations?

First of all, it is unclear, who reacts with an increase in risk perception in response to precautionary recommendations. This question refers to recipient variables that potentially moderate the effect of precautionary recommendations on risk perception (and related variables like trust). As pointed out in Chapter III section3, the recommendations increase risk perception on the mean level. However, some studies also pointed out that risk perception remains unaffected by precautionary recommendations in many people and in some risk perception even decreases (Barnett et al., 2007; Nielsen et al., 2010). Features of people who react to precaution in different ways are not known so far. Knowing who is affected by the communication in what way is useful for identifying different target groups for risk communication and for tailoring risk communication to these groups. Research question 1 is investigated in Chapter V and a replication study is reported in Chapter VII.

Research Question 2: Can precautionary recommendations be amended so that they do not increase risk perception?

It is an important question whether precautionary recommendations can be amended in ways that change their effect on risk perception. If this can be achieved, the costs of recommending precautions would be zero (at least if it is assumed that there are no other unknown costs), and precaution could be communicated without doing much harm. This research question is addressed in Chapter VI.

Research Question 3: What are the implications of the increase in risk perception due to precautionary recommendations?

This research question addresses the boundaries of the effect, thereby delineating the costs of the recommendations in the above sense (European Commission, 2000). What does it actually mean that precautionary recommendations increase risk perception? What does this increase lead to? Thus far, the effect has almost exclusively been shown in questionnaires and mostly been restricted to the concept of risk perception. Whether the effect actually induces a state of anxiety, as has been purported by some scholars (Burgess, 2004; Sunstein, 2005), is investigated in Chapter V. Chapter VIII analyses whether precautionary recommendations change the experiences made when people are allegedly exposed to RF EMFs, i.e. if the reception of precautionary recommendations leads to more nocebo responses.

The allocation of these three research questions to the subsequent chapters and to the different empirical studies conducted within the current monograph is summarised in Table 3.

Table 3. Overview of Empirical Studies Conducted Within this Monograph

Chapter	Study Title	Research Question	Investigated Aspect
V	The Effects of Precautionary Messages about Electromagnetic Fields from Mobile Phones and Base Stations revisited: The Role of Recipient Characteristics.	1 3	Interaction of precautionary messages and personality – initial study with students Effects of messages on anxiety
VI	Improving Precautionary Communication in the EMF field? Effects of Making Messages Consistent and Explaining the Effectiveness of Precautions.	2	Amending precautionary messages
VII	A Replication of the Interaction between Precautionary Messages and Trait Anxiety.	1	Interaction of message and personality – replication study in general population
VIII	Does precautionary information about electromagnetic fields trigger nocebo responses? An experimental risk communication study.	3	Effects of messages on nocebo responses

Chapter V

The Effects of Precautionary Messages about Electromagnetic Fields from Mobile Phones and Base Stations Revisited: The Role of Recipient Characteristics

Abstract

Precautionary messages have been shown to increase recipients‘ threat perceptions about radiofrequency electromagnetic fields (RF EMFs) emitted by mobile phones and mobile phone base stations. The current study explored the interplay of variables on the side of message recipients with this effect. The individual difference variables of interest were gender, trait anxiety, personal need for structure and personal fear of invalidity. Furthermore, the study determined whether the increased threat perception is accompanied by emotional distress. 298 university students answered a survey after reading either a basic text about RF EMFs or a text including precautionary information. Linear multiple regression with interactions analyses showed that the effect of precautionary messages differed for people with different levels of trait anxiety. How trait anxiety was related to the effect of precautionary messages in turn depended on participants‘ gender. Personal need for structure and personal fear of invalidity were mostly unrelated to the effect of precautionary messages. Regarding participants emotional distress, we found no difference in state anxiety scores between those participants who received precautionary information and those who did not. The findings show that the effects of precautionary messages on threat perception depend on individual difference variables such as recipients‘ trait anxiety and gender. Also, the fact that precautionary communication did not result in heightened state anxiety challenges the assumption that precautionary messages induce fear or anxiety.

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1 Introduction

The increased use of technologies over the last two decades that utilise radio-frequency electromagnetic fields (RF EMFs) has prompted concern about the safety of their use, and stimulated public debate about possible adverse health effects stemming from long-term EMF exposure (Feychting, Ahlbom, & Kheifets, 2005).

The risk assessment of RF EMF has been interpreted in different ways. The International Agency for Research on Cancer (IARC) classified radiofrequency electromagnetic fields emitted by mobile phones as possibly carcinogenic to humans (Baan et al., 2011). IARC experts underlined that available scientific evidence to date does not allow it to preclude a risk of developing brain cancer for heavy users of mobile phones (Baan et al., 2011). The International Commission on Non-Ionizing Radiation Protection suggest that there has been no convincing evidence demonstrating a public health risk (ICNIRP, 2009), in spite of a substantial body of research.

However, there is still a considerable public concern about RF EMF. For instance, a 2010 Eurobarometer survey (TNS Opinion & Social, 2010) showed that 46% of the people in the 27 European countries included were still ‘fairly’ or ‘very concerned’ about potential health risks of EMF. This has been replicated in a more recent multinational European study (Wiedemann, P. M. & Freudenstein, F., 2014), in which 38% of the over 3000 participants reported that they were ‘fairly concerned’ or ‘very concerned’ about potential health risks of EMFs from mobile phones. However, when interpreting these findings, one has to bear in mind that questions like ‘How concerned are you about potential health risks of electromagnetic fields’ (TNS Opinion & Social, 2010) might overestimate people’s true concern due to wording effects (Kalton, 2004; Kalton & Schuman, 1982). Nevertheless, public concerns as well as scientific concerns about the potential risk of RF EMF exposure (IARC, 2013) have shifted regulatory policy towards the application of the precautionary principle in many countries. For instance, it is now implemented in Australia, Belgium, Canada, France Spain and Switzerland[10]. Interestingly, the European Commission (2000) considers risk communication as an integral part of the precautionary principle. Furthermore, political ‘common sense’ is expecting that communicating the applied precautionary measures will help to reduce public concerns about the potential health effects of RF EMF exposure. Public health policies in various countries have been directed at the dissemination of precautionary messages, aiming to provide concerned people with information to assist in reducing their exposure and also to decrease concern directly. For example, after stating that ‘there is no established scientific evidence that the use of mobile phones causes any health effects’, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) recommends on its website that ‘parents encourage their children to limit their exposure by reducing call time, by making calls where reception is good, by using hands-free devices or speaker options, or by texting’[11].

Given that precautionary stances are intended for situations where there is uncertainty, and that evaluative terms such as ‘proportionality’ are inherent in its conception, it is

[10] see http://ehtrust.org/cell-phones-radiation-3/international-policy-actions-on-wireless (retrieved 2 March 2016)
[11] http://www.arpansa.gov.au/mobilephones/index.cfm (retrieved 2 March 2016)

unlikely that there will emerge a simple consensus as to when and where they are justified (Foster, 2000). However, in order to evaluate the relative merits of precaution, evidence regarding the (positive) practical consequences of the approach is required. In terms of the communication of precaution, the available evidence point in a different direction. It has been proposed that precautionary messages could result in negative consequences, e.g. in an increase of fear among recipients (Burgess, 2004; Sunstein, 2005). Empirical support for this hypothesis has come from the Wiedemann group. Their initial studies within German-speaking samples showed that precautionary communication increased the degree to which people were concerned by mobile communication technologies, and reduced their trust in both public health governance and scientific knowledge about RF EMFs (Wiedemann & Schütz, 2005; Wiedemann, Thalmann et al., 2006). The results regarding public concern were replicated in a large multinational study (Wiedemann et al., 2013) and by other researchers (Barnett et al., 2007; Barnett et al., 2008; Nielsen et al., 2010). Hence, there is a cost involved with precautionary messaging regarding mobile phones and base stations that needs to be better understood in order to enable its cognisant application. It is important to note that the abovementioned studies from the Wiedemann group analysed differences in group means (Wiedemann et al., 2013; Wiedemann & Schütz, 2005; Wiedemann, Thalmann et al., 2006). Different approaches were used by Nielsen and colleagues and by Barnett and colleagues (Barnett et al., 2007; Barnett et al., 2008; Nielsen et al., 2010). Though generally finding the same effect for recipients' concern about potential health effects, Nielsen et al. found that only about 35% of their participants reported a higher concern after receiving a precautionary message than before, while roughly half of their participants remained unaffected by the precautionary message and the rest even reported reduced concern. Similar results were obtained in two studies led by Julie Barnett (Barnett et al., 2007; Barnett et al., 2008). About 50% of their participants thought that precautionary messages increased their concerns while roughly 25% said their attitude remained unaffected and 25% said they felt reassured by them. Thus, precautionary messages about RF EMFs appear to affect different people in different ways.

The present study will address two important issues that follow on from the above. The first aim is to determine whether the effect of precautionary messages on people's concerns about mobile communication technologies is related to characteristics of the message recipient. The individual difference variables of interest are gender, two cognitive styles and trait anxiety (see section 1.1 of the current chapter). The choice of constructs and the methods of analysis regarding the first aim have to be regarded as explorative, given that to our knowledge there is no existing literature on the relationship between personality constructs and the reception of precautionary messages. The second aim is to determine whether this effect of precautionary messages extends beyond increased cognitive appraisal of threat and results in a negative emotional state referred to as 'state anxiety'.

1.1 Background and Study Aims

This section derives from the literature pertaining to the potential relevance of the recipient characteristics that we hypothesise to be related to the effect of precautionary messages. With regard to gender, an extensive body of research suggests that women and men differ in their perception of technological risks, with women reporting higher risks than men (Davidson & Freudenburg, 1996; Gustafson, 1998). With respect to RF EMFs from mobile phones and base stations, reported a correlation between gender and a technological risk perception factor that comprised Siegrist, Gutscher, and Earle (2005) the perception of 6 technological risks, with mobile phone EMF risk perception and base station EMF risk perception being the items with the highest loadings on this factor. This supports the assumption that gender plays a role in the risk perception of RF EMFs of mobile communication technologies in general. There are many potential explanations for gender differences in risk perception, such as gender roles, role expectations or living conditions (Davidson & Freudenburg, 1996). These explanations, however, try to make sense of 'existing' gender differences in risk perception. In contrast to these general explanations, the current study assumes specifically that the reception of precautionary messages differs between women and men. A useful theoretical framework for gender differences in reception processes can be found in the selectivity hypothesis posited by Myers-Loken and colleagues (Meyers-Levy & Loken, 2015). This hypothesis focuses on differences in attentional and cognitive processes. It posits that women process incoming information more comprehensively and that they possess a lower threshold at which they apprehend information. In the case of precautionary messages about RF EMFs from mobile communication technologies, a more comprehensive message processing could lead women to the discovery of message inconsistencies (e.g. the fact that precautionary measures are communicated despite the safety of existing exposure limits) that men oversee. This in turn could lead to a higher risk perception.

Personality differences may also be a source of variance in risk perception in response to precautionary messages. Trait anxiety may influence risk perception about mobile communication technologies, as it has been shown to be associated with heightened perceptions of the likelihood and severity of negative outcomes (Maner & Schmidt, 2006) and with heightened risk perception in general (Kallmen, 2000; Lerner & Keltner, 2001), although the relation is not evident in all studies (Bouyer, Bagdassarian, Chaabanne, & Mullet, 2001). To our knowledge, the role of trait anxiety in the interpretation of precautionary messages has not yet been investigated. Nevertheless, there is a substantial body of research showing that anxious people differ in attentional processes related to (potential) threat stimuli (Mathews & Mackintosh, 1998) and in the interpretation of ambiguous material as either threatening or harmless (Eysenck, Mogg, May, Richards, & al, 1991; Mathews & Mackintosh, 1998). These findings might be of importance in the study of the reception of precautionary messages, too.

Besides trait anxiety, we considered two other psychological variables as potentially important for the reception of precautionary messages – the personal need for structure, and the personal fear of invalidity (Thompson, Naccarato, Parker, & Moskowitz, 2001). Both are so-called 'cognitive styles' that capture enduring individual differences in cognitive processing. Their focus lies on 'how people tolerate the existence of uncertainty' (Thompson et al., 2001), thereby being of interest in the context of precaution. In psychological research, cognitive styles have not been as popular as classical trait conceptions, such as the state-trait anxiety concept (Spielberger, 1983) or the 'Big 5' personality conception (Costa & McCrae, 1992). Consequently, with a few exceptions (Fagerlin et al., 2011; Meertens & Lion, 2008), risk researchers have not explored the concepts. Personal need for structure describes a cognitive style that is characterised by a 'high (and) chronic need for structure […] with ambiguity and grey areas proving troublesome and annoying' (Thompson et al., 2001). It is associated with a general disposition for decisiveness (and confidence); experiencing discomfort from experience with, and exposure to, vacillation; and the use of information processing heuristics (e.g. stereotypes). It is negatively related to general risk-taking as measured by the Risk Propensity Scale (Meertens & Lion, 2008). Personal fear of invalidity describes a cognitive style that is aversive to decision making, and favours behavioural and cognitive hesitancy because of a preoccupation with the perceived costs of committing an error of judgement. It is associated with indecisiveness; thorough examination of data; and a rejection of information processing heuristics.

The second component of the study addresses whether the heightened sense of threat caused by precautionary messages is accompanied by state anxiety. That is, although anxiety pertaining to precautionary messaging may be beneficial in altering behaviour, it can also be maladaptive and psychologically harmful. Though an anxiety or fear inducing effect of precautionary communication has been hypothesized (Burgess, 2004; Sunstein, 2005), this has not yet been investigated directly, as prior studies only investigated concern of or threat posed by RF EMFs. In our opinion, a large effect of a precautionary message on state anxiety would represent an impediment to its communication.

To summarize, the current study aims to determine the role of gender, trait anxiety and two cognitive styles in the effect of precautionary measures, as well as the clinical significance of the associated 'sense of threat', in relation to mobile communication technologies.

2 Method

2.1 Study Sample

Participants were recruited via the Psychology Research Participation Scheme, across the University of Wollongong, Wollongong Campus, Australia. 376 university students accessed the research website, of which 308 provided sufficient responses for the following analyses. 10 participants were subsequently excluded because of their completion times. Mean completion time was approximately 16 minutes with a standard deviation of 8 minutes and 25 seconds. We excluded 3 participants with completion times greater than 70 minutes (because they were clear outliers in terms of their reaction times) and 7 participants that completed the questionnaire in less than 4 minutes and 30 seconds (because pretesting in our lab showed it was not possible to complete the questionnaire properly in less than 5 minutes). Further, there was a gap in the distribution of completion times with the fastest participant above 4 minutes and 30 seconds completing the survey in more than 5 minutes and 30 seconds. Of the remaining 298 participants, 222 (75%) were female. Participants were enrolled in various University of Wollongong subjects, with the vast majority (68%) studying psychology and the rest being a diverse student population (6% studied exercise science and 4% law, all other percentages were lower than this). Psychology students received credit towards their psychology subjects in return for their participation. The research was approved by the University of Wollongong Human Research Ethics Committee.

2.2 Procedure

An experimental design with exploratory research aims was employed. The design was mixed 2 × 2 factorial with message type as the first factor (between-subjects) and technology type as the second factor (within-subjects). Participants completed 1 of 2 versions of an online questionnaire (which constituted the basic message or precautionary message conditions; first factor). Participants received a message and answered questions separately for both mobile phones and base stations. The order of presentation for mobile phone and base station scenarios was randomized (second factor). After this 'principle questionnaire', all participants received 4 'additional questionnaires'. All participants were provided with an attachment which contained a short glossary explaining terms such as 'non-ionizing radiation', 'exposure', 'SAR value' and other terms included in both conditions.

2.3 Materials

2.3.1 Principle Questionnaire

Following Wiedemann et al. (2013), for the basic message a factual statement was provided explaining the current state of science concerning health and mobile phone or base station exposure, and for the precautionary message it provided the same factual statement as well as a subsequent precautionary statement (see Table 4). Positive framing was used for all texts (i.e. protecting health), and only the 'sensitive populations' version of the Wiedemann et al. (2013) texts was used as it showed the greatest effect of a precautionary message in Australia, when both mobile phone and base station threat perception were considered (Wiedemann et al., 2013).

Table 4. Basic and Precautionary Text Modules

Condition	Experimental text
Basic Text	In order to protect public health, the International Commission for Non-Ionizing Radiation Protection - an international body collaborating with the World Health Organization - has established exposure guidelines and recommended exposure limits. However, in some countries a debate about the potential health risks of mobile telephony is still ongoing at all levels of the society.
Precautionary message for mobile phones	As a precaution, to protect public health, some experts (e.g. www.bioinitiative.org) strongly recommend that young children should not use cell phones at all.
Precautionary message for base stations	As a precaution, to protect public health, some experts (e.g. www.bioinitiative.org) strongly recommend that base stations should not be sited near locations of potentially sensitive subpopulations such as kindergartens, schools or hospitals.

After the initial randomisation, participants either read the basic message or the precautionary message, either about mobile phones or about base stations. Subsequently, three

7-point Likert scales were provided, which asked participants to indicate their perception of threat (henceforth called 'threat'), their trust in public health protection (henceforth called 'trust'), and their opinion about the state of scientific knowledge (henceforth called 'knowledge'). Scales were adopted from Wiedemann et al. (2013) and can be found in Appendix A Table A1. Afterwards, the perceived benefits of the respective mobile communication technology were assessed with three questions, followed by a question about general interests (ranging from sports to politics) and 7 questions about science and technology beliefs. Benefits, general interests and science and technology beliefs were not analysed in the current study. The second message which was the same type as the first (in terms of basic message/precautionary message) but now about the other mobile communication technology, was displayed subsequently. Participants again rated threat, trust, knowledge and benefits with respect to this mobile communication technology. The principal questionnaire was concluded by questions about participants' usage patterns and demographics.

2.3.2 Additional Questionnaires

The State-Trait Anxiety Inventory (STAI Form Y, Spielberger, 1983) was administered in order to measure the degree to which anxiety may play a role in the effect of precautionary messages on threat perception. This self-report questionnaire measures the presence and severity of current (state) anxiety symptoms, and a personality propensity (trait) to be anxious. Normative Australian adult data are available for the STAI (Crawford, Cayley, Lovibond, Wilson, & Hartley, 2011).

The personal need for structure questionnaire (Thompson et al., 2001) consists of 12 items, which require a true or false response by the participants. Statements such as 'I hate to change my plans at the last minute' assess the participant's propensity for personal need for structure.

The Personal Fear of Invalidity questionnaire (Thompson et al., 2001) consists of 14 items, likewise requiring a true or false response by the participants. Questions such as 'I tend to struggle with most decisions' assess the participant's propensity for personal fear of invalidity. Figure 10 depicts the flow of the study.

2.4 Statistical Analyses

At first, we performed analyses in order to (1) test findings from previous studies and (2) get an impression of the overlap among the personality variables (trait anxiety, personal need for structure, personal fear of invalidity, gender) as well as of the relationships among threat, trust and knowledge.

(1) In order to examine the differences between the precautionary message and basic message groups in terms of mobile phone threat, trust and knowledge, and base station threat, trust and knowledge, six independent samples t-tests were conducted. For the same variables, in order to replicate research on gender differences in risk perception, six independent samples t-tests were run. To test the effect of order reported by Wiedemann and colleagues (2013), independent samples t-tests were computed for each of mobile phone threat, trust and knowledge, and base station threat, trust and

knowledge, comparing participants that had received the message about mobile phones first with those who had received the message about base stations first. To test the differences reported between the risk perception of base stations and mobile phones, three paired samples t-tests were conducted for each of threat, trust and knowledge.

(2) To determine the associations of trait anxiety, personal need for structure and personal fear of invalidity as well as of threat, trust and knowledge, bivariate Pearson correlations were calculated. The relation of gender with the personality variables was analysed using independent samples t-tests.

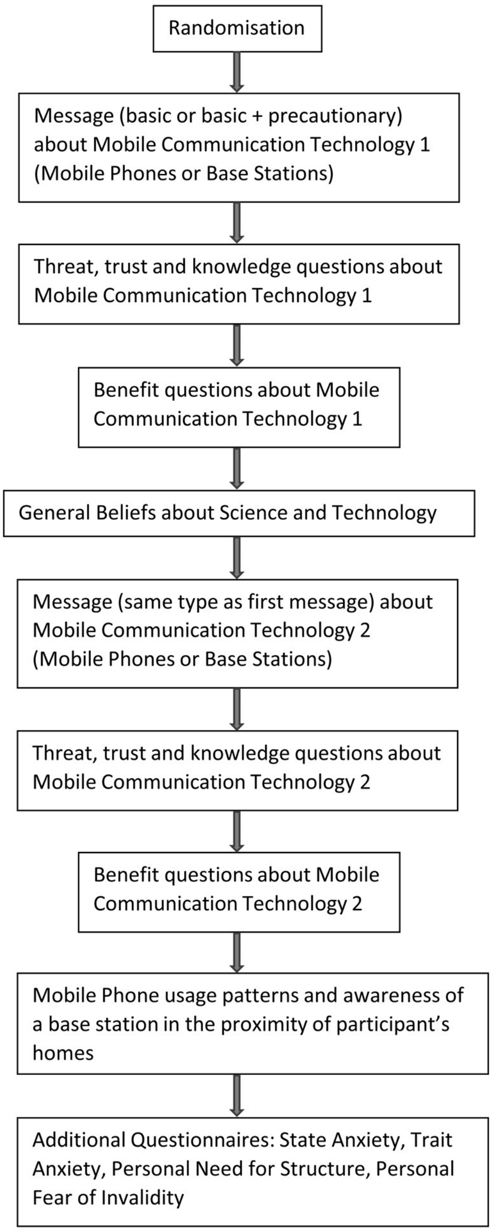

Figure 10. Flowchart of the study about precautionary messages and personality characteristics.

2.4.1 Interactions of Personality Variables, Gender, and Message Type

In order to determine how the effect of information on precautionary measures varies for people with different personalities and different gender, linear multiple regression (LMR) analyses were performed. All continuous independent variables were z-standardized prior to LMR analyses. Gender and text were dummy-coded, with 1 referring to both males and the precautionary message group. The interaction terms text × personality, text × gender and the three-way interaction text × personality × gender were computed and included in the regression models. In regression models with three-way interactions all two-way interactions need to be included (Aiken, West, & Reno, 2010), so the interaction term gender * personality was also computed and included in the regressions.

Analyses were conducted separately for each of the six dependent variables mobile phone threat, trust and knowledge, and base station threat, trust and knowledge. Furthermore, the three personality variables trait anxiety, personal need for structure and personal fear of invalidity were entered in separate regression models. Separate regression models were used to reduce the complexity of each model – entering all variables in the same regression would have resulted in too many combinations of the independent variables in the post-hoc analysis (see below; e.g. we would have to calculate 16 different simple slopes for each dependent variable). Furthermore, our primary interest was not in the overlap (which we expected, see e.g. Thompson et al., 2001) or the incremental contributions of the independent variables, but in the relation of each personality variable with the effect of precautionary messages. Another advantage of this procedure is that it avoids multicollinearity and elevated standard errors, which are especially a problem with correlated independent variables (Cohen, 2003). This resulted in 6 * 3 = 18 separately computed regression models. In each regression, all independent variables were entered in the regression model at once (forced into the model). We did not apply type 1 error adjustment.

Each of the regression equations had the form

Dependent Variable = b0 + b1 × Text + b2 × Gender + b3 × Personality + b4 × Text × Gender + b5 × Text × Personality + b6 × Gender × Personality + b7 × Text × Gender × Personality.

In LMR analysis, step down procedures as recommended by Aiken et al. (2010) were used. Aiken and West recommend this procedure when interaction effects are not yet well established in the literature, which is the case for this research. If the three-way interaction was not significant, the three-way interaction term was excluded from the equation and the regression was computed again with all remaining predictor variables.

In case of a significant interaction effect, the nature of the interaction was investigated using post-hoc simple slopes analysis (Aiken et al., 2010) of the dummy coded text variable. The simple slope of this variable indicates the difference between the precautionary message and the basic message group in the dependent variable for specified values of the other independent variables (gender and personality variables). We computed simple slopes for men and women both at high and low levels of the personality constructs ($z = 1$ and $z = -1$). Subsequently we tested whether the simple slopes differed significantly from zero as well as from other simple slopes. Slope significance tests were conducted using the 'three-way-with-all-options' Excel worksheet provided by Jeremy Dawson (http://www.jeremydawson.co.uk/slopes.htm, see Dawson & Richter, 2006). Only significant ($p < 0.05$, two-sided test) comparisons are reported.

Where trait anxiety was significantly associated with the effect of the precautionary message, we analysed the role of this construct in detail by partialling state anxiety out of trait anxiety and then rerunning the regression with the residual variable.

2.4.2 Precautionary Messages and State Anxiety

To compare the means of state anxiety in the basic message and precautionary message groups, an independent samples t-test was conducted. In order to compare the frequency of clinically relevant state anxiety scores (defined as at or above the 90^{th} percentile in the normative Australian data for 18- to 24-year-olds, Crawford et al., 2011) in the precautionary message versus the basic message group, a χ^2-test was conducted.

3 Results

3.1 Effects of Message Type, Gender, Order and Mobile Communication Technology

The means of the participants in the precautionary message and basic message conditions (see Appendix A Table A2) differed significantly for each of mobile phone (MP) threat ($t = -2.678$, $p = .008$, Cohens $d = -.31$), MP trust ($t = 2.456$, $p = .015$, $d = .29$) and base station (BS) knowledge ($t = 2.557$, $p = .01$, $d = .30$); MP threat was higher, and MP trust and BS knowledge lower in the precautionary message condition. There were no mean differences for MP knowledge ($t = .516$, $p = .61$), BS threat ($t = -.945$, $p = .35$) or BS trust ($t = .263$, $p = .79$).

Independent samples t-tests failed to identify significant differences between males and females for MP or BS threat, MP or BS trust, and MP or BS knowledge (all $t < |1.842|$, $p > .07$, see Appendix A Table A3).

There was a significant effect of order for MP threat ($t = -2.318$, $p =.03$, $d = -.27$), BS threat ($t = 3.987$, $p < .001$, $d = .46$) and BS trust ($t = -3.7$, $p < .001$, $d = -.43$); both MP and BS threat were rated higher when asked second, and BS trust was lower when asked second. No order effects were observed for MP trust, MP knowledge and BS knowledge (all $t < |.81|$, $p > .40$). Means and standard deviations with respect to message order can be found in Appendix A Table A4.

Whereas trust ($t = -.339$, $p = .74$) and knowledge ($t = .244$, $p = .81$) did not differ for mobile phones and base stations, threat scores were significantly higher for base stations ($t = -2.739$, $p = .007$, $d = -.16$). The means and standard deviations are shown in Appendix A Table A5.

3.2 Interrelations Among Variables

The three variables trait anxiety, personal need for structure and personal fear of invalidity had medium to high correlations with each other. Personal need for structure and personal fear of invalidity were positively related (r = .27, p < .001). Trait anxiety was negatively related to personal need for structure (r = -.33, p < .001) and negatively related to personal fear of invalidity (r = -.57, p < .001). Among threat, trust and knowledge (see Table 5), the highest correlations were between MP and BS threat (r = .51, p < .001), MP and BS trust (r = .58, p < .001) and MP and BS knowledge (r = .57, p < .001). Furthermore, both threat variables correlated negatively with both trust variables, and trust and knowledge were positively related. There was only a weak relation between threat and knowledge. Trait anxiety was significantly higher in females (t = -2.451, p = .02) and personal need for structure was significantly higher in males (t = 2.455, p = .02). There was no gender difference in personal need for structure (t = 1.656, p = .10).

Table 5. Pearson Correlations Among Threat, Trust and Knowledge for Mobile Phones and Base Stations.

	MP Threat	MP Trust	MP Knowledge	BS Threat	BS Trust
MP[1] Trust	-.43**				
MP Knowledge	-.12*	.30**			
BS Threat	.51**	-.31**	-.07		
BS Trust	-.34**	.58**	.25**	-.50**	
BS Knowledge	-.14*	.26**	.57**	-.06	.28**

[1] MP = Mobile Phone, BS = Base Station, * p < .05, ** p < .01

3.3 Interactions of Personality Variables, Gender, and Message Type

Multiple regression models are described separately for each of the independent variables trait anxiety, personal need for structure and personal fear of invalidity. As all regressions for MP knowledge did not yield any significant predictions, MP knowledge was omitted from the report in favour of a better readability.

3.3.1 Trait Anxiety

There was a significant three-way interaction between text, gender and trait anxiety for the prediction of MP threat, MP trust, BS threat and BS trust, but the overall regression models for BS threat and BS trust fell short of significance (see Figure 11 and Table 6). The three-way interaction was not significant for the dependent variable BS knowledge. After omitting the three-way interaction term from the equation, a significant interaction of text and trait anxiety was observed.

Figure 11 depicts the simple slopes for the text variable for males and females at high and low levels of trait anxiety (one standard deviation above and below the mean, respectively). For MP threat, the simple slope for women low in anxiety differed significantly from zero (b = .57, t = 2.953, p = .003) and significantly from the slope of males low in anxiety (t = 2.945, p = .003) indicating that women low in anxiety had higher scores in the precautionary message than in the basic message group and that this precautionary message effect was higher in women low in anxiety than in men low in anxiety.

For MP trust, the simple slope for women low in trait anxiety differed significantly from zero (b = -.67, t = -3.696, p < .001), from the slope of males low in trait anxiety (t = 3.353, p = .001) and from the slope of females high in trait anxiety (t = 3.058, p = .002). These results indicate (1) that there is a difference in MP Trust between low-anxious females that received the basic message or the precautionary message, and (2) that this difference is more evident in low-anxious females than in both low-anxious males and high-anxious females.

For BS threat, the simple slope of women low in trait anxiety differed significantly from the slope of males low in trait anxiety (t = -2.058, p = .04), indicating that the precautionary message effect for BS threat is more prevalent in females low in anxiety than in males low in anxiety.

For BS trust, the simple slope of women low in trait anxiety differed significantly from the slope of males low in trait anxiety (t = 2.009, p < .05) and from the slope of females high in trait anxiety (t = -2.551, p = .01). Again, this indicates that the precautionary message effect is more prevalent in females low in anxiety than in males low in anxiety, as well as in females high in anxiety.

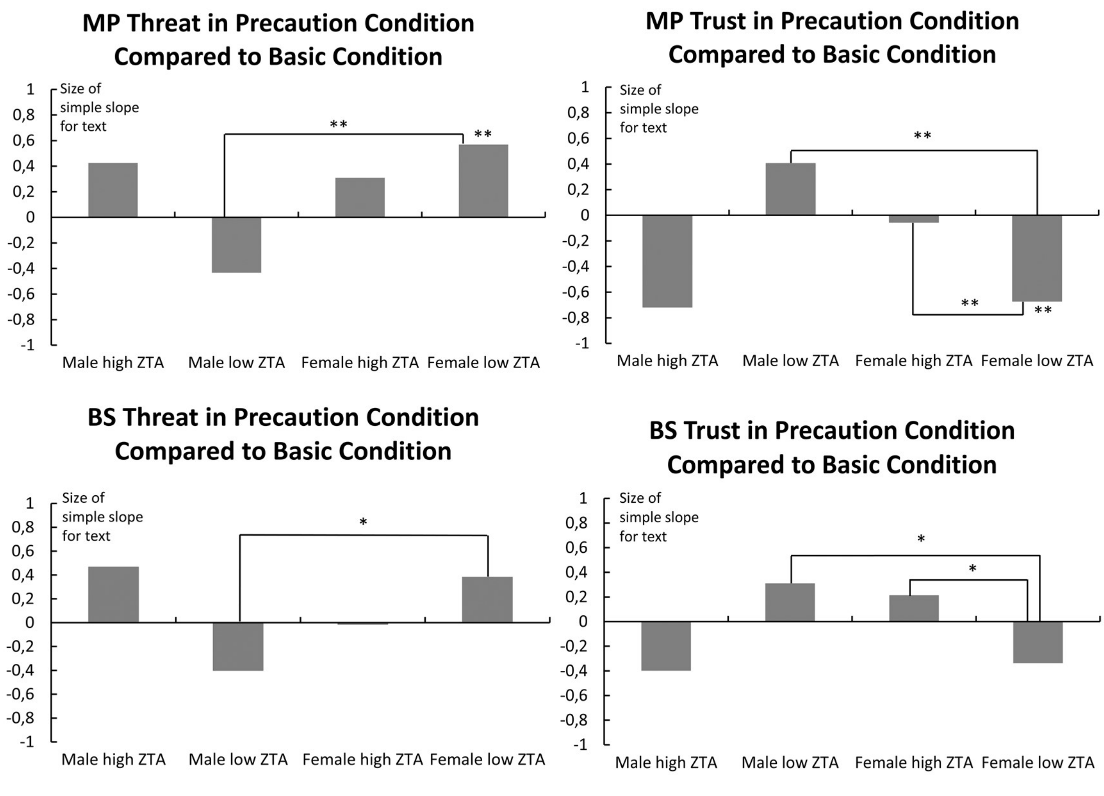

Figure 11. Sizes of the simple slopes for the text variable at values of 1 and -1 of the z-score of trait anxiety (ZTA) for both males and females. A simple slope of 1 refers to an increase of the respective variable of 1 scale point on a 5-point Likert-scale. A simple slope of -1 conversely to a decrease of the same amount. * p < .05; ** p < .01

Table 6. Results of the Linear Multiple Regression Analyses with Text, Gender and Trait Anxiety as Independent Variables

	MP Threat		MP Trust		BS Threat		BS Trust		BS Knowledge[2]	
	B	p	B	p	B	p	B	p	B	p
Intercept	2.13		3.11		2.43		2.97		2.86	
Text	.44	<.001	-.36	.003	.18	.21	-.06	.62	-.26	.06
Gender	-.02	.89	.021	.90	-.19	.35	.16	.33	.001	.99
ZTA[1]	.17	.05	-.22	.008	.16	.11	-.25	.003	-.14	.11
T*G	-.44	.1	.207	.41	-.15	.61	.02	.94	-.15	.58
T*ZTA	-.13	.32	.308	.01	-.2	.18	.28	.03	.26	.03
G*ZTA	-.38	.04	.529	.003	-.4	.06	.49	.006	-.09	.53
T*G*ZTA	.56	.03	-.87	<.001	.63	.03	-.63	.01		
Multiple R^2	.07		.08		.03		.05		.04	
F (p)	3.23 (<.001)		3.381 (.002)		1.461 (.18)		2.018 (.05)		2.098 (<.05)	
R^2 change	.03		.05		.02		.03		.02	
F change (p)[3]	2.375 (.05)		3.843 (.005)		1.437 (.22)		2.435 (<.05)		1.902 (.13)	

[1] ZTA = Z-score of Trait Anxiety, T = Text, G = Gender, MP = Mobile Phone, BS = Base Station, [2] Step down procedures according to Aiken & West (1991) were used as the three-way interaction was not significant. [3] Change in R^2 and F compared to baseline regression with independent variables Text, Gender and ZTA without interaction terms.

3.3.2 Personal Need for Structure

Multiple regression models with personal need for structure did not yield any significant three-way interactions, nor did step down procedures reveal any two-way interactions for any of the six dependent variables threat, trust and knowledge for mobile phones and base stations, respectively.

3.3.3 Personal Fear of Invalidity

In the regression of MP trust a significant three-way interaction between text, gender and personal fear of invalidity was found (see Figure 12 and Table 7). For the other five dependent variables, neither three- nor two-way interactions were found.

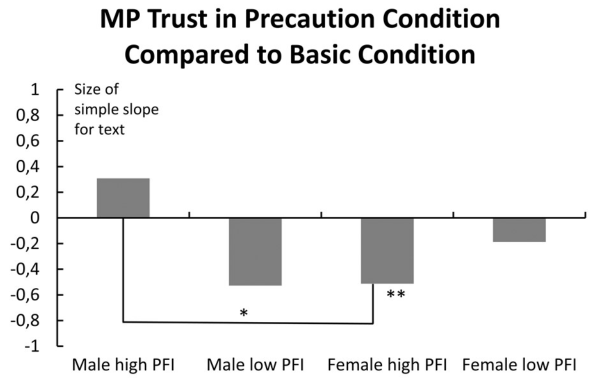

Figure 12. Sizes of the simple slopes for the text variable at values of 1 and -1 of the z-score of personal fear of invalidity (ZPFI) for both males and females. A simple slope of 1 refers to an increase of the respective variable of 1 scale point on a 5-point Likert-scale. A simple slope of -1 conversely to a decrease of the same amount. * $p < .05$; ** $p < .01$

Table 7. Results of the Linear Multiple Regression Analyses with Text, Gender and Fear of Invalidity as Independent Variables

	MP Trust	
	B	p
Intercept	3.11	
Text	-0.35	0.005
Gender	-0.05	0.76
ZPFI[1]	0.17	0.03
T*G	0.24	0.33
T*ZPFI	-0.16	0.19
G*ZPFI	-0.25	0.20
T*G*ZPFI	0.58	0.03
Multiple R^2	0.06	
F (p)	2.718 (0.01)	
R^2 change	0.02	

[1] ZTA = Z-score of Personal Fear of Invalidity, T = Text, G = Gender, [2] Change in R2 and F compared to baseline regression with independent variables Text, Gender and ZTA without interaction terms.

The simple slope of the text variable differed significantly from zero for women high in personal fear of invalidity ($t = -.2.877$, $p = .004$). The simple slope for men high in personal fear of invalidity differed from the simple slope for women high in personal fear of invalidity ($t = 2.450$, $p = .02$).

State anxiety correlated highly with trait anxiety ($r = .69$, $p < .001$). Residualising trait anxiety for state anxiety variance prior to LMR analyses did not affect the resulting interaction patterns.

3.4 Precautionary Messages and State Anxiety

An independent samples t-test failed to identify an effect of message type on state anxiety scores ($t = -1.621$, $p = .11$). The means of both the precautionary message ($M = 36.7$, $s = 10.2$) and the basic message groups ($M = 38.7$, $s = 11$) lie well within one standard deviation of the normative Australian mean for 18 to 24 year olds ($M = 36.8$, $SD = 13.6$, Crawford et al. 2011). Out of 153 participants in the basic message group, 7 scored at or above the 90th percentile of the normative Australian data for the age group of 18-24 (Crawford et al., 2011). In the precautionary message group, 6 out of 145 participants scored at or above this level. The difference between these proportions was not significant ($\chi^2_{df=1} = .034$, $p = .85$).

4 Discussion

Past research about precautionary messages regarding the radiofrequency electromagnetic fields (RF EMFs) emitted by mobile phones and base stations has shown that these messages can result in heightened threat or concern (Barnett et al., 2007; Barnett et al., 2008; Nielsen et al., 2010; Wiedemann et al., 2013; Wiedemann & Schütz, 2005; Wiedemann, Thalmann et al., 2006). Precautionary messages were also observed to reduce trust in sufficient protection of the public and to reduce the perceived state of scientific knowledge about electromagnetic radiation health effects (Wiedemann & Schütz, 2005).

Our analyses replicated the effects of precautionary messages for mobile phone threat and mobile phone trust, but not for base station threat and base station trust. Additionally, participants judged the state of scientific knowledge as being lower for base stations after reading the precautionary message (but not for mobile phones). Furthermore, our analyses revealed an effect of order; whichever of mobile phone and base station threat was asked second, resulting in higher threat scores. Also, base station trust was rated lower by participants that had answered the question for mobile phone trust before. This order effect is in line with prior results (Wiedemann et al., 2013).

Trait anxiety and gender emerged as the variables associated with the effect of the precautionary message, while personal need for structure was not associated with the effect of the precautionary message. Personal fear of invalidity was only related to the effect of the precautionary message on mobile phone trust but not any of the other five dependent variables.

More specifically, there was a significant three-way interaction between text, gender and trait anxiety on threat perception and trust, both for mobile phones and base stations. Three-way-interactions can be interpreted in different ways. In our case, with text being the primary independent variable of interest, we think of the following interpretation as the most useful one: The way precautionary messages (compared to basic messages) influence threat perception and trust depends on recipient's trait anxiety. But how trait anxiety moderates the effect, differs for males and females. Figure 13 depicts this relationship, with mobile phone threat as the exemplary dependent variable.

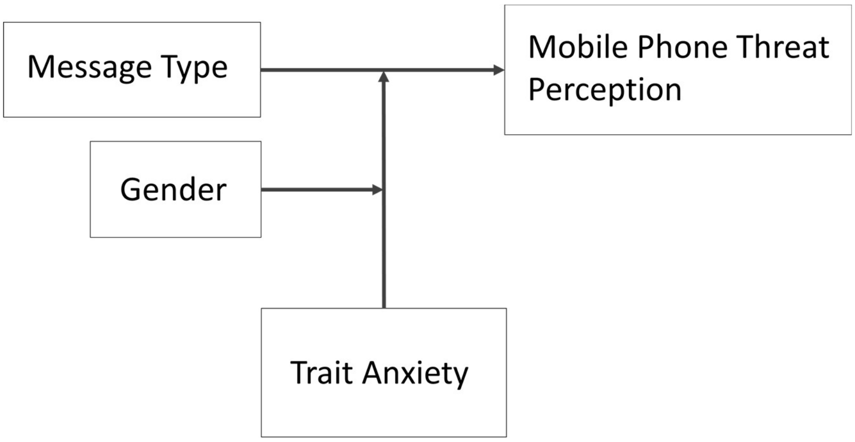

Figure 13. The moderating role of trait anxiety and gender on the influence of precautionary messages on mobile phone threat perception.

As there is no strong theoretical background, we did not expect this pattern to emerge as stable across four of the dependent variables. In the following we offer a detailed interpretation and a theoretical context for this finding. At first, our results suggest that the effect of precautionary messages documented in the literature (Barnett et al., 2007; Barnett et al., 2008; Nielsen et al., 2010; Wiedemann et al., 2013; Wiedemann & Schütz, 2005; Wiedemann, Thalmann et al., 2006) is most prominent in females with low trait anxiety. Conversely, the effect is less pronounced (and did not reach significance) in females with higher trait anxiety levels. As recipient characteristics were ignored in previous experimental studies on the effects of precautionary messages (Wiedemann et al., 2013; Wiedemann & Schütz, 2005; Wiedemann, Thalmann et al., 2006), it could be that the effects on mean level risk perception in these studies were mainly driven by a subset of their participants – females low in trait anxiety. Indeed, in two of those studies (Wiedemann et al., 2013; Wiedemann & Schütz, 2005) there are significantly more female than male participants (which presumably also increases the proportion of females relatively low in anxiety). One of them is a multinational study (Wiedemann et al., 2013) in which, all countries taken together, 59% of participants were female. In some countries that reported a relatively pronounced effect of precautionary messages in that study, the proportion of females was even higher (88% females in the United Kingdom and 66% in Australia). However, we do not know anything about participants' trait anxiety in these studies, which is why this connection to prior results remains speculative.

Regarding the magnitude of the effects that are predicted for low-anxious females, an increase in mobile phone threat of 0.57 units and a reduction of mobile phone trust of -0.67 units on a five-point Likert-scale seem quite noteworthy, bearing in mind that the only difference between the basic and the precautionary group was a short text paragraph informing about one single precautionary recommendation. Government agencies like the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) or the German Federal Office for Radiation Protection (BfS), for instance, inform in greater detail about precautionary options, recommending several precautionary measures. One could expect the effect to be even larger in such cases.

At first sight, it may seem counterintuitive that the precautionary message has the biggest influence in females with low trait anxiety. In line with Spielberger (1983), one would expect high-anxious individuals to perceive the precautionary message more in terms of danger or threat than low-anxious individuals. However, a closer look at the results reveals that the observed pattern is due to differences in the basic condition. While in the basic condition high-anxious females report a higher mobile phone threat than low-anxious females (2.31 vs. 1.96 on a 5-point Likert scale), mobile phone threat is about the same in the precaution condition (2.62 vs. 2.53). The precautionary message hence raises low-anxious women's mobile phone threat up to the level of high-anxious women. Similar patterns were observed for mobile phone trust, base station threat and base station trust.

There are at least three ways of explaining this pattern of results. The first two options are proposed in Mathews & Mackintosh's cognitive model of selective processing in anxiety (Mathews & Mackintosh, 1998). First, the model posits that there is a difference between high and low trait anxiety individuals in their attention to weak threat cues. While high-anxious individuals attend to them, low-anxious individuals do not. Such a difference does not exist for strong threat cues – both high- and low-anxious individuals attend to them. In the current study, this could mean that the basic message represents a weak threat cue while the precautionary message represents a strong threat cue. The second explanation is based on ambiguity. According to Mathews & Mackintosh (1998), highly anxious individuals are more likely to judge ambiguous cues as threatening than low-anxious individuals. In the current study, the basic message could be 'ambiguous' in this sense; it posits that although guidelines have been established and limits were recommended, that 'in some countries a debate about the potential health risks of mobile telephony is still ongoing at all levels of the society'. According to the ambiguity explanation, this would only be interpreted as a threat cue by highly anxious individuals. A third explanation could be that the difference in basic scores is due to pre-existing differences in threat that have nothing to do with the properties of the basic message. This, however, could only explain the difference in the basic condition but not why there is (almost) no difference in the precaution condition.

Regarding males, our data do not allow firm conclusions about the way anxiety influences the effect of the precautionary message. The effect of the precautionary message seems to be reversed in males with low versus high trait anxiety, with highly anxious males having a higher threat perception and lower trust after reading the precautionary message. However, it did not differ significantly from zero, neither in high, nor in low-anxious males. This might be due to the small proportion of males in our sample (26%, N = 76). What can be said with a substantial degree of certainty is that the effect of the precautionary message in males low in anxiety is smaller than the effect in females low in anxiety.

Interestingly, the patterns of how gender and trait anxiety relate to the message effect remained mostly the same when state anxiety variance was partialled out of the trait anxiety variable prior to multiple regression analysis. Although it is not clear what exactly the residualised trait anxiety variable represents, the result indicates that differences in the reaction to precautionary messages in people with varying trait anxiety levels are not due to momentarily higher anxiety levels after precautionary messages, but rather due to a stable anxiety component. Specifically, the precautionary message effect remained highest in women low in the trait anxiety residual variable. Instead of state anxiety, we think it is likely that information processing varies among recipients with different trait anxiety levels and causes the observed differences.

Although precautionary communication has been hypothesised by some scholars (Burgess, 2004; Sunstein, 2005) to raise fear or anxiety, its effects on primarily affective endpoints (e.g. endpoints that assess affective states unrelated to a particular hazard) have not been reported so far. The current study shows that there is neither an increase in mean state anxiety following the reception of the precautionary message, nor is there an increase in the proportion of participants reporting a clinically relevant level of anxiety. Apparently, precautionary communication does not lead to higher concurrent anxiety. This finding questions the often tacit assumption about the relation between cognitive risk perception measures and concurrent emotional states. However, whether precautionary messages result in higher state anxiety levels in exposure situations (e.g. when talking on the mobile phone) *after* receiving a precautionary message is a question the current study cannot answer.

Finally, the complexity of the relationship between trait anxiety, gender and type of message has implications for risk communication in general as it once more shows the importance of the target person's personality characteristics and therefore of tailoring risk communication.

Also, in future reception studies analysing the effects of different types of risk communication, complex interaction patterns should be considered. In the base station scenario for instance, the simple comparison of means between the precautionary and the basic group showed no differences in threat and trust. Still, the regression analysis showed that the precautionary message nonetheless affected participant's threat and trust, but the effects were countervailing in different participants.

General anxiety has been related to risk perception in many studies (Kallmen, 2000; Lerner & Keltner, 2001; Maner & Schmidt, 2006). Still, to our knowledge, it has not been studied in the context of precautionary communication before. Given the broadness of the trait anxiety construct (it does not refer to any specific hazard), it would be interesting to investigate its role in the reception of precautionary messages about other hazards, e.g. potential food hazards. We think it is plausible that trait anxiety plays a crucial role in the reception of precautionary messages about various hazards.

Some limitations of this study have to be taken into consideration. Firstly, the effect sizes observed in the multiple regression analyses were generally small. This is in line with past research (Wiedemann et al., 2013) that used a similar experimental procedure. In order to avoid confounding the experimental manipulation, the dependent variables were not assessed prior to the manipulation. We assume that a large portion of the variability in the dependent variables could be accounted for by pre-existing differences. The study from Nielsen et al. (2010) supports this assumption. The authors used a pre-post design and assessed risk perception prior to and after giving different messages (one of them a precautionary message). They reported that after the precautionary message, about half of their participants did not report a change in their concern in relation to mobile phone use. Besides, Wiedemann et al. (2013) reported that other variables that have been widely researched did not have larger effect sizes in terms of explaining risk perception.

Secondly, we chose one specific precautionary measure for each of base stations and mobile phones. It is possible that the observed effects might differ for other measures. It could be that, for instance, the effect of the precautionary message was (on average) most pronounced in women with low trait anxiety due to the subject of the message, in this case the recommendation to keep mobile phones away from children. Thirdly and as mentioned above, the small proportion of men in the sample limits conclusions about potential moderator variables for men. Fourthly, as we did not apply type 1 error adjustment in the linear multiple regression analyses, there remains the possibility that one or more of the 'significant' results was due to chance alone. Therefore, the results should be interpreted cautiously until they have been replicated. Finally, the whole sample only comprised university students in one country (Australia), which limits the generalisability of the results.

5 Conclusions

The extent of the increase in threat perception caused by messages about precautionary measures regarding electromagnetic fields emitted by mobile phones and base stations seems to differ in accordance with message recipients‘ gender and trait anxiety. In particular, women low in trait anxiety show a pronounced increase in threat perception. Their threat perception is raised to the level of women high in anxiety due to the precautionary message. We think that the most likely explanation for this effect is that with the precautionary information included, the message is interpreted as a threat cue by both high and low-anxious females, while a message without precautionary content is only interpreted as a threat cue by high-anxious females. Precautionary communication did not result in higher concurrent anxiety. This questions the assumptions of some scholars (Burgess, 2004; Sunstein, 2005) who ascribe fear-inducing properties to precautionary messages. Additionally, the relationship between risk perception and emotional distress does not seem to be as simple as often assumed.

Chapter VI

Improving Precautionary Communication in the EMF Field? Effects of Making Messages Consistent and Explaining the Effectiveness of Precautions

Abstract

Many radiation health agencies communicate precautionary measures regarding the use of mobile communication devices, e.g. the use of a headset while talking on the phone. These precautionary messages have, however, been shown to unintentionally increase risk perceptions about radiofrequency electromagnetic fields (RF EMFs). The current study tested two potential ways of amending precautionary messages in order to minimise this unintentional effect. Firstly, the messages' potential to be perceived as inconsistent and thereby raise suspicions was addressed; secondly, the effectiveness of the precautions was explained. An experimental design was applied in which a quota sample of 1717 Australian residents was randomly assigned to one of six message conditions. Three different risk perception measures served as dependent variables, two of them are conditional measures. The original effect of precautionary messages to amplify risk perceptions could not be replicated. Furthermore, amending precautionary messages in favour of more consistency had no effect, while explaining the effectiveness of the precautions increased conditional risk perception under the condition that no precautions are taken. This was contrary to our assumptions. We infer from these results that changing precautionary messages in terms of consistency and effectiveness in order to reduce risk perception is hardly possible. The use of conditional risk perception measures seems fruitful for studies looking at the effects of precautionary or protective messages, given that previous studies have only investigated effects on unconditional risk perception. However, the present results should not be over-interpreted as the measures' validity in the EMF context still needs further investigation.

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1 Introduction

In radiation protection, the precautionary principle is a backbone of risk policy. In line with this maxim, precautionary messages regarding the use of mobile communication devices are disseminated by radiation health authorities in various countries, e.g. in Australia, Austria, France, Germany and the United Kingdom (Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail, n.d.; Australian Radiation Protection and Nuclear Safety Agency, n.d.; Bundesamt für Strahlenschutz, n.d.a; Bundesministerium für Gesundheit und Frauen, n.d.; Public Health England). The term precaution itself can be defined in different ways; indeed there exist many different versions of the so called precautionary principle, some of them weaker and others stronger (see for example Ashford et al., 1999; European Commission, 2000; Morris, 2000; Sunstein, 2005). With the provision of precautionary messages, public health authorities aim at providing protection without unduly increasing concern. What is seen as a 'reasonable amount' of concern is debatable for any kind of risk, of course. Nevertheless, when comparing proven health risks like smoking and uncertain risks like exposure to radiofrequency electromagnetic fields (RF EMFs) used in mobile telecommunications, it is obvious that for the former, increasing risk perceptions seems a reasonable goal, while for the latter the benefit of increasing risk perceptions is less clear. Thus, the proportionality of public concern and the risk at hand should be kept in mind when informing about risks and precautions.

Yet desired effects and the effects that risk communication efforts factually have on their recipients are two different things. Mostly unexpected by radiation health authorities, precautionary communication regarding potential health effects of exposure to RF EMFs used in mobile telecommunications has been shown to increase recipients' risk perception about RF EMFs (Barnett et al., 2008; Nielsen et al., 2010; Wiedemann et al., 2013; Wiedemann & Schütz, 2005; Wiedemann, Thalmann et al., 2006). This effect seems to be robust, as it has been shown with different kinds of messages and by different researchers. However, one study (Cousin & Siegrist, 2011), using information brochures as stimuli, did not find an effect of precautionary messages. In that study, information about RF EMFs and mobile phone and base station radiation patterns increased mobile phone risk perception, regardless of whether there were additional precautionary recommendations. Furthermore, limiting the generalizability of the effect, most of the studies reporting it have been conducted with ad-hoc (Barnett et al., 2008; Wiedemann & Schütz, 2005) or student samples (Wiedemann et al., 2013; Wiedemann, Thalmann et al., 2006), a limitation that the current study intends to overcome.

Still, until recently, how precautionary messages increase recipients' concerns about potential health effects has not been investigated in depth. A recent study found that the effect is dependent on recipient characteristics (Boehmert, Wiedemann, Pye, & Croft, 2017), but cognitive or affective processes involved in the effect remain unknown. Furthermore, and more interesting from a practical risk communication perspective, it is also unknown whether precautionary messages can be amended such that they do not unintentionally increase participants' risk perception. The current study attempts to answer the latter question. The practical implications of this research are clear – if there is a way to amend precautionary recommendations so that they do not unintentionally increase participants' risk perceptions, then these amendments should be applied to precautionary communication. If there is no way to reduce the concern-increasing effect of precautionary messages, then authorities need to reconsider their communication practice regarding, at least, the handling of public RF EMF related concerns and worries. Of course, the above assumes that increasing concern is not a desired outcome of the precautionary message, but this may not always be the case. For example, heightened concern can be seen as a facilitating condition for applying precautionary behaviours (in line with Roger's Protection Motivation Theory outlined below), and so if communicators want recipients to carry out the recommended protective behaviours, then the heightened concern would be a desired effect. However, for the purpose of this paper, in relation to RF EMFs, it is assumed that the goal is not to 'increase concern in order to encourage protective behaviours'.

1.1 Two Potential Ways to Alter Precautionary Messages

1.1.1 Inconsistency of Precautionary Messages

From our perspective, there are two conceivable reasons for the countervailing concern-increasing effect of precautionary communication. The first one is inherent to the logic of any precautionary message. Precautionary messages inform about already implemented precautions (e.g. by a government) or about precautions that should be implemented in the future (e.g. by the message recipient) due to potential health risks. That is, precautionary messages do, either implicitly or explicitly, suggest a health risk. The second reason has to do with the communication of uncertainty. As Longman, Turner, King, and McCaffery (2012) have shown, communicating uncertainty results in increased risk perceptions and decreased perceived credibility. Communicating precautionary messages may, therefore, undermine the trust established in exposure guidelines, as already feared by the WHO in 2000 (WHO, 2000). That is, it is not necessarily logical for people to believe both that the guidelines protect from detrimental health effects, and that precautionary measures are needed. Past qualitative research (Timotijevic & Barnett, 2006) suggests that message recipients notice and interpret this inconsistency. In that focus group study, participants mentioned that 'it's quite contradictory to say that there are none [no evidence of risk] and then to recommend caution'. Timotijevic and Barnett (2006) also reported participants voicing their suspicions ('I'm sure they know more than they're letting on'). Although the study provides no explicit link between the perceptions of inconsistency and these suspicions, it seems plausible that the former gives rise to the latter.

Wiedemann, Boerner, and Claus (2017) propose a theoretical explanation for the role of inconsistency in the effect of precautionary messages. They assume that the inconsistency of the message results in a state of cognitive dissonance (Festinger, 1957), and that this dissonance amplifies one's risk perception. This dissonance can be reduced by questioning the claim that the existing limit values for RF EMF exposure protect public health, or by questioning the claim that precautionary measures are needed. The questioning of the first claim should result in increasing one's risk perception.

In the current study, we address this issue by disclosing a potential rationale behind the communication of the precautionary measures so as to reduce the perception of inconsistency (i.e. providing concerned people with a measure to reduce their exposure to RF

EMFs should they wish to reduce it, rather than it being recommended because the science shows that it will reduce risk; see Appendix B for the wording). Our hypothesis pertaining to message consistency is that reducing the precautionary message's potential to be perceived as inconsistent will reduce risk perception, compared to a precautionary message without the text to reduce the apparent inconsistency.

1.1.2 Belief in the Effectiveness of Precautionary Measures

A classical theory of health behaviour is protection motivation theory (PMT; Maddux & Rogers, 1983; Rogers, 1975). The PMT was developed to investigate the effects of a specific kind of health risk message: fear appeals. The theory was developed by Ronald W. Rogers who was the first to postulate three essential components of a fear appeal, namely: (1) the probability that a threat would occur; (2) its magnitude of noxiousness; and (3) the effectiveness of the recommended response (Rogers, 1975). These message components are able to influence the central cognitive constructs that in turn influence protection motivation. In a revised model (Maddux & Rogers, 1983), the central cognitive constructs of PMT, a threat appraisal and a coping appraisal, are each determined by several variables. Threat appraisal is determined by the perceived severity of a threat, the perceived vulnerability to that threat and intrinsic or extrinsic rewards of a maladaptive behaviour. The coping appraisal is determined by the perceived efficacy of a (protective) behaviour, a person's self-efficacy and the response costs.

While PMT tries to predict protective behaviour or behavioural intentions, our main variable of interest in the context of precautions against the potential health effects of exposure to RF EMFs is risk perception. Hence, we suggest an effect that has not been modelled in PMT – namely a direct relation between perceived efficacy and risk perception (or 'threat appraisal' as it is termed in PMT). Positing this relationship seems generally plausible, given that the relation between efficacy appraisal and threat appraisal has been a major point of discussion in PMT (Norman, Boer, & Seydel, 2005; see also the paragraph about conditional risk perception measurement below). Further, it seems a reasonable approach for investigating the effects of RF EMF precautionary information specifically.

In order to understand how PMT may be relevant in the case of RF EMFs from mobile communication devices, it is important to note that there are some common misconceptions among lay people regarding RF EMF exposure patterns (Cousin & Siegrist, 2010b): (1) exposure is erroneously believed to decrease linearly, and not with the inverse square of the distance from the source; and (2) the relative contribution of base stations to overall exposure is overestimated, and hence the contribution of mobile phones underestimated. Consistent with this view, concerns about RF EMFs emitted by base stations are higher than concerns about RF EMFs from mobile phones (Boehmert, Wiedemann et al., 2017; Cousin & Siegrist, 2010b; Siegrist, Earle et al., 2005; Wiedemann et al., 2013). In fact, many people do not appreciate that their mobile phone itself is a small base station (Cousin & Siegrist, 2010b). Thus, it would be expected that recipients underestimate the effectiveness of precautionary measures communicated by radiation health authorities because these aim at increasing a person's distance to the mobile phone or at reducing the strength of the RF EMF emitted by the phone. Our hypothesis pertaining to the effectiveness of the precautions thus states that emphasizing the effectiveness of precautionary measures by: (1) explaining the importance of the distance variable; and (2) explaining that mobile phones are responsible for a larger share of personal exposure than base stations, would attenuate the precautionary message's potential to increase risk perception.

Claassen et al. (2015) conducted a study providing their participants with similar information. One of their text modules explained the distance-exposure relationship and also the relative contribution of nearby EMF sources (e.g. mobile phones) versus sources that are far away (e.g. base stations). In contrast to the current study, Claassen et al. (2015) focussed on mere knowledge provision and did not use these facts to explain the relative effectiveness of precautionary measures. They did not find an effect of this text module on risk perception. However, given the rather small effect sizes of information provision on risk perception reported in previous studies (Boehmert, Wiedemann et al., 2017; Wiedemann et al., 2013), this study might have been underpowered with an N = 245 and a 2 × 2 × 2 group design. Furthermore, we think that communicating this information in order to explain the effectiveness is likely to change its effect.

1.2 A Methodological Issue: Conditional Risk Perception Measurement in Studies Testing Communications of Precautionary or Protective Measures

Risk perception is usually measured with one or more items that simply ask participants how risky, dangerous or threatening a particular situation or behaviour is. According to Ronis (1992) and van der Velde, Hooykaas, and van der Pligt (1996), this type of measurement captures people's unconditional risk perception. 'Unconditional' refers to the fact that it remains unknown if participants include the possibility of taking precautionary or protective actions in their rating. Opposed to this, van der Velde et al. (1996) suggest that measures of conditional risk perception should be applied more often. Conditional risk perception measures are more closely related to the concepts used in various social cognitive models (Janssen, van Osch, Vries, & Lechner, 2011; Norman et al., 2005; Ronis, 1992; Weinstein & Nicolich, 1993), among them the Protection Motivation Theory. An item capturing conditional risk perception either explicitly asks for the risk estimate 'without precautions' (e.g. 'How dangerous do you think the electromagnetic fields from mobile phones are while talking on the phone without using any precautionary measures?') or 'if precautions are taken' (e.g. 'How dangerous do you think the electromagnetic fields from mobile phones are while talking on the phone if precautionary measures that you deem appropriate are used?'). We think that this distinction is very important in research studying the effects of the communication of precautionary or protective measures (i.e. the communication of measures against a proven risk) as an unconditional measurement is not able to tap potentially important processes. For instance, one person could think that exposure to RF EMFs is very risky if no precautionary measures are taken (high conditional risk 1), but because she or he also thinks that there are effective precautionary measures at hand (low conditional risk 2), he or she may judge the unconditional risk as low. Another person might not include their view of conditional risk 2 in his or her rating of the unconditional risk and hence give a high risk estimate. This example shows that it can be quite difficult to interpret unconditional risk perception measures. Notably, all studies that have looked at the effects of precautionary messages about RF EMFs have so far used unconditional risk perception measures (Barnett et al., 2008;

Boehmert, Wiedemann et al., 2017; Cousin & Siegrist, 2011; Nielsen et al., 2010; Wiedemann et al., 2013; Wiedemann & Schütz, 2005; Wiedemann, Thalmann et al., 2006).

Thus, in general, it is difficult to disentangle whether unconditional risk perceptions 'drive health-protective intentions or whether these intentions are used to infer risk perceptions' (Norman et al., 2005). To get a clearer picture of participants' actual risk perceptions, we will therefore analyse conditional risk perception measures in the current study. To ensure the comparability with former studies, we will also analyse unconditional measures and compare these with the conditional measures. In the following hypotheses section every hypothesis is stated specifically for each of the three risk perception measures (unconditional risk perception, conditional risk perception without precautions and conditional risk perception if precautions are taken).

1.3 Hypotheses

Hypothesis 1 (replication): In line with previous research, we hypothesise that risk perception will be higher after reading a precautionary message than after a basic message which does not contain precautionary information. The effect should be observed for unconditional risk perception (UR) and conditional risk perception without precautions (CR1). We do not expect to find the effect for conditional risk perception if precautions are taken (CR2). In fact, new knowledge about the measures might even cause CR2 to be lower after the precautionary message. As previous studies used UR measures, the replication with the unconditional measure (hypothesis 1a) can be regarded as a 'literal replication' according to the terminology of replications introduced by Kelly, Chase, and Tucker (1979). Hypotheses 1b and 1c test the effect of the same experimental variation on dependent variables that have previously not been used. In the terminology of Kelly et al., this can be called an operational replication.

Hypothesis 1a: $UR_{precaution} > UR_{basic\ message}$

Hypothesis 1b: $CR1_{precaution} > CR1_{basic\ message}$

Hypothesis 1c: $CR2_{precaution} \leq CR2_{basic\ message}$

The previous studies on the effects of precautionary messages were based on a simple factorial design. Here, the decisive factor referred to precaution, and, usually, two experimental conditions are used: a basic text about how the exposure guidelines protect health, and a precautionary text that informs about additional precautionary measures (Wiedemann et al., 2013). Following the basic concept of the Solomon four group design, it seems useful to add a further treatment step. It consists of a group that receives no information at all about RF EMFs in mobile telecommunications. This allows one to test for an effect of the basic message stating the safety of the current exposure limits. Such an effect is plausible on the basis of former studies (cf. MacGregor, Slovic, & Morgan, 1994) and useful to investigate as, to our knowledge, this 'safety' basic message forms part of many risk communication efforts by national health authorities.

Hypothesis 2 (no message baseline): For the comparison of the basic message with the condition of not reading any text at all, we expect the same pattern as for the comparison of the precautionary message with the basic message UR and CR1. We expect the basic message also to increase CR2.

Hypothesis 2a: $UR_{basic\ message} > UR_{no\ message}$

Hypothesis 2b: $CR1_{basic\ message} > CR1_{no\ message}$

Hypothesis 2c: $CR2_{basic\ message} > CR2_{no\ message}$

Hypothesis 3 (consistency): Regarding the consistency amendment of the precautionary message, we hypothesise that risk perception will be lower after the consistent precautionary message than after the original precautionary message. This effect should be observed for unconditional risk perception (UR) and conditional risk perception without precautions (CR1). It was not quite clear to us as to how increased message consistency might influence conditional risk perception if precautions are taken (CR2). We therefore hypothesise that we will not find an effect.

Hypothesis 3a: $UR_{precaution} > UR_{consistent\ precaution}$

Hypothesis 3b: $CR1_{precaution} > CR1_{consistent\ precaution}$

Hypothesis 3c: $CR2_{precaution} = CR2_{consistent\ precaution}$

Hypothesis 4 (effectiveness): Regarding the effectiveness amendment of the precautionary message, we hypothesise that risk perception will be lower after the precautionary message containing effectiveness information than after the original precautionary message. This effect should be observed for unconditional risk perception (UR) and conditional risk perception if precautions are applied (CR2). However, for the judgement of conditional risk perception, if precautions are not applied (CR1), the effectiveness amendment should not make any difference.

Hypothesis 4a: $UR_{precaution} > UR_{effective\ precaution}$

Hypothesis 4b: $CR1_{precaution} = CR1_{effective\ precaution}$

Hypothesis 4c: $CR2_{precaution} > CR2_{effective\ precaution}$

Hypotheses 3 and 4 concern the specific effects of two additional text modules. However, in practice, the two types of information might be communicated together. Communicating both the consistency and effectiveness information may be useful to ensure that, if different recipients find different types of additional information important, then in this case all recipients would avoid unduly increasing their concern. Additionally, studying the effect of the combination of both text modules allows us to test the hypothesised pattern of influence of each text on each of the conditional variables once more. That is, while the effectiveness is assumed to influence CR2 but not CR1, consistency is hypothesised to act conversely.

Hypothesis 5 (consistency plus effectiveness): We hypothesise that the combination of the consistency and effectiveness information will lead to decreased scores on all three risk perception variables, compared with each of the consistency and effectiveness conditions separately. The exceptions are that the additional effectiveness information is not hypothesised to influence CR1 and that the additional consistency information is not assumed to influence CR2.

Hypothesis 5a:

(1) $UR_{effective + consistent\ precaution} < UR_{consistent\ precaution}$ and

(2) $UR_{effective + consistent\ precaution} < UR_{effective\ precaution}$

Hypothesis 5b:

(1) $CR1_{effective + consistent\ precaution} = CR1_{consistent\ precaution}$ and

(2) $CR1_{effective + consistent\ precaution} < CR1_{effective\ precaution}$

Hypothesis 5c:

(1) $CR2_{effective + consistent\ precaution} < CR2_{consistent\ precaution}$ and

(2) $CR2_{effective + consistent\ precaution} = CR2_{effective\ precaution}$

2 Materials and Methods

2.1 Sample

The study was conducted with an online panel of Australian residents managed by a global market research institute (Survey Sampling International). In order to increase the representativeness of the sample for the general population, interlocking quotas for gender, age and region of residence were applied for each experimental group separately (this procedure resulted in many ‘overquota responses’). In total, 2276 participants aged between 18 and 65 fully completed the study materials. Participants were excluded in three subsequent steps. Firstly, 181 participants were excluded because they had ‘straight lined’ 20 questions on one page in a row. Secondly, 176 participants who had given a wrong answer to the question ‘what day was it yesterday’ were excluded. Subsequently, 175 participants were discarded prior to the analyses because they had completed the experiment implausibly quickly, indicating that they did not read the text material and/or answered the questions without reading them properly. Pretesting in our lab had shown that completing only the questionnaire (no text condition, see Table 8) could not be done adequately in less than 5 min and 30 s. Conservatively, we excluded participants in this group if they had completion times < 5 min. For the other groups, the completion time below which we excluded participants varied with the length of text they were presented with. For instance, Group 6 received all the text modules (see Appendix B). In this group, we excluded participants that had completion times < 7 min. In addition, 27 participants were excluded because they had completion times > 90 min (none of the results changed in terms of statistical significance if participants with completion times > 90 min were included). The final sample consisted of 1717 participants. Participants received reward points from the market research company for their participation. These reward points could be combined with reward points from other studies and used to purchase vouchers, for example for online shops.

Table 8. Different Types of Messages About Radiofrequency Electromagnetic Fields from Mobile Phones in the Different Study Groups.

Group No.	N	Information Group	Gender % Female	Age Mean (SD)
1	303	No text group[1]	53.8	42.7 (13.2)
2	281	Basic group	53.7	43.8 (13.2)
3	279	Precaution group	53.4	43.4 (13.9)
4	297	Consistency group	51.2	42.5 (13.5)
5	292	Effectiveness group	56.5	42.8 (13.8)
6	265	Consistency + effectiveness group	56.2	43.1 (13)

[1] In Group 1, participants received an introductory sentence before answering the conditional risk perception questions. The sentence stated that some people apply precautionary measures. Without this information, the questions would have been meaningless to those who had never heard about precautionary measures before.

2.2 Procedure

Members of the market research company's panel were contacted via email and invited to 'take a survey'. The invitations randomly contained one of six links, allocating participants to one of the six experimental groups. If a person agreed to take the survey, they were then redirected to the start page of the survey that first checked their eligibility in terms of the above-mentioned quotas. If eligible, they were then provided with a participant information sheet informing them about the researchers, the aim of the research, their task and other general information. After the participant information sheet, they were provided with the different types of information. Five groups each received one of five versions of a message about exposure to RF EMFs from mobile phones and health. One group did not receive any information and directly started with the questionnaire. The questionnaire was the same for all groups. After completing the questionnaire, participants were informed about the scope of the study and provided with the researcher contact information once again as well as with a link to the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), in case they wanted more information. The study was approved by the University of Wollongong Human Research Ethics Committee (Code: HE15/286).

2.3 Design and Information Provision

The six experimental conditions are listed in Table 8. The wording of the text modules can be found in Appendix B. A full 2 (basic text) × 2 (precaution) × 2 (consistency) × 2 (effectiveness) factorial design was not applicable as, for example, trying to make the message consistent by explaining why precaution is recommended is only meaningful if the precautionary information is actually given (and not only the basic message). Group 1, the 'no text group' did not receive any information at all and started answering the questionnaire right away. Group 2, the 'basic group' read a basic text about the safety of the current exposure limits. Group 3, the 'precaution group' read the basic text and additionally a precautionary message about several ways to reduce personal exposure (e.g. by using a headset or a landline phone). Group 4, the 'consistency group', received the same information as the 'precaution group' and additionally a short paragraph explaining the motives behind the communication of the precautionary measures. Group 5, the 'effectiveness group', received the same information as the 'precaution group' and additionally a longer paragraph explaining the effectiveness of the precautionary measures, including a table. Group 6, the 'consistency + effectiveness group' was provided with both the paragraphs about the motives for communicating precautionary measures and the effectiveness of the precautionary measures. The order of the text modules was always kept the same across all groups: (1) Basic text (2) precautionary text (3) consistency text (4) effectiveness text. In giving the basic text prior to the precautionary text, we follow the communication practice of national radiation health authorities, for instance those in Australia, France, Germany, Israel and the United States (Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail, n.d.; Australian Radiation Protection and Nuclear Safety Agency, n.d.; Bundesamt für Strahlenschutz, n.d.a; Federal Communications Commission, n.d.; Israel Ministry of Environmental Protection, n.d.).

2.4 Questionnaire

The course of the questionnaire is summarised in Figure 14. The questionnaire started with the question for unconditional risk perception ('How dangerous do you think the electromagnetic fields from mobile phones are while you talk on the phone?'), followed by a question about their perceived control of mobile phone EMFs and a question about whether they think there is a need to reduce exposure to EMFs from mobile phones. On the next page, exposure perception was assessed by showing participants a picture of a man talking on a mobile phone held at his ear and asking them 'In your opinion, how strong is the exposure to the person in the picture above?' On the next page, conditional risk perception without precautions ('How dangerous do you think the electromagnetic fields from mobile phones are while talking on the phone without using any precautionary measures?') and conditional risk perception with precautions ('How dangerous do you think the electromagnetic fields from mobile phones are while talking on the phone if precautionary measures that you deem appropriate are used?') were assessed.

The three risk perception items were all rated on seven-point Likert-scales that were numbered from one to seven and had labelled endpoints (1 = not dangerous at all, 7 = very dangerous). Previous studies of EMF risk perception have frequently used this type of scale ranging from no danger/risk to high danger/risk (e.g. Cousin & Siegrist, 2008, 2011; MacGregor et al., 1994; Sjöberg, 2000d; Wiedemann et al., 2013). Still, one has to be aware of the fact that the scale is imbalanced as all but one scale point indicate (to some extent) a danger/risk. Hence, this form of measurement can potentially overestimate 'real' risk perception (Gaskell et al., 2016). However, the absolute value of risk perception was of minor importance for the current study, as we were interested in the differences between the experimental groups.

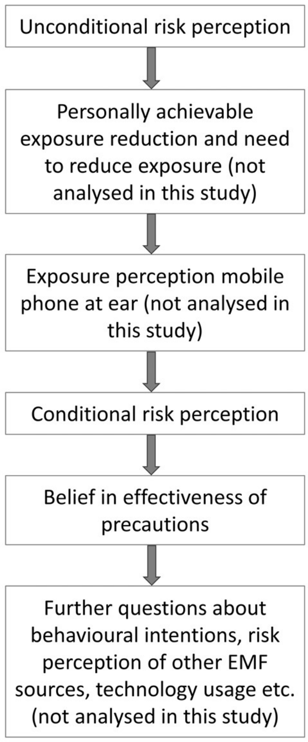

Figure 14. Flowchart of the course of the questionnaire.

Perceived control of exposure, need for exposure reduction and exposure perception were not analysed for the current study. On the subsequent page, participants indicated their belief in the effectiveness of six precautionary measures. On top of this page, they were presented with the initial statement ‘I believe that using the following measures reduces the likelihood of any negative health effects that mobile phone calls could have.’ Below this statement they were given six precautionary measures (e.g. ‘Using a headset when making mobile phone calls’) and had to indicate the strength of their belief on a numbered Likert-scale ranging from ‘1 = I do not believe this at all’ to ‘7 = I believe this very much’.

2.4.1 Order of Risk Perception Items

As described above, unconditional risk perception was assessed prior to the conditional risk perception questions and on a separate page. The unconditional item had to be assessed first because once the distinction between conditional risk perception without precautions and conditional risk perception with precautions is introduced, the lack of specification in the unconditional item becomes obvious and potentially confusing for the participants. The conditional risk perception items were both asked on the same page. Hence, participants could compare and adjust their answers relative to each other. How the two items interact with each other and if they would be answered differently if asked separately, are open questions. To mitigate potential unwanted effects, they were introduced with the following statement: ‘One of the previous questions was ‘How dangerous do you think the electromagnetic fields from mobile phones are while you talk on the phone’. We will now ask two related questions that focus on different aspects of your opinion. Some people might answer both questions differently while others might give the same answer. Please remember that we are interested in your opinion, so there is no right or wrong'. This statement was supposed to: (1) differentiate the items clearly from the unconditional item; and (2) avoid that the distinction between the two conditional items causes respondents to answer the questions differently 'just because it seems logical to give different answers'. The order of the two questions was not varied and conditional risk perception without precautions was asked first. This order has been used previously (Janssen et al., 2011), though it has to be noted that participants had to answer other questions in between the conditional items in the cited study. Furthermore, to us, it seems more in line with everyday thinking for the participants to rate the risk if nothing is done as a kind of baseline first and then to rate the risk if precautions are taken than doing it conversely.

2.5 Statistical Analyses

2.5.1 Risk Perception Measurement

In order to obtain data on the characteristics of the three dependent variables (unconditional risk perception, conditional risk perception without precautions and conditional risk perception if precautions are taken), means and standard deviations were calculated for these variables on the level of the entire sample. The significance of the mean differences between the three variables was calculated using paired-samples t-tests. Pearson correlations were also calculated for these three variables.

2.5.2 Effects of Different Types of Information on Risk Perception

For the analysis of the effects of different types of information on risk perception, we divided our hypotheses into two sets. The first set comprises hypotheses 1 and 2, which aim to replicate former results and analyse the effect of the basic message itself. Hypotheses 3 to 5 have a different scope. Each of these hypotheses aims to test the effect of a textual addition to the precautionary message. Therefore, we treat these hypotheses as the second set. For the two sets, separate one-way ANOVAs were calculated (see Table 9). For each of the three dependent variables (unconditional risk perception, conditional risk perception without precautions, and conditional risk perception with precautions) we conducted separate ANOVAs, resulting in six ANOVAs being calculated in total. In case of a significant ANOVA, we calculated independent samples t-tests to determine whether the hypothesised differences were observed. We used t-tests and not typical post-hoc tests like the Scheffé test or Tukey because we hypothesised specific differences a priori. In sum, we planned to conduct 18 t-tests (three for each of hypotheses one to four and six for hypothesis five). Type one error accumulation can be a problem when conducting multiple tests regarding the same hypothesis. In our case, however, hypotheses differ from each other and do not simply test the same effect on a different dependent variable. Nevertheless, we set $\alpha = .01$ for the t-tests. For significant group differences, Cohen's d was calculated as a measure of the effect size.

Table 9. Structure of the Conducted Analyses of Variance

Hypothesis No.	Factor	Factor Levels
Hypothesis 1 and 2	Information Type	no text; basic text; precaution
Hypothesis 3, 4 and 5	Information Type	precaution; consistency; effectiveness; consistency + effectiveness

3 Results

3.1 Risk Perception Measurement

The means, standard deviations and correlations of the three risk perception variables for the whole sample are depicted in Table 10. As expected, the means differ significantly from each other (all $t \geq 15.57$, all $p < .001$), with the mean of conditional risk perception without precautions (CR1) being higher than the mean of unconditional risk perception (UR). The mean of conditional risk perception with precautions (CR2) is much lower than both of the other means. All variables are highly and positively correlated.

Table 10. Means, Standard Deviations and Correlations of the Risk Perception Variables (N = 1717)

	CR1[1]	CR2[2]	UR[3]
CR1	4.65(1.56)		
CR2	.50	3.08(1.35)	
UR	.77	.50	4.30 (1.44)

[1] CR1 = conditional risk perception without precautions; [2] CR2 = conditional risk perception with precautions; [3] UR = unconditional risk perception. Means (standard deviations). All correlation coefficients are significant ($p < .001$).

3.2 Manipulation Check

In order to examine whether reading the text module about the precautionary measures' effectiveness increased the belief in the effectiveness of the measures, the mean score of the six items capturing the beliefs in the different measures was calculated. Using an independent samples t-test, this mean score was then compared between the precaution group and the precaution plus effectiveness group. We did not include items for checking whether the consistency text module actually reduces perceptions of inconsistency. This is discussed as a limitation in the discussion section.

The assumptions for conducting the independent samples t-test for the comparison of the belief in the efficacy of the precautions were met (Levene's test $F = .493$, $p = .48$, the Kolmogorov–Smirnov test indicated the deviation from the normal distribution in the groups but this can be neglected for large samples). The mean response effectiveness scores were 4.64 in the 'precaution group' and 5.06 in the 'effectiveness group'. This difference was highly significant ($t = -4.055$, $p < .001$) and indicates that the effectiveness text module served the intended function.

3.3 Effects of Different Types of Information on Risk Perception

Means and 99% confidence intervals of the three risk perception variables in each group can be found in Table 11. Table 12 summarises the outcomes of the hypothesis tests reported below.

Table 11. Means (99% Confidence Intervals) of Risk Perception in the Experimental Groups

Experimental Group	UR [1]	CR1 [2]	CR2 [3]
no text	4.07 (3.84–4.30)	4.30 (4.06–4.54)	3.08 (2.88–3.28)
basic text	4.21 (3.98–4.44)	4.51 (4.26–4.76)	3.19 (2.98–3.40)
basic + precaution	4.35 (4.14–4.56)	4.55 (4.32–4.78)	3.11 (2.91–3.32)
basic + precaution + consistency	4.20 (3.98–4.41)	4.49 (4.27–4.72)	3.01 (2.81–3.21)
basic + precaution + effectiveness	4.50 (4.29–4.72)	5.05 (4.83–5.28)	3.03 (2.83–3.24)
basic + precaution + consistency + effectiveness	4.49 (4.28–4.71)	5.03 (4.79–5.26)	3.08 (2.86–3.30)

[1] UR = unconditional risk perception; [2] CR1 = conditional risk perception without precautions; [3] CR2 = conditional risk perception with precautions.

3.3.1 Hypotheses 1 and 2

A Levene's test indicated that the homogeneity of variances assumption for calculating an ANOVA was not violated for any of the three dependent variables (all $F < 2.065$, all $p > .12$). A Kolmogorov–Smirnov test for normality of the distribution of errors in each group was significant for all three dependent variables, indicating the deviation from the normal distribution (all $d > .191$, all $p < .001$). These deviations were due to moderate negative kurtosis ($-.65 \leq k \leq .09$ for all kurtosis values) and due to moderate skewness ($-.38 \leq s \leq .42$ for all skewness values). While skewness does not influence the ANOVA significance test, a negative kurtosis can inflate type one error (Lüpsen, 2016; Wirtz & Nachtigall, 2002). However, because ANOVA is robust towards violations of the normality assumption for large samples, the kurtosis violation was moderate and because we adjusted for type 1 error for the subsequent t-tests, we proceeded with the ANOVA.

None of the three ANOVAs conducted yielded a significant result (for UR $F = 2.742$, $p = .07$; for CR1 $F = 2.083$, $p = .13$; for CR2 $F = .516$, $p = .60$). Thus, on all three risk perception variables, there were no differences among the 'no text group', the 'basic group' and the 'precaution group'. Hypotheses 1a and 1b and Hypotheses 2a, 2b and 2c are therefore rejected. The results are consistent with Hypothesis 1c.

3.3.2 Hypotheses 3, 4 and 5

A Levene's test indicated that the homogeneity of variances assumption for calculating an ANOVA was not violated for any of the three dependent variables (all $F < .586$, all $p > .62$). A Kolmogorov-Smirnoff test for normality of the distribution of errors in each group was significant for all three dependent variables, indicating the deviation from the normal distribution (all $d > .187$, all $p < .001$). These deviations were due to skewness

($-.81 \leq s \leq .57$ for all skewness values) and moderate, mostly negative kurtosis ($-.50 \leq k \leq .38$ for all kurtosis values). Due to the same reasoning as for the ANOVAs for Hypothesis 1 and 2, we still conducted the ANOVAs.

The ANOVA F-test showed significant group differences in UR ($F = 3.142$, $p = .02$) and in CR1 ($F = 11.695$, $p < .001$), but not in CR2 ($F = .336$, $p = .799$). This indicates that at least two of the included groups (precaution group, consistency group, effectiveness group and consistency + effectiveness group) differ significantly in the t-test from each other in UR and CR1 on a significance level of $\alpha = 0.05$. For the significant ANOVAs, we proceeded with our planned comparisons using t-tests. As the ANOVA was not significant for CR2, we do not report any further t-tests for this variable. As CR2 group differences in the ANOVA were not significant, we rejected Hypotheses 4c and 5c(1). Finding no difference is consistent with Hypotheses 3c and 5c(2).

The homogeneity assumption was met for every t-test we calculated (all $F < 1.205$, all $p > .27$). The variables were not normally distributed, however, for group sizes of $n_i > 30$ the t-test is robust against a violation of this assumption.

Pairwise Comparisons for Hypothesis 3

All mean differences between the ‘precaution group’ and the ‘consistency group’ were statistically not significant ($t_{df = 574} = 1.345$, $p = .18$ for UR and $t_{df = 574} = .458$, $p = .65$ for CR1). Hypotheses 3a and 3b therefore have to be rejected.

Pairwise Comparisons for Hypothesis 4

The mean difference in UR between the ‘precaution group’ and the ‘effectiveness group’ was not significant ($t_{df = 569} = -1.309$, $p = .19$). Hypothesis 4a was therefore rejected. There was a highly significant difference between the two groups in CR1 ($t_{df = 569} = -4.052$, $p < .001$, Cohen’s $d = .33$), with the mean in the ‘effectiveness group’ being higher. We hypothesised CR1 to be equal in the ‘precaution group’ and the ‘effectiveness group’. Therefore, Hypothesis 4b was rejected.

Pairwise Comparisons for Hypothesis 5

The ‘consistency group’ and the ‘consistency + effectiveness group’ differed considerably in UR, but not significantly on the applied significance level of $\alpha = .01$ ($t_{df = 560} = -2.536$, $p = .01$). The ‘effectiveness group’ and the ‘consistency + effectiveness group’ did not differ in UR ($t_{df = 555} = .077$, $p = .94$). Therefore, Hypotheses 5a(1) and 5a(2) are rejected. For CR1, there was a significant difference between the ‘consistency group’ and the ‘consistency + effectiveness group’ ($t_{df = 560} = -4.262$, $p < .001$, Cohen’s $d = .36$) with the mean being higher in the ‘consistency + effectiveness group’. As we assumed the means to be equal, we rejected hypothesis 5b(1). The ‘effectiveness group’ and the ‘consistency + effectiveness group’ did not differ in CR1 ($t_{df = 555} = .224$, $p = .82$). Hypothesis 5b(2) was thus rejected.

Table 12. Summary of Hypotheses Decisions in Chapter VI

Hypothesis No.		Specific Hypothesis for UR, CR1 and CR2 [1]	Decision
Hypothesis 1	a	$UR_{precaution} > UR_{basic\ message}$	Reject
	b	$CR1_{precaution} > CR1_{basic\ message}$	Reject
	c	$CR2_{precaution} \leq CR2_{basic\ message}$	(Accept) [2]
Hypothesis 2	a	$UR_{basic\ message} > UR_{no\ message}$	Reject
	b	$CR1_{basic\ message} > CR1_{no\ message}$	Reject
	c	$CR2_{basic\ message} > CR2_{no\ message}$	Reject
Hypothesis 3	a	$UR_{precaution} > UR_{consistent\ precaution}$	Reject
	b	$CR1_{precaution} > CR1_{consistent\ precaution}$	Reject
	c	$CR2_{precaution} = CR2_{consistent\ precaution}$	(Accept)
Hypothesis 4	a	$UR_{precaution} > UR_{effective\ precaution}$	Reject
	b	$CR1_{precaution} = CR1_{effective\ precaution}$	Reject (countervailing)
	c	$CR2_{precaution} > CR2_{effective\ precaution}$	Reject
Hypothesis 5	a(1)	$UR_{effective\ +\ consistent\ precaution} < UR_{consistent\ precaution}$	Reject
	a(2)	$UR_{effective\ +\ consistent\ precaution} < UR_{effective\ precaution}$	Reject
	b(1)	$CR1_{effective\ +\ consistent\ precaution} = CR1_{consistent\ precaution}$	Reject (countervailing)
	b(2)	$CR1_{effective\ +\ consistent\ precaution} < CR1_{effective\ precaution}$	Reject
	c(1)	$CR2_{effective\ +\ consistent\ precaution} < CR2_{consistent\ precaution}$	Reject
	c(2)	$CR2_{effective\ +\ consistent\ precaution} = CR2_{effective\ precaution}$	(Accept)

[1] UR = unconditional risk perception, CR1 = conditional risk perception without precautions, CR2 = conditional risk perception with precautions; [2] '(Accept)' refers to results that were consistent with our predictions but for which the null hypothesis was not rejected.

4 Discussion

This study extended previous research that showed that precautionary messages about radiofrequency electromagnetic fields (RF EMFs) increased recipient's risk perceptions. Two ways of amending precautionary messages were tested. Firstly, an additional text module that addressed the inconsistency of precautionary messages being communicated along with messages stating the safety of the current exposure limits. Secondly, an additional text module that explained the effectiveness of the recommended measures was tested. Furthermore, this study introduced a new component to the measurement of risk perception in the field of precautions against EMFs. That is, while in previous studies risk perception had always been measured unconditionally, we additionally assessed two items attempting to capture participants conditional risk perceptions (i.e. the perception of the risk 'if precautions are taken' and 'if precautions are not taken'). Each of the items asked specifically for the risk 'while talking on the phone'.

Before interpreting the results of the new message components, it has to be noted that the previously-reported effect of precautionary messages, an increase in risk perception, could not be replicated in the current study. Compared to a basic massage stating the safety of the existing limits, the addition of a precautionary message did not increase risk perceptions. Thus, in retrospect, the rationale of 'avoiding the effect of precautionary messages by changing the message' that we formulated on the basis of existing research, does not fit the data we obtained. Why did we not find the previously reported effect of precautionary messages? There are several potential explanations for this. Firstly, risk perception in general might have gone down as mobile phone RF EMF and health might not be considered as much an issue as was the case previously. However, this does not seem to be the case as the mean in Wiedemann et al. (2013) in the basic message group is similar to those of former studies (2.86 for the Australian subsample in and 2.91 in the current study; however, it is difficult to compare these two values as: (1) we had to transform the values of the current study from a seven-point to a five-point scale which can be problematic; and (2) the wording of the items was not exactly the same). Secondly, another explanation would be that the effect was sensitive to our change in what the risk perception question was specifically referring to. While in former studies risk perception was assessed for mobile phones in general, we assessed it for a specific exposure situation, namely 'while talking on the phone'. Thirdly, while the current study was conducted with a general population sample, former studies have mostly tested student populations (Boehmert, Wiedemann et al., 2017; Wiedemann et al., 2013; Wiedemann, Thalmann et al., 2006). The effect might only exist in student samples. Nevertheless, analysing both new experimental conditions of 'consistency' and 'effectiveness' is still useful, especially from a practical risk communication point-of-view for which clear, consistent and effective messages are of special importance.

Increasing the message's consistency by providing a rationale behind the communication of the precautionary information did not decrease risk perceptions significantly. That is, explaining that precautionary messages are only intended to provide behavioural options to those who are already concerned about potential health effects does not lower recipient's risk perceptions. Apparently, perceptions of inconsistency are not important in the reception of precautionary messages. However, a limitation of our study is that we did not test whether our consistency text module actually was perceived as more consistent by the participants. An alternative explanation for our results is hence that the way in which we addressed the inconsistency simply did not lower the perceived inconsistency of the recipients. A further explanation is that people might apply a simple social heuristic 'fear risks that are feared by other people' for their risk perceptions (Gigerenzer & Gaissmaier, 2011): If some people are concerned about RF EMF exposure then be cautious too.

We expected the additional text module that explained the effectiveness of the precautions to decrease conditional risk perception if precautions are taken and potentially also unconditional risk perception, compared to the precautionary message only. We found an opposing picture that, however, seems reasonable from a psychological view (see below). In response to the effectiveness text module people judged RF EMFs from mobile phones as even more dangerous – but only if they judged the risk under the condition that no precautions are taken. Notably, the combination of both effectiveness and consistency information, which was tested as well, had the same effect. We see this as a sign of the robustness of the effect of communicating the measures' effectiveness, and the lack of importance of communicating consistency.

Before interpreting this finding, it is important to mention an alternative explanation that could be responsible for the effect. The effectiveness text module was by far the longest module so that a 'mere exposure to more information' effect (cf. Zajonc, 1968) for the general effect and reference (Cousin & Siegrist, 2011) for the effect in RF EMF risk perception) on risk perception cannot be ruled out with our design. None-the-less, we think that the content, rather than magnitude, of the message are more likely to explain our findings. Specifically, in the effectiveness condition we explained how effective precautionary measures are by providing two important facts about individual RF EMF exposure; that exposure declines exponentially with the distance to the RF EMF source, and that that mobile phones generally contribute more to the individual exposure to RF EMFs than base stations do. While this information about the exposure patterns was intended to explain the effectiveness of the measures, the majority of the recipients might have focused on the information about the RF EMF exposure patterns themselves, neglecting the line of argumentation the information was embedded in; in this case explaining the effectiveness of the precautionary measures. Informing about exposure patterns has been shown to selectively increase the risk perception of mobile phones and decrease the risk perception of base stations (Cousin & Siegrist, 2011). This is also in line with other research that has shown that RF EMF risk perception is highly correlated with RF EMF exposure perception (Freudenstein, Wiedemann, & Brown, 2015). Our results suggest that on the group level, the information about exposure patterns – presumably regardless of whether it is an explanation for the measures' effectiveness or not – shifts the recipients' focus to the mobile phone as a major RF EMF source and hence the risk perception 'while talking on the phone' is increased.

The results demonstrate that message interpretation is an activity of the recipient that is not under the control of the communicator. Therefore, even additional explanations that serve in the view of the communicator a strict reassuring goal, may be regarded as alarming by the recipient.

Finally, we would like to discuss our dependent variables. While conditional risk perception measures have been known in risk perception research (Janssen et al., 2011; van der Velde et al., 1996) they have not been used in previous studies about RF EMF precautionary communication. We derive from our data that their use is promising and might help uncover new facets of people's risk perception in relation to precaution. Of particular importance is the fact that the mean of unconditional risk perception was lower than the mean of conditional risk perception if no precautions are applied. We interpret this as an indication that (some) people already include the application of precautionary measures or the potential to apply them in their unconditional ratings. Furthermore, conditional risk perception if precautions are taken had a mean of around 3 on a seven-point Likert scale in every group. This indicates that even if precautions are taken people do not let go of all their concerns. However, two potential problems regarding the conditional measures need mentioning. On the one hand, the conditional risk measures might have confounded our experimental groups; mentioning precautionary measures in the wording of the question might itself trigger the same effect that the precautionary text module does. There is, however, no way around this when assessing conditional risk perception. Besides, the unconditional risk perception measure was assessed prior to the conditional ones and is hence in no way influenced by them. On the other hand, the conditional risk perception measures might be providing cues for our subjects (Schwarz, 1999) in the sense that the questions shape the answers and therefore confound how much a person's risk perception depends on the application of precautionary measures. We tried to mitigate this potential issue by introducing the two questions with the statement that 'some people might answer both questions differently while others might give the same answer'. Future research could usefully validate this form of measurement in the context of RF EMF precautions.

5 Conclusions

All in all, this study with an Australian population quota sample came to three major findings. Firstly, information about precautionary measures did not increase the risk perception of RF EMFs during mobile phone calls in comparison to a group that had received information about the current limits. In previous studies, this effect had been detectable. Why this effect was absent remains an open question.

Secondly, the additional information that we added to reduce risk perceptions did not achieve the intended effect. Making the message more consistent for the reader did not have any effect on the mean level, and explaining the effectiveness of the precautions even led to an increase in risk perception scores. There might be other ways of amending precautionary messages in order to reduce risk perception, but these two ways do not seem to work.

Thirdly, from a methodological perspective, the conditional measurement we implemented in this study seems to be a promising avenue for future studies in the field of precautionary communication. However, this first attempt of a differentiation in this area should not be over-interpreted as the conditional measurement needs to be validated in future studies.

Chapter VII

A Replication Study of the Interaction Between Trait Anxiety and Precautionary Messages

1 Rationale of the Replication

The study in Chapter V reported an interaction effect of precautionary messages, trait anxiety and gender on risk perception and trust. The exploratory character of that study was one of its limitations. Multiple statistical tests with multiple independent and dependent variables were conducted. As mentioned in the limitations section of that study, it is possible that some of the interaction effects found were only due to chance alone. Therefore, a replicating analysis was conducted with the dataset of the study reported in Chapter VII. Besides replicating the effect, this analysis also allows for conclusions regarding a broader population, because the sample of the study in Chapter V was a student sample while the sample in Chapter VII was drawn from the general population. It is important to note that the data used for the replication were not specifically collected for this purpose, but for another, i.e. to provide answers to the research questions in Chapter VI.

2 Method

The methods of this replication study will only be described very concisely. For information about study design, procedure and sample the reader is kindly referred to the method section of Chapter VI. For information about data analysis the reader is referred to Chapter V. Only relevant differences to the approach of the study in Chapter V are explained in detail.

2.1 Experimental Design

Of the seven experimental groups in the study reported in Chapter VI, only the ‘basic information group’ and the ‘precautionary information group’ are considered for this replication. This is because the study in Chapter V also only had two groups of this kind.

2.2 Methodological Differences Between Original Study and Replication

The methods of the two studies are compared in Table 13. The major differences are

a) the size and nature of the sample;
b) that the replication was only about mobile phones. i.e. both the experimental texts and the dependent variables focussed on potential mobile phone health risks and not on potential base station health risks;
c) that both basic and precautionary message were more extensive in the replication study;
d) differences regarding the dependent variables: In the study in Chapter V, three dependent variables were used (unconditional threat/risk perception[12], trust in public protection, evaluation of scientific knowledge). In the replication, unconditional risk perception was used as well. In addition, two conditional risk perception measures were used (risk perception if no precautions are taken and risk perception if precautions are taken).

[12] Differences in the questionnaire wording lead to a different terminology in Chapter V and Chapter VI.

Only the interaction effect on risk perception can thus be part of this replication interaction. Trust was not assessed. Importantly, the interaction effect can be present in the absence of a significant main effect of precautionary information. Leaving statistical power related issues aside, finding a linear interaction without a significant main effect would mean that in some participants the precautionary information decreases risk perception and in others it increases risk perception.

2.3 Hypotheses

It is hypothesised that there is a three-way interaction between information condition, trait anxiety and gender. It is hypothesised that women low in trait anxiety show the most pronounced increase in risk perception. Women with higher levels of trait anxiety are not expected to show an increase. This effect is hypothesised for (1) unconditional risk perception and (2) conditional risk perception if precautions are not taken. The effect is not hypothesised for conditional risk perception if precautions are taken, because it is unclear how taking the measures should mean something different for people differing in their gender or general anxiety. However, for exploratory purposes, interaction effects are also calculated for conditional risk perception if precautions are taken.

Table 13. Comparison of Methods of the Original Study in Chapter V and the Replication

	Study in Chapter V[1]	Replication[2]
Sample	Ad-hoc sample of Australian university students (N = 298)	Quota sample of Australian general population (N = 560)
Experimental situation	Online Survey	
Experimental Design	2x2 Design First factor: one group with basic information. one group with basic + precautionary information Second factor: Order (Information about mobile phones or about base stations first)	2 groups (out of the 7 groups in the study in Chapter VI). one group with basic information. one group with basic + precautionary information
Type of precautionary information	Precautionary information regarding sensitive populations ('children'; for mobile phones) and regarding sensitive areas ('kindergardens'; for base stations)	Information about various precautions regarding the use of mobile phones (e.g. use of wired landline phone. use of a headset etc.)
Moderating variables	Gender, Trait Anxiety (STAI form Y. Spielberger et al. 1983)	
Dependent variables	Mobile phone threat/risk perception (unconditional)	Mobile phone risk perception (one item unconditional and two items conditional)

[1] Detailed information can be found in the method section of Chapter V; [2] Detailed information can be found in the method section and in the Appendix B.

2.4 Statistical Analyses

The analyses follow those conducted in Chapter V. The multiple regression equation predicting the three different dependent variables had the form of

Dependent variable = b0 + b1 × Text + b2 × Gender +b3 × Trait Anxiety + b4 × Text × Gender + b5 × Text × Trait Anxiety + b6 × Gender × Personality + b7 × Text × Gender × Trait Anxiety.

Step-down procedures are applied in case higher-order effects are not significant (cf. Aiken & West. 1993). For the simple slopes analysis including significance tests, Andrew Hayes' SPSS macro PROCESS, version 2.16 (Hayes, op. 2013).

3 Results

The regression analyses for all three dependent variables did not show significant three-way-interaction coefficients. Thus, the three-way-interaction found in Chapter V could not be replicated. Subsequently, the three-way-interaction term was omitted from the equations, as well as the Gender x Trait Anxiety interaction. The resulting coefficients for these regressions are shown in Table 14. As already reported in Chapter VI, there is no significant effect for the text variable on any of the three dependent variables. Gender has quite a strong influence on all three variables, with males reporting constantly lower risk perceptions than females. There are no interaction effects of text and gender. The partial regression coefficient of trait anxiety is significant for the two conditional measures. For these two measures, there is also a significant interaction between text and trait anxiety. As in the study in Chapter V, the simple slopes of the text variable were calculated for regressions with significant interaction effects. The simple slopes for the text variable are depicted in Figure 15. As hypothesised, the regression predicts a significantly higher conditional risk perception without precautions in females low in anxiety (i.e. females with trait anxiety values one standard deviation below the mean) in the precautionary group compared to the basic group. There is no such effect for females high in anxiety. The simple slopes for males are not significant, either. The predicted values of the regressions for the two types of conditional risk perception are shown in Table 15. These should only be interpreted in relation to the significant findings reported in Table 14 and Figure 15.

Regarding conditional risk perception with precautions, males and females low in anxiety show higher values in the precaution group, however, these simple slopes do not significantly differ from zero. Females and males high in anxiety have significantly lower values on this variable in the precaution group, compared to the basic group.

Table 14. Results of the Linear Multiple Regression Analyses with Text, Gender, and Trait Anxiety as Independent Variables

	UR[a]		CR1		CR2	
	B	p	B	p	B	p
Intercept	4.45		4.79		3.34	
Text[b]	.12	.46	.1	.59	-.03	.83
Gender[c]	-.52	.002	-.58	.001	-.31	<.05
ZTA	.07	.41	.18	<.05	.21	.01
T x G	.04	.87	-.13	.62	-.11	.64
T x ZTA	.02	.84	-.29	.03	-.28	.01
Multiple R^2	.04		.05		.03	
F, p	4.49	<.001	6.41	<.001	3.90	.002
R^2 change[d]	0		.01		.01	
F change, p	.04	.84	4.99	.03	6.28	.01

[a] UR = unconditional risk perception, CR1 = conditional risk perception without precautions, CR2 = conditional risk perception with precautions, ZTA = z-score of trait anxiety, T = text, G = gender; [b] Coding of text variable: basic information = 0, precautionary information = 1; [c] Coding of gender: female = 0, male = 1; [d] Comparison of model with T x ZTA interaction and model with main effects only

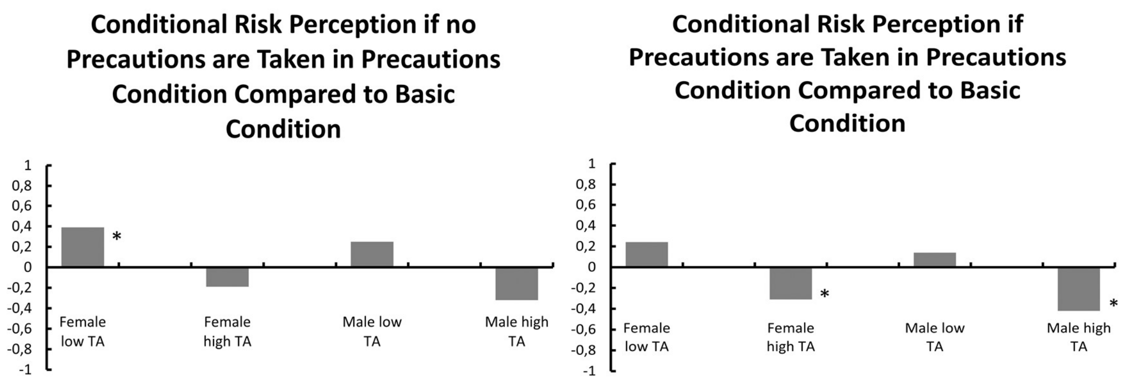

Figure 15. Sizes of the simple slopes for the text variable at values of 1 and –1 of the z-score of trait anxiety (TA) for both males and females. A simple slope of 1 refers to an increase of the respective variable of 1 scale point on a seven-point Likert-scale. A simple slope of –1 conversely to a decrease of the same amount. *p < 0.05 (one-sided).

Table 15. Predicted Values of Conditional Risk Perception

			CR1[1]	CR2
High ZTA	Basic	Female	4.97	3.55
	Precaution	Female	4.78	3.24
	Basic	Male	4.39	3.24
	Precaution	Male	4.07	2.82
Low ZTA	Basic	Female	4.61	3.13
	Precaution	Female	5	3.38
	Basic	Male	4.03	2.82
	Precaution	Male	4.29	2.96

[1] CR1 = Conditional Risk Perception if no precautions are taken, CR2 = Conditional Risk Perception if precautions are taken.

4 Discussion

Comparing the results of the replication study to the results of the original study pertaining to the effects of precautionary messages on risk/threat perception, several points catch the eye. Firstly, in the replication, neither an effect of the text variable itself exists (cf. hypothesis 1 in the study in Chapter VI) nor interaction effects for unconditional risk perception. This might be due to the different wordings used in the study in Chapter V ('All in all, how threatened do you feel by electromagnetic radiation emissions from cell phones') and the study in Chapter VI ('How dangerous do you think the electromagnetic fields from mobile phones are while talking on the phone?'). However, it is not easy to explain this finding, especially given that, secondly, there was an interaction effect between trait anxiety and text for conditional risk perception if no precautions are taken. As predicted, the text condition made a significant difference for women low in anxiety, but did not affect other groups significantly. Furthermore, the interaction between trait anxiety and text was not moderated by gender, as can be seen in Figure 15, where the directions of the effect are alike for males and females.

Thirdly, the conditional effects of the text variable are smaller in the replication study than in the original study in Chapter V. The reader has to be aware of the fact that the dependent variables have not been standardised in either study: While the original study used a five-point Likert scale to measure risk perception, the replication study used a seven-point Likert scale. Hence, even in the case of a simple slope of the text variable of equal size in the two studies, the relative increase or decrease in risk perception due to the text variable is smaller in the replication study. This is also reflected in smaller changes in R^2 due to the interaction (see Table 14). Fourthly, the analysis also revealed an interaction effect of text and trait anxiety for conditional risk perception if precautions are taken. Both males and females high in anxiety had significantly lower scores on this variable after receiving the precautionary information than after receiving only the basic information. Apparently, the recommendation of precautionary measures selectively strengthened highly anxious participants' beliefs in the power of the precautionary measures. This is certainly a point that needs special highlighting, because it is usually hard to lessen the concerns held by highly preoccupied individuals. However, a high general/trait anxiety must not be confused with a high prior risk perception of EMFs specifically. For the group of people with high prior risk perception, Wiedemann and Schütz have observed an 'immunity to reasoning' (Wiedemann & Schütz, 2002).

Fifthly, because of the bigger sample which was also more representative for the general population, the findings of this replication study should be given a bigger weight compared to the original study (if the general population is considered).

To conclude, as in the study Chapter VI, the pattern of results becomes more complex and harder to interpret when different conditional risk perception variables are assessed. Nevertheless, the findings of the original study in Chapter V could be replicated in so far as the moderating role of trait anxiety in the reception of precautionary information was again underscored. Gender, however, did not interact with the other variables but had a main effect risk perception, independently of the text condition.

Chapter VIII

Does Precautionary Information About Electromagnetic Fields Trigger Nocebo Responses? An Experimental Risk Communication Study

Abstract

Background

Regarding electromagnetic fields from mobile communication technologies, empirical studies have shown that precautionary information given to lay recipients increases their risk perceptions, i.e. the belief that electromagnetic fields are dangerous. Taking this finding one step further, the current study investigates whether precautionary information also leads to higher symptom perceptions in an alleged exposure situation. Building on existing research on nocebo responses to sham electromagnetic fields, an interaction of the precautionary information with personality characteristics was hypothesised.

Methods

An experimental design with sham exposure to an electromagnetic field of a WLAN device was deployed. The final sample is constituted by N = 137 participants. Participants received either only basic information about the safety of current WLAN exposure limits or in addition also precautionary information (e.g. 'prefer wired connections if wireless technology can be relinquished'). Subsequently, symptoms and other variables were assessed before and after sham exposure to a WLAN electromagnetic field.

Results

Results are not in favour of the hypothesised effects. There was neither a main effect of precautionary information, nor were there any of the hypothesised interaction effects of precautionary information and personality characteristics on perceived symptoms under sham exposure. Exploratory analyses highlight the role of prior risk perception as a predictor of nocebo responses, and of symptom expectations as a mediator between these two variables.

Conclusions

As the statistical power to detect even small effects was relatively high, we interpret this as a robust indication that precautionary information does not lead to increased nocebo responses by itself. The implications for health authorities' communication with the public are discussed.

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1 Background

In many countries across the world, the precautionary principle is a cornerstone of radiation protection. This is especially true for non-ionizing radiation protection, i.e., regarding radio-frequency electromagnetic fields (RF EMFs) emitted by base stations, mobile phones and other wireless gadgets. The International Commission on Non-Ionising Radiation Protection (ICNIRP) emphasises that despite a substantial body of research, there is no conclusive evidence for any health effects of radiofrequency electromagnetic fields within the recommended exposure limits (ICNIRP, 2009), a stance that has also been adopted by the World Health Organisation (WHO). However, the International Agency for Research on Cancer (IARC) has classified RF EMFS of mobile phones as a 2B 'possible carcinogen' to humans, but emphasises that that the evidence for an increase in glioma and acoustic neuroma among users of mobile phones was limited and that the evidence for an increase in other cancers was inadequate (Baan et al., 2011). Most countries have adopted the exposure limits recommended by ICNIRP. In the face of the two differing assessments, RF EMF precautionary actions are recommended by many regulatory agencies and scientific organisations across the world (e.g. ARPANSA in Australia, ANSES in France, the German BfS, UK National Radiological Protection Board, now the UK Health Protection Agency, and the BAG in Switzerland). Usually, these approaches entail the recommendation of individual precautions. For instance, regarding Wireless Local Area Networks (WLAN), the German radiation protection agency recommends to reduce exposure by using a LAN cable and by not installing WLAN-routers in places where people stay permanently (Bundesamt für Strahlenschutz, n.d.c; a translation can be found in Table 16). In some countries, further precautions are taken. For instance, in Switzerland stricter exposure limits have been set for mobile phone base stations and other stationary EMF-emitting antennas.

The core of the precautionary principle is the obligation to base risk regulation on an ex ante approach, where precautionary actions or measures are put in place to avoid potential risks before they become definite or confirmed risks. Here, two issues are important. On the one hand, precautionary action should not be postponed until full scientific understanding of a risk issue is reached. This is especially true for uncertain risks - for which adverse effects are not proven. In other words, precautionary actions should aim to reduce potential harm from inadequately understood risks (Foster, 2017a). On the other hand, however, the Commission of the European Communities (2000) underlines that '[the] precautionary principle is not a justification for ignoring scientific evidence'. According to the Commission, the principle should be invoked 'where preliminary objective scientific evaluation, [sic!] indicates that there are reasonable grounds for concern'. In this case, precautionary actions should be proportional to the chosen level of protection (European Commission, 2000).

With regard to implementation, the challenge is to bring RF EMF precautionary actions in line with RF EMF protection policies - usually exposure limits - that are based on scientifically identified risks. The critical issue is whether the precautionary actions might undermine trust in science-based exposure limits. Some agencies simply assume that precautionary measures align with the science-based exposure limits. For instance, Kheifets, Hester, and Banerjee (2001) argue that it is possible to introduce precautionary measures without undermining trust in science-based exposure limits. However, whether that is the case is an empirical question. Previous studies (e.g. (Wiedemann & Schütz, 2005), (Wiedemann, Boerner et al., 2017), see below) raise some doubts. In the words of Paul Watzlawick and colleagues, precautionary actions might be part of the problem, not the solution (Watzlawick, Weakland, & Fisch, 1974).

1.1 Effects of Precautionary Communication

Empirical studies have found that the communication of precautions elevates risk perceptions of its recipients (Barnett et al., 2007; Barnett et al., 2008; Boehmert, Wiedemann et al., 2017; Nielsen et al., 2010; Wiedemann et al., 2013; Wiedemann, Boerner et al., 2017; Wiedemann & Schütz, 2005; Wiedemann, Thalmann et al., 2006). While the empirical base of these findings seems robust, there are two divergent findings that need mentioning. Firstly, it has been challenged that the increase in risk perception is a specific effect of precautionary communication (Cousin & Siegrist, 2011). In that study, participants tended to have increased risk perceptions after reading EMF information brochures no matter if these brochures contained precautionary information or only other information, e.g. about technical aspects. Secondly, the effect might be more pronounced in subgroups of the population. While studies using ad-hoc and student samples mostly found an effect (Boehmert, Wiedemann et al., 2017; Wiedemann et al., 2013; Wiedemann & Schütz, 2005), a recent study only found weak indications of the effect in an Australian general population sample (Boehmert, Wiedemann, & Croft, 2016). As a mechanism behind the effect of precautionary communication, reduction of cognitive dissonance has been discussed (Wiedemann, Boerner et al., 2017). Stating on the one hand that the exposure limits are safe while on the other hand recommending precautions is likely to be perceived as inconsistent, a perception that can result in a state of cognitive dissonance. For a person with dissonant cognitions, a potential way of reducing the dissonance would be to dismiss the statement about the safety of the current limits and to believe that the risk is actually higher.

All of the studies capturing the effects of precautionary communication have so far used questionnaires to assess changes in risk perception and other variables (e.g. trust in public health protection) after the reception of precautionary information. These outcome variables were assessed in fictitious settings (e.g. situations without real exposure). Thus, it remains unclear to what extent a change in risk perception, i.e. the perception of RF EMFs as dangerous, expressed in a questionnaire and without being currently 'at risk', actually corresponds to different perceptions, cognitions, emotions or behaviour in everyday exposure situations. The current study attempts to extend existing knowledge by combining questionnaire-based methods and a sham exposure paradigm. The main research question is, can precautionary communication affect participant's symptom experiences in a situation of alleged exposure to an EMF? Whereas the practical implications of the known increase in risk perception due to precautionary information are not entirely clear (Wiedemann, Freudenstein et al., 2017), it would in our eyes be a clear-cut indication against the dissemination of precautionary information if a nocebo response (i.e. symptom experience under sham exposure, see next section) would be triggered by it. In this case, we would recommend authorities to reconsider their communication practice.

1.2 Symptom Experience Under (sham) Exposure to Electromagnetic Fields

An issue that remains controversial are the reports of a proportion of the population who claim to experience a range of unpleasant and debilitating non-specific symptoms when in the vicinity of devices or infrastructure which emit EMF. These individuals suffer from a condition known as Idiopathic Environmental Intolerance attributed to Electromagnetic Fields (IEI-EMF). Although it has been estimated that between 1.5 and 13.5% of the population experience this condition (Baliatsas et al., 2015; Blettner et al., 2009; Eltiti, Wallace, Zougkou et al., 2007; Hillert, Berglind, Arnetz, & Bellander, 2002; Levallois, Neutra, Lee, & Hristova, 2002; Meg Tseng, Lin, & Cheng, 2011; Schreier, Huss, & Röösli, 2006; Schröttner & Leitgeb, 2008), the evidence to date indicates that there is no relationship between exposure to EMF and the reported symptoms (Röösli, Frei, Mohler, & Hug, 2010; Rubin, Nieto-Hernandez, & Wessely, 2010). For instance, when tested in double-blind provocation studies, IEI-EMF participants have been shown to be unable to detect the presence of EMF and do not report an increase in symptoms to EMF (Röösli et al., 2010; Rubin et al., 2010). On the other hand, sham exposures and a person's belief or awareness of being exposed have been found to be sufficient to trigger symptoms (Eltiti, Wallace, Ridgewell et al., 2007; Hillert et al., 2008; Landgrebe et al., 2008; Nam et al., 2009; Oftedal, Straume, Johnsson, & Stovner, 2007; Rubin et al., 2010; van Moorselaar et al., 2017; Wallace et al., 2012; Wilén, Johansson, Kalezic, Lyskov, & Sandström, 2006). These studies underscore the importance of nocebo responses, where conscious or subconscious symptom *expectation* shapes the formation or detection of symptoms in a *perceived* EMF exposure situation.

Negative expectations about an exposure are considered to be one of the strongest predictors of a nocebo effect (Webster, Weinman, & Rubin, 2016). It is understood that these expectations may arise through explicit suggestions about the effects of an exposure (Benedetti, Lanotte, Lopiano, & Colloca, 2007; Webster et al., 2016).

Interestingly, there is evidence to suggest that the manipulation of expectations via explicit suggestions about EMF exposure can induce symptoms, influence somatosensory perception and increase the likelihood of a person believing that they are sensitive to EMF in healthy participants. For example, Szemerszky, Köteles, Lihi, and Bárdos (2010) demonstrated that suggestions about the strength of EMF exposure can increase symptom scores and enhance perception of a sham magnetic field. Witthöft and Rubin (2013) found that viewing an inaccurate mainstream media report about potential adverse health effects of WLAN exposure increases the likelihood of a person with high pre-existing levels of state anxiety experiencing symptoms following a sham exposure and developing an apparent sensitivity to EMF. In a similar study, the researchers found that participants who watched a film focusing on 'adverse effects of Wi-Fi' perceived tactile electrical stimuli as more intense during a cued WLAN exposure (sham) compared to a cued no WLAN condition (Bräscher et al., 2017). This effect, however, was not moderated by anxiety. To find out whether a 'subtler' type of information given by government agencies, namely precautionary information, can have a similar effect, is the scope of the current study.

1.3 Hypotheses

In line with the reported effect in the study by Witthöft and Rubin (2013), we propose that the effect of precautionary information on experienced symptoms will be moderated by recipient characteristics, such as personality traits or their current emotional state. That study reported an interaction effect with state anxiety, which we hypothesise as well. In addition, we also assume interaction effects with more stable recipient characteristics.

For the dependant variables 'belief to perceive the sham EMF', 'difference in symptom perception' and 'attributed symptoms' we hypothesise that

A. the precautionary information group will have higher scores than the basic information group.

We assume this effect of information type to be more present in some recipients than others. As the interacting recipient variables we propose

B. (1) Trait anxiety, precautionary information leading to more symptom perception in highly trait anxious but not in low trait anxious individuals; (2) also, we assume that there is an equivalent interaction effect for state anxiety, as observed before (Witthöft & Rubin, 2013);
C. Somatosensory Amplification (SSA), with the effect of precautionary information being present to a higher degree in individuals with higher SSA. SSA has been shown to influence nocebo responses. The construct has been conceptualised as containing three components, (a) an increased body awareness, (b) labelling minor sensations as pathological, and (c) reactions of fear or distress to these sensations (Köteles & Doering, 2016). It is supposed to give rise to symptom expectations and attributions (Köteles & Witthöft, 2017). The message should have no effect among those who do not tend to interpret bodily symptoms in a negative way;
D. Prior EMF risk perception, with the effect being present to a higher degree in individuals with higher prior EMF risk perception. If a person already thinks that EMFs are dangerous, she or he is more likely to interpret precautionary information as a warning sign for an existing danger.

2 Methods

2.1 Sample

Participants were recruited with two advertisements in a local newspaper, with leaflets on blackboards in supermarkets and bakeries, and by disseminating flyers at different universities in Karlsruhe as well as at a local science festival. The study was also advertised on Facebook and Twitter and on the webpage of a local TV channel. A priori power calculations with an effect size of $f^2 = .051$ from a former study (Witthöft & Rubin, 2013; M. Witthöft, personal communication, February 6, 2017) indicated that 158 participants would have to be tested for a power of $1-\beta = .80$ in a multiple regression based analysis of the hypothesised interaction effects.

157 participants took part in the study, as one participant did not show up on the penultimate day of testing. Due to noise from a nearby construction site during the first week of testing, 13 participants had to be excluded. The manipulation check of two participants revealed that they had not believed the cover story and had guessed correctly that the study was about the information material provided. They were also excluded. During testing, it turned out that four participants were not capable of fully understanding the questionnaire properly due to limited knowledge of the German language. They too were excluded. One participant withdrew from the experiment before the sham exposure.

The final sample hence consisted of 137 participants (45% females). Participant's age distribution and their education are displayed in Table 17. It can be seen that while the aim was to recruit a sample more representative for the general population than a pure student sample, it turned out to be difficult to recruit participants aged between 30 and 50.

90% reported they use WLAN at home. 75% reported to use it at 'work/university' (2% reported not to know whether they used WLAN at work). The achieved statistical power with 137 participants was $1-\beta = .75$.

2.2 Study Design

The study consisted of two parts. The first part was an online survey that assessed participant variables (T_0 questionnaire). The second part was the experiment, for which participants were randomly assigned to one of two groups using an online random number generator. During the experimental session participants read the information material and where afterwards sham exposed to an electromagnetic field of a 'WLAN device' in front of them, consisting of a self-constructed 'router' supposed to appear like a prototype and a 31.5 centimetres high antenna available at shops and usually used by customers as an additional antenna to strengthen reception. We experimentally varied one factor (type of information) with two factor levels (technical information including information about the safety of the current exposure limits vs. the same information plus precautionary information).

2.3 Setting

The experiment took place in a measurement room (see Figure 16) in the basement of the university's electrical engineering department. The measurement room is an anechoic chamber that is usually used to determine radiation characteristics of high-frequency antennas. The room is not a complete Faraday Cage, and, as described below, the door to the room was kept ajar during the experiment. The walls, floor and the ceiling are covered with pyramidal RF absorbers that absorb electromagnetic waves and also sound waves to a certain extent. Because of the latter, participants have to accommodate to the acoustics in the room (i.e. the absence of an echo).

Before running the experiment the electromagnetic power level in the room was measured to ensure that there is no relevant source of electromagnetic waves that could potentially confound the experimental design (i.e. sham EMF exposure). The power level was measured in the frequency range from 700 MHz to 6 GHz, covering the mobile radio bands, like GSM, UMTS and LTE as well as the WLAN bands around 2.45 GHz and 5.8 GHz. The measured power level was in the range of -80 dBm (10 pW) and there was no distinct peak. This means the measured power is not a signal but a noise floor and far below the allowed 100 mW EIRP e.g. in the 2.45 GHz WLAN band[13].

Pre-tests indicated that the room made participants think that the experiment was 'serious', however, they did not feel intimidated (this is also confirmed by the low state anxiety scores at T_1 of almost all participants). A side effect of the acoustic properties of the room was that all experimenters and a large proportion of participants experienced ear noise to some extent. In the analyses, ear noise is included in the mean symptom variables reported below. However, we also conducted analyses for mean symptom variables without ear noise, but none of the results changed in terms of significance. Therefore, we only report results for the mean symptom variables including ear noise.

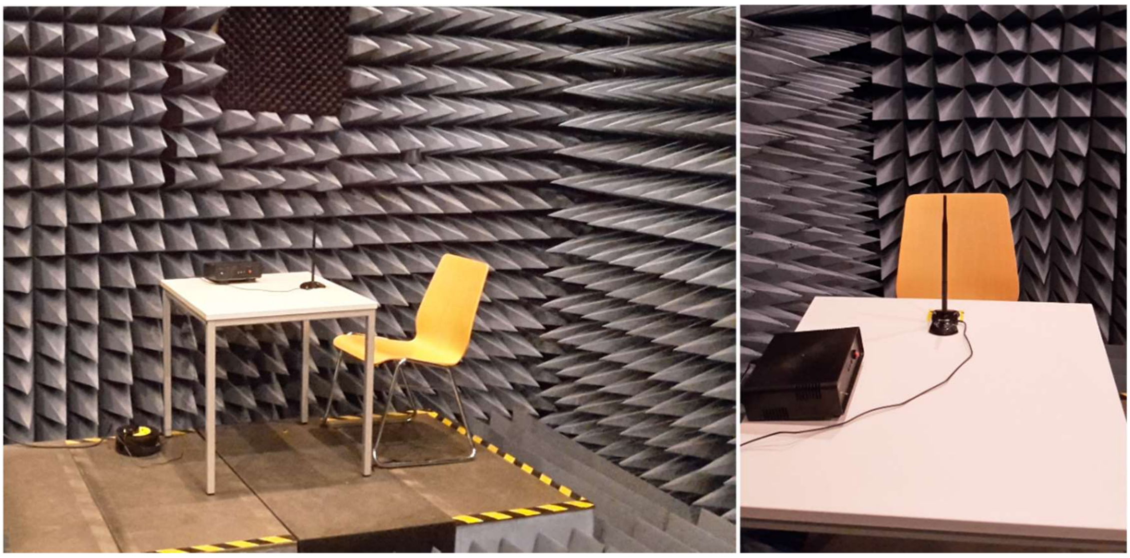

Figure 16. Experimental setup in the measurement room at Karlsruhe Institute of Technology.

2.4 Materials

2.4.1 Experimental Manipulation (Between T_1 and T_2)

The two different versions of the information about EMF are shown Table 16. The beginning of both texts contained technical information about WLAN. Both groups received the basic information but only one group received the precautionary information. The text was taken directly from an information sheet on the website of the German radiation protection agency ('Bundesamt für Strahlenschutz', BfS) and was modified with regard to two points only. Firstly, the original information sheet contained technical information about Blue Tooth; this information was excluded from the experimental material. Secondly, the passages about the safety of the existing limits and the precautionary

[13] In response to the request of a reviewer the power level in the frequency range from 1 MHz to 700 MHz was measured. For these measurements, the measured power level was also in the range of -80 dBm (10 pW) and there was no distinct peak.

information were marked in bold. The sheets containing the experimental manipulation were inserted on a clipboard in between the T1 and the T2 questionnaires by a research assistant who was otherwise not involved in the study.

Table 16. Information About WLAN Health Effects and Precautions Used for Experimental Manipulation

Basic information	Precautionary information
Are there health risks? The specific absorption rate (SAR) is the basis for evaluating if high-frequency electromagnetic fields pose a health risk due to immediate effects. The SAR describes how much radiated power is absorbed by human body tissue in a given situation. For health protection, recommended limit values are - 0.08 watts per kilo (W/kg) averaged over the whole body - 2 W/kg locally averaged over body parts e.g. in the head **If the limit values are met, no detrimental health effects on body tissue have been established so far.** SAR values of radio waves of WLAN devices usually remain under the recommended limit value, especially when the device is far from the body. WLAN senders (2.4 GHz) in a laptop placed on a desk emitting with maximum transmitting power have local SAR-values of about 0.1 to 0.2 (W/kg). In unfavourable situations (e.g. laptop on the lap and sender immediately above the thigh), values in the dimension of the recommended limits can occur. You can find more information at www.emf-forschungsprogramm.de.	**Recommendations and precaution** 1) Respect the minimum distances indicated by manufacturers. **2) The trend to portable and mobile radio applications leads to an overall increase in exposure to high-frequency electromagnetic fields. The Bundesamt für Strahlenschutz (BfS) recommends in general to minimize personal exposure in order to keep possible but not identified health risks low. Simple measures for this purpose are:** **- Prefer wired connections if wireless technology can be relinquished** **- Avoid placing central WLAN connection points in immediate proximity of places where people stay permanently, e.g. at the workplace** **- If existing, enable the distance regulation to reduce maximum radiated power.** More information regarding precautionary measures can be found by following the link www.bfs.de/elektro.

Note. Translation from German by the first author.

2.4.2 Risk Perception (T_0 and T_3)

As well as sociodemographic questions, the online questionnaire also comprised of four questions about EMF risk perception regarding (1) WLAN devices, (2) mobile phones while talking on the phone and (3) while transmitting data, and (4) mobile phone base stations. The items were worded 'I consider electromagnetic fields from … dangerous for health' and had to be answered on a five-point Likert-type answer format ranging from 'I do not agree at all' to 'I fully agree'. The same questions were used again at T_3 of the experimental part of the study.

In the online questionnaire, endurance of risk perceptions (Wiedemann, Freudenstein et al., 2017), i.e. the frequency of thinking about and talking about the potential health effects of EMFs was also assessed with two items each. Response scales of two questions had verbal labels ranging from '(almost) never' to 'very often', response scales of the other two questions had numeric labels, ranging from 'not once' to 'more than six times'.

2.4.3 Personality Variables (T_0)

Trait anxiety was assessed with the Trait anxiety part of the STAI Form Y (Spielberger, 1983) Somatosensory Amplification was measured with the Somatosensory Amplification Scale (SSAS; Barsky, Wyshak, & Klerman, 1990). Social Desirability was assessed with the Social Desirability Scale-17 (SDS-17; Stöber, 2001).

2.4.4 State Anxiety (T_1,T_2 and T_3)

We assessed state anxiety (SA) with the STAI-SKD (Englert, Bertrams, & Dickhäuser, 2011), a 5-item version of the state part of the Spielberger state-trait-anxiety inventory.

2.4.5 Belief to Perceive the EMF (During sham Exposure), Symptoms (T_2 and T_3), Expected Symptoms (T_2) and Symptom Attribution (T_3)

The 'belief to perceive the EMF' was assessed after each trial of sham exposure. (1) 'Did you perceive the electromagnetic field during this trial?' This question had four answering options (a. 'Yes, I am sure'; b. 'Yes, I think so'; c. 'No, I do not think so'; and d. 'No, definitely not'). In the analysis, we treated this variable as a dichotome variable, with answering options a. and b. treated as 'yes' and options c. and d. treated as 'no'. If participants gave answer a. or b., they also answered question (2) 'How did you realise that there was an electromagnetic field?' This question was answered in form of a short text or bullet points. Question 2 was not analysed in this study.

Twenty different symptoms were assessed after the experimental manipulation and before the sham exposure (T_2) and again after sham exposure (T_3). Participants could also list two more symptoms if they experienced something that was not on the symptom list. They rated the presence of each symptom on a 4-point Likert-type answer format ranging from 'not at all' to 'strong'. Symptoms could be divided into three major groups, firstly symptoms related to head and mind (headache, dizziness, restlessness or irritability, drowsiness, fatigue, blurred vision, ear noise, dryness of the mouth, congestion of the nose, concentration difficulties), body-related symptoms (palpitation, breathlessness, breathing difficulties, muscle tension or trembling, nausea, stomach ache) and skin-related symptoms (Feeling of warmth on skin, itching of skin, prickling of skin, sweating).

Expected symptoms were assessed with the same items directly after the T_2 symptoms, on a 5-point Likert-type answer format ranging from 'certainly not' to 'certainly'. Symptom expectations were not involved in our main hypotheses. Still, as expectations are known to be a major factor in nocebo responses (Webster et al., 2016), we also assessed expectations and used it in an exploratory analysis.

To assess symptom attribution, we asked participants 'In your opinion, to what extent were the bodily perceptions or symptoms to be ascribed to the antenna's electromagnetic field?' Participants answered on a 4-point Likert-type answer format ranging from 'not at all' to 'to a strong extent'. There was also the additional option to choose 'no symptoms or perceptions experienced'. If they had ascribed symptoms or perceptions to the EMF, they were supposed to list those as bullet points below.

2.4.6 Manipulation Check (T_3)

The final question of the T_3 questionnaire was an open-ended question asking participants what they thought the experiment was about. This question acted as a manipulation check. As noted above, 2 participants were excluded because they had anticipated the study rationale. Of the 137 participants remaining after participant exclusion, 75% believed that the study was about effects of EMFs on the body or on the mind. An additional 6% thought that it was about EMF effects in conjunction with an analysis of the role of expectations or a placebo effect. The most common other answers to the manipulation check were 'effects of prior beliefs and expectations' (4%), a 'placebo effect' (3%), and answers that did not have any relation to the content (10%; e.g. 'study for master thesis').

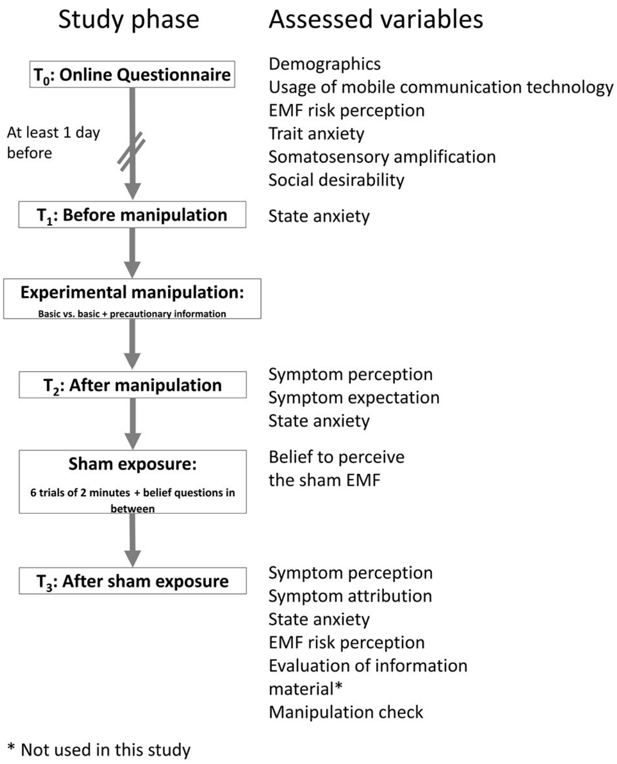

Figure 17. Flowchart of the course of the study

2.5 Procedure

Figure 17 gives a brief overview of the flow of the study and of the implemented questionnaires. Those interested in participating contacted the principal researcher or a research assistant via email or telephone. After making an appointment for the study, participants were sent an email with a link to the online questionnaire which they completed one day prior to the experiment, at the latest. Two participants received the questionnaire by mail and three participants completed the questionnaire immediately before the experiment because they had not completed it at home.

On arrival at the university, participants were first briefed about the ensuing session and signed an informed consent form. Afterwards, they were asked to turn off all electronic devices and were told about the 'special character of the experimental room' to which they would be led shortly, as the room 'is shielded from outside electromagnetic fields and there are no reflections from electromagnetic fields emitted inside the room'. As the experimental room was not grounded, we provided participants with electrostatic discharge overshoes to avoid any discharge. After being asked to leave all of their belongings in an adjacent room, participants and experimenter entered the experimental room where they were seated at a table in front of the antenna and the WLAN device, which were obviously unplugged. The experimenter then explained the four stages of the experiment briefly (see below).

After this, the first stage commenced and participants were left alone in the room for two minutes 'to accommodate to the room'. They were explicitly told to pay attention to any unusual perceptions they might have, 'without the antenna being activated, as the room is already special'. Afterwards, the experimenter would return with a clipboard containing the T_1 questionnaire, the information material either with or without the precautionary information (depending on randomisation), and the T_2 questionnaires. During this second stage, participants filled out the questionnaire and read the information material. The experimenter sat down in the experimental room, approximately 2.5 meters away from the participants, in order to answer any questions. In order to remain blinded to the experimental condition, experimenters pretended to read papers they had with them and avoided looking at participants while they filled out the questionnaire and read the information material. In nine cases, the experimenter did not remain blinded, most of the times because participants had a question regarding the information material. Those participants remained in the dataset, however, hypotheses A to D were additionally tested and reported without those nine cases to control for a potential bias.

After completing the questionnaire, the third stage commenced. The experimenter plugged in the WLAN device and turned it on 'with the antenna still not being active'. The antenna was then positioned in front of the participants at a point marked with tape and the participants were asked to move the chair to a standard position as marked by tape on the floor. The participants were then asked to lean back with hands on the lap and not to touch the antenna throughout the experiment. The experimenter then explained the procedure. Participants would activate the antenna on their own, once the experimenter left the room. The door would be kept ajar throughout the experiment to ensure that communication was possible in case of any problems. When activating the antenna, the WLAN device's green LED lights would start to flash and a short beep would sound. After two minutes, there would automatically be another beep and the LED lights would turn off, indicating that the antenna was not emitting an EMF anymore. Participants then answered two questions about their perceptions of the sham EMF (see materials section). After answering the two questions, they started the next trial by activating the antenna again. Participants were told that the antenna would emit an EMF in all trials, but that the strength of the emitted EMF would vary between the trials. If asked, the experimenter stated that exposure would always remain within the limit values set by law (this information had also already been given during the participant briefing). After the sixth and final trial, participants called the experimenter who then returned with the T_3 questionnaire (stage four). The experimenter unplugged the antenna and removed it from its position in front of the participants and stayed in the room until participants had completed the questionnaire. After leaving the room, participants were asked if everything was alright. If they showed signs of concern about the experiment, they were debriefed immediately. If not, they were debriefed either by email (those who had not reported any symptoms) or by telephone (those who had experienced symptoms) after completion of the whole study. Finally, the experimenter handed out the monetary reimbursement and brought participants to the exit of the building. The whole experimental session lasted 45 minutes on average. Data were collected between May and July 2017.

2.6 Data Analysis

Main effects and the hypothesised interaction effects of personality variables and experimental group were analysed in linear multiple regressions (LMR). For that purpose, the experimental group variable was dummy-coded (with 1 referring to the precautionary information group) and the continuous independent variables were z-standardised prior to building their interaction term, as recommended by Aiken, West & Reno (Aiken et al., 2010). As the dependant variables, we used a sum score of the belief to have perceived the sham EMF, indicated right after each of the six two-minute sham exposure periods ('belief to perceive the sham EMF'), the difference score between the mean symptom perception before and after the sham exposure ('symptom difference T_3-T_2'), and a composite score that made use of the T_3 symptom scores and participants' attribution of symptoms to the EMF ('attributed symptoms'). In that score, symptoms at T_3 were only counted if participants indicated that they had attributed symptoms to some extent to the EMF. Analyses were carried out separately for each of these three dependent variables. All analyses were conducted with SPSS version 24.

In the exploratory results section, we report a mediation analysis that was conducted with Andrew Hayes' SPSS macro PROCESS, version 2.16 (Hayes, op. 2013). Throughout the results section, we treat results with a p-value $< .05$ (two-sided test) as statistically significant. For the sake of readability, we only use the term 'significant', which always refers to statistical significance.

3 Results

Sample characteristics are displayed in Table 17. 53 participants (39%) did not perceive the EMF in any trial while 84 participants (61%) indicated that they at least perceived the EMF in one trial. 48 participants (35%) perceived it in three or more trials. Means and standard deviations of trait anxiety, somatosensory amplification and T_0 risk perception are shown in Table 18. The bivariate correlation between trait anxiety and somatosensory amplification was significant ($r_{TA,\,SSA} = .27$, $p = .001$). T_0 risk perception was not correlated with the two variables ($r_{TA,\,T0RP} = .07$, $p = .41$; $r_{SSA,\,T0RP} = .16$, $p = .06$). State anxiety before the experimental manipulation was significantly higher in the precaution group than in the basic group. Because participants and experimenters were blinded, this difference can only be due to chance. This difference poses a threat to the experiments because potential group differences might not only be causally attributed to the experimental manipulation but also to the pre-existing difference in state anxiety. The difference between the two groups remained after the experimental manipulation. Symptom perceptions and their means at T_2 and T_3 are displayed in Appendix C Table C1. Bivariate correlations of social desirability with independent and dependent variables were insignificant except for a correlation with T_0 and T_3 risk perception regarding WLAN devices (both $r = .17$, $p < .05$) and with 'symptom difference' ($r = .20$, $p = .02$). However, when social desirability was included as independent variable in the regressions, none of the relations between independent and dependent variables in the linear multiple regression analyses changed in terms of significance. Results are therefore reported for the equations without social desirability.

Table 17. Sociodemographic Characteristics and WLAN Use of the Participants in the two Experimental Groups

	Experimental Condition		
	Basic information (n = 64)	Basic + precautionary information (n = 73)	Test statistic (differences between groups)
Number of females (%)	27 (42%)	35 (48%)	χ^2 =.46 (p =.50)
Number of participants in age group (%)			
18-30	43 (67%)	51 (70%)	Mann-Whitney U-Test
31-40	5 (8%)	3 (4%)	Z = -.23 (p = 0.82)
41-50	3 (5%)	4 (6%)	
51-60	6 (9%)	7 (10%)	
older than 60	7 (11%)	8 (11%)	
Number of participants with education level (%)			
No graduation	0 (0%)	0 (0%)	Mann-Whitney U-Test
Junior high school	7 (11%)	7 (10%)	Z = -.343 (p =.73)
High school	26 (41%)	32 (44%)	
Bachelor degree	15 (23%)	19 (26%)	
Master degree (or equivalent)	16 (25%)	15 (21%)	
Use of WLAN at home	57 (89%)	66 (90%)	χ^2 =.07 (p =.80)
Use of WLAN at work/university	49 (77%)	55 (75%)	χ^2 =.22 (p =.90)

Table 18. Descriptive Statistics of Independent and Dependent Variables in the two Experimental Groups

	Experimental Condition		
	Basic information (n = 62-64)	Basic + precautionary information (n = 71-73)	
Independent variables	M (90% CI)	M (90% CI)	Test statistic (differences between groups)
Mean trait anxiety	2.22 (2.15-2.29)	2.23 (2.16-2.31)	$t_{df=133}$ = -.22 (p = .82)
Mean somatosensory amplification	2.71 (2.61-2.82)	2.83 (2.72-2.94)	$t_{df=135}$ = -1.3 (p = .20)
Sum social desirability	10.58 (10.05-11.10)	10.58 (10.02-11.13)	$t_{df=135}$ =.01 (p = .99)
T_0 risk perception WLAN score	2.56 (2.33-2.79)	2.59 (2.38-2.79)	$t_{df=135}$ = -.14 (p = .89)
Mean T_1 state anxiety	1.36 (1.29-1.42)	1.50 (1.41-1.59)	$t_{df=134}$ = -2.18 (p = .03)
Mean T_2 state anxiety	1.29 (1.22-1.35)	1.42 (1.33-1.50)	$t_{df=134}$ = -1.96 (p = .05)
Dependent variables			
Mean symptom difference $T_3 – T_2$	.09 (.04-.14)	.12 (.07-.17)	$t_{df=135}$ = -.65 (p = .52)
Mean attributed symptoms	1.13 (1.09-1.16)	1.15 (1.11-1.19)	$t_{df=135}$ = -.74 (p = .46)
Sum of trials with belief to perceive sham EMF	1.53 (1.17-1.90)	2.10 (1.70-2.49)	$t_{df=135}$ = -1.74 (p = .08)

3.1 Effect of Information and Personality Characteristics on Symptom Variables

Symptom variables were not normally distributed. However, as visual inspection of the distributions of regression residuals showed only minor deviations from the normal distribution, we did not transform symptom variables. Multicollinearity was not present in any of the regression equations (all variance inflation factors < 4). Stepwise LMR analyses showed no main effect of the experimental condition, neither on ‘symptom difference’ (b = .03, p = .52), nor on ‘attributed symptoms’ (b = .02, p = .46), nor on ‘belief to perceive the sham EMF’ (b = .57, p = .08). Regression weights for main effects of personality variables are reported for regressions without interaction terms. Trait anxiety was related to ‘belief to perceive the sham EMF’ (b = .34, p = .04, change in R^2 = .03) with a higher trait anxiety predicting a more frequent belief. Trait anxiety was unrelated to ‘symptom difference’ (b = .03, p = .19) and ‘attributed symptoms’ (b = .02, p = .14).

State anxiety at T_2 was related to 'attributed symptoms' ($b = .08$, $p < .001$, change in $R^2 = .19$) and to 'belief to perceive the sham EMF' ($b = .35$, $p = .04$, change in $R^2 = .03$). State anxiety at T_2 was not related to 'symptom difference' ($b = -.01$, $p = .65$).

Somatosensory amplification was related to 'symptom difference' ($b = .06$, $p = .007$, change in $R^2 = .05$) and to 'belief to perceive the sham EMF' ($b = .65$, $p < .001$, change in $R^2 = .12$), with participants high in somatosensory amplification having both a higher difference in symptom perceptions and a more frequent 'belief to perceive the sham EMF'. Somatosensory amplification was unrelated to 'attributed symptoms' ($b = .03$, $p = .08$).

T_0 risk perception significantly predicted all three dependent variables ($b = .09$, $p < .001$, change in $R^2 = .13$ for 'symptom difference'; $b = .04$, $p = .009$, change in $R^2 = .05$ for 'attributed symptoms' and $b = .75$, $p < .001$, change in $R^2 = .15$ for 'belief to perceive the sham EMF').

There was a significant interaction between state anxiety at T_2 and information type for 'symptom difference' ($b = -.11$, $p = .03$, change in $R^2 = .04$). In the subsequent analysis of the simple slopes (Aiken et al., 2010), predictions for four groups were regarded (high vs. low state anxiety; basic vs. precautionary information). Predicted symptom differences were positive for all groups, indicating that T_3 symptom scores are predicted to be higher than T_2 scores in all groups. Predicted symptom differences for the basic information condition were .16 for participants with high state anxiety (one standard deviation above the mean) and .04 for low state anxious participants (one standard deviation below the mean). In the precautionary information condition, predicted values were .08 for high state anxious individuals and .17 for low-anxious individuals. There were no interactions between personality variables and experimental condition (all $p > .07$).

When entering all independent variables together into one regression, explained variances rose to $R^2 = .26$ for 'symptom difference' $R^2 = .25$ for 'attributed symptoms', and $R^2 = .28$ for 'belief to perceive the sham EMF'. Significant predictors for 'symptom difference' were T_0 risk perception ($b = .10$, $p < .001$) and somatosensory amplification ($b = .09$, $p = .006$). The only significant predictor for 'attributed symptoms' was state anxiety at T_2 ($b = .08$, $p = .005$). The 'belief to perceive the sham EMF' was significantly predicted by T_0 risk perception ($b = .77$, $p < .001$), somatosensory amplification. All other predictors and their interaction terms were insignificant.

Subsequently, the nine cases for which the experimenter did not remain blinded throughout the experiment were excluded from the data and the hypotheses were tested again. None of the results changed in terms of significance except for the interaction between somatosensory amplification and information type, which was now significant for the dependent variable 'symptom difference' ($b = -.09$, $p = .04$). Predicted symptom differences for the basic information condition were .23 for participants with high state anxiety (one standard deviation above the mean) and -.01 for low state anxious participants (one standard deviation below the mean). In the precautionary information condition, predicted values were .15 for high state anxious individuals and .10 for low-anxious individuals.

To conclude, the null hypothesis was not rejected for any of the interaction effects tested.

3.2 Exploratory Analyses

Mean risk perceptions regarding WLAN at T_0 and T_3 are shown in Table 19. An independent samples t-Test showed that the risk perception difference between T_0 and T_3 did not differ between the two experimental conditions ($t_{df=135} = -1.08$, $p = .28$).

Table 19. Mean Risk Perceptions of WLAN Devices Before and at the End of the Experiment

	Risk perception WLAN T_0 M (90% CI)	Risk perception WLAN T_3 M (90% CI)	Test statistic (differences between T_0 and T_3)
Whole sample (N = 137)	2.58 (2.43-2.73)	2.42 (2.27-2.56)	$t_{df=136} = -2.51$ (p = .01)
Basic information (N = 64)	2.56 (2.33-2.79)	2.33 (2.13-2.53)	$t_{df=63} = -2.65$ (p = .01)
Precautionary Information (N = 73)	2.59 (2.38-2.79)	2.49 (2.28-2.70)	$t_{df=72} = -1.04$ (p = .30)

Interestingly, mean risk perception for WLAN devices was lower at T_2 than at T_0 for the whole sample ($t = -2.51$, $p = .01$). As can be seen in Table 19, this decrease was mostly driven by the basic information group.

As T_0 risk perception was the most powerful predictor for all three dependent variables, we analysed its effects in depth by means of a mediation analysis. The mediator in question is expected symptoms. Results from the mediation analysis can be found in Table 20. The 95% confidence intervals in Table 20 were obtained with 5000 bootstrap resamples. Figure 18 depicts the mediation. We use the nomenclature established by Baron & Kenny (Baron & Kenny, 1986)) to label the different mediation paths. Symptom expectation had a significant relationship with T_0 risk perception ('path a' in the nomenclature of Baron & Kenny) as well as with all dependent variables, controlling for T_0 risk perception (b paths). Comparisons between the total effect of T_0 risk perception on the dependent variables (c paths) and the partial effects when controlling for symptom expectation (c' paths) show a reduction in the size of the regression b-weights in all cases. As the c' path b-weight remains significant for 'symptom difference' and 'belief to perceive the sham EMF', the mediation can be called a partial mediation in these cases. In the case of 'attributed symptoms', the c' path b-weight does not remain significant, indicating a full mediation.

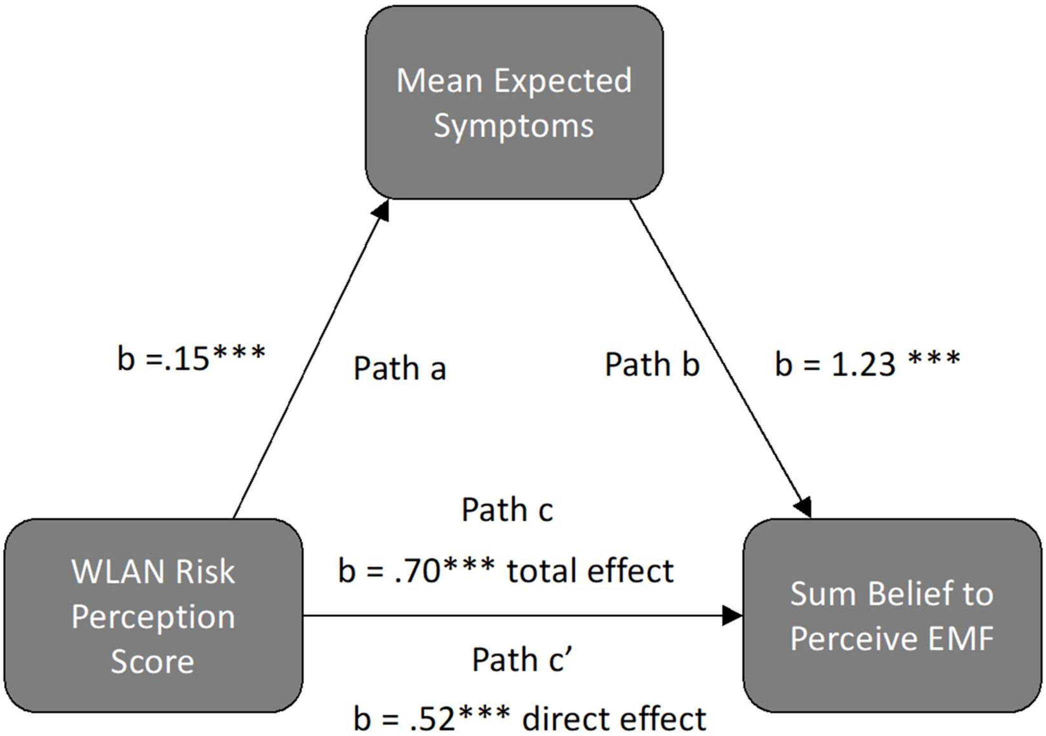

Figure 18. Exemplary mediation effect of T_0 risk perception on the belief to perceive the sham EMF with symptom expectation as mediator. Note. b = bivariate regression coefficient (paths a, b and c) and semipartial regression coefficient (parth c’, with the variance of ‘mean expected symptoms’ partiallised out of ‘WLAN risk perception score’); *** = statistically significant ($p < .001$).

4 Discussion

The present study tested whether precautionary communication regarding EMFs emitted by WLAN devices can influence symptom perceptions under sham exposure.

It was hypothesised that symptom perceptions would be higher after receiving precautionary information compared to basic technical information including a statement about the safety of the existing exposure limits. In line with existing research, it was hypothesised that the effect would be moderated by state anxiety. Additionally, it was assumed that trait anxiety, somatosensory amplification and prior risk perception would have a moderating influence. Previous studies that reported an effect of different types of information on a nocebo experience (Köteles et al., 2016; Witthöft & Rubin, 2013) selected media reports that strongly suggested the harmfulness of EMFs. In contrast to these studies, the aim of the current study was to test specifically whether precautionary information, which does not directly suggest harmfulness and is disseminated by many health authorities, can also cause this effect.

Table 20. Mediation Analyses with T_0 Risk Perception as Independent Variable and Symptom Expectation as Mediator

		Coefficient	ANOVA		Sobel Test	
Dependent Variable	Path	b-weight; t (p)	F (p)	R^2	Indirect effect, b-weight (95% CI)	Z (p)
(Path a equal for all models)	a	.15; 3.69 (<.001)	13.65 (< .001)	.09		
Symptom difference	b	.14; 3.71 (<.001)	17.65 (<.001)	.21	.02 (.008, .043)	2.57 (.01)
	c'	.06; 3.3 (.001)				
	c	.08; 4.44 (<.001)	19.70 (<.001)	.13		
Attributed Symptoms	b	.16; 5.69 (<.001)	20.56 (<.001)	.23	.02 (.009, .048)	3.07 (.002)
	c'	.02; 1.09 (.28)				
	c	.04; 2.66 (.008)	7.08 (.008)	.05		
Belief to perceive sham EMF	b	1.23; 4.40 (<.001)	23.77 (<.001)	.26	.19 (.007, .364)	2.79 (.005)
	c'	.52; 3.72 (<.001)				
	c	.70; 4.98 (<.001)	24.78 (<.001)	.16		

Multiple regression analyses indicated that although all symptom variables were on average higher in the group that had received precautionary information, this difference was not significant. Furthermore, out of 12 tested interaction effects (with the four independent variables state anxiety, trait anxiety, somatosensory amplification and prior risk perception tested for three different dependent variables each), none of these interactions were significant or conform with the hypotheses. Thus, it can be concluded that precautionary information does not lead to increased symptom perception under a sham EMF exposure. Prior studies that found media effects on symptom perception have suggested a 'triggering role of information in the form of written instruction or television reports' (Bräscher et al., 2017), potentially leading to avoidance of EMF sources, thereby being one possible step in the development of IEI-EMF (Bräscher et al., 2017; Witthöft & Rubin, 2013). Yet, whether the nocebo effect is the starting point for IEI-EMF, or whether it acts as an aggravator of pre-existing medically unexplained symptoms, as suggested previously (Dieudonné, 2016), remains to be determined. As the current study did not find a short-term effect of the reception of precautionary information on symptom perception, it does probably not trigger any long-term effects by itself, either.

A special methodological feature warrants mentioning, i.e. the high ecological validity of this finding. The experimental material used in this study was original material from the German national radiation health authority ('Bundesamt für Strahlenschutz', BfS). Hence, it can quite reasonably be derived that the precautionary communication from the BfS does not lead to the presumably unintended effect of an increased nocebo response. Moreover, other radiation health authorities worldwide communicate in similar ways, allowing us to conclude that their communication probably does not have the hypothesised effect on its recipients, either. However, this transfer might not hold for every country that communicates precautions, (a) because the pattern of communication is often similar but never the same as the one from the BfS and (b) cultural differences might lead to a different reception process.

While there is converging evidence in the literature that precautionary information increases risk perception (see e.g. Wiedemann et al., 2013), this is the second study that delineates the boundaries of this effect. In a recent study, precautionary information led to an increase in risk perception, however, the same participants did not show signs of increased state anxiety (Boehmert, Wiedemann et al., 2017). Seen from this angle, the practical relevance of EMF risk perception can be questioned. Nevertheless, prior risk perception was by far the most powerful predictor of a nocebo experience in the current study. Personality variables, namely somatosensory amplification and, to a lesser extent also trait anxiety, also predicted a nocebo experience, but had much less explanatory value. Exploratory findings show that high prior risk perception is connected to the expectation of symptoms, which in turn predict a nocebo response. This mediation, however, was only partial in two of three cases.

A sensible albeit speculative way of clarifying the role of EMF risk perception is to cast a closer look at the situation it is assessed in. In former studies, it was directly assessed after some information, either containing precautionary advice or not, had been given. Participant's evaluation was thus directly connected to that information and the induced difference in risk perception reported in former studies might not have been sustainable. In the current study, risk perception was assessed at minimum one day before the experiment. Because of this, participants answers could be assumed to reflect the persons' general view to a greater extent than the situational circumstances. In former studies, the effect sizes of the precautionary information on risk perception were quite small (e.g. Cousin & Siegrist, 2011; Wiedemann et al., 2013). Consequently, there may also be a very small effect of precautionary information on a nocebo response. Nonetheless, statistical power in the present study was high for rather small effects, so it is very unlikely that if there was an effect, it would be of much practical relevance.

Interestingly, the average risk perception regarding EMFs from WLAN devices was lower after our experimental manipulation than before. In our eyes, this effect is probably rather due to the sham exposure situation itself than due to the information given before. As Weber (2006) points out, direct experience is more likely to influence risk perceptions than any kind of information. In line with this, we think that the experience that an alleged EMF from a WLAN device does not do much harm might have outweighed any information-based effects on risk perception in our study.

Some limitations of our study need to be mentioned. Firstly, our study probably suffered from a sampling bias. People with concerns about EMFs may have been underrepresented. During recruiting, some potential participants were first interested in participating, but declined after hearing that the study was about EMFs, often muttering phrases like 'I am already exposed enough'. It is possible that these already concerned people react stronger to precautionary information. However, we also think that among those concerned, many already know about precautions that can be taken. Therefore, the precautionary information used in this study might not have been new to them. Secondly, we chose a WLAN device as the source of the alleged EMF. The effect of precautionary information regarding other EMF sources might be different. As WLAN radiation risk perception is generally lower than mobile phone or base station risk perception (Freudenstein et al., 2015), recipients of precautionary information regarding WLAN might not as readily react to that information as they would to precautionary information regarding other EMF sources. For instance, in the case of mobile phones, a precautionary recommendation to use a headset for mobile phone calls might – regardless of our findings – lead to a more pronounced nocebo response. In that sense, the study might suffer from a 'floor effect' where the supposed interaction did not manifest itself. Thirdly, and related to the second point, our exposure situation (sitting in front of a WLAN device) might not have been perceived as dangerous as the exposure situations in earlier studies that found an effect of experimental manipulation. Although 61% believed to perceive the sham EMF to some extent in our study, symptoms were generally mild. A difference due to prior reception of precautionary information might only become apparent when experiencing stronger nocebo responses.

5 Conclusions

Despite these limitations, we conclude that this study can be regarded as a robust indication that precautionary information does not trigger nocebo responses. Furthermore, the absence of an interaction effect indicates that this is also true among persons who are more likely to experience a nocebo effect (i.e. people with high prior risk perception, high somatosensory amplification and high trait anxiety).

Chapter IX

General Discussion

1 Cross-Chapter Considerations

Wireless communication devices have become ubiquitous. Mobile telephony and wireless local area networks (WLAN) have changed communication habits profoundly. These technologies transmit signals via electromagnetic fields (EMFs) in the radiofrequency (RF) range. These EMFs interact with the human body. To prevent detrimental health effects, most countries worldwide have implemented exposure limits in their legislations. Although many research projects have been conducted and the dominant view among scientists and health authorities is that these exposure limits are safe, a debate about potential health effects below the limits still persists among experts as well as in the general public. Under these circumstances, the common practice among national health authorities is to inform the public about precautionary measures against potential health effects. For instance, it is recommended to use a headset when making phone calls in order to minimise exposure from the mobile phone. Another example is the advice to limit childrens' use of wireless communication devices.

The problem with precautionary recommendations is that empirical communication research has shown that they increase the risk perception of their recipients. Although the goals of risk communication can be diverse in practice (see e.g. Rohrmann, 1992; Rowan, 1994), it is relatively safe to assume that, given the current state of scientific knowledge about potential health effects, this effect is an unwanted effect and that most authorities would like to avoid fuelling public concerns. According to the European Commission (2000), when implementing precautionary measures (such as recommending individual precaution or setting stricter exposure limits), costs and benefits need to be weighed against each other and compared to the costs and benefits of other policy options. The increase in risk perception among the recipients of precautionary recommendations can be regarded as a cost in that sense. Adopted precautionary approaches should always be subject to review, and in the light of substantially new findings or developments, precautionary measures have to be amended or abandoned (European Commission, 2000). The reader is referred to Chapter III section 1.3 for the European Commission's position and to Chapter VI for how the main research questions are derived from cost-benefit considerations.

The current monograph aimed to shed some light on the costs of precautionary recommendations. First, it was explored whether the effect of precautionary recommendations on risk perception occurs more in individuals with certain personality characteristics (e.g. trait anxiety) than in others (Chapter V and Chapter VII). Second, it was studied whether precautionary recommendations can be framed so that they do not increase risk perception (Chapter VI). Third, the implications of the increase in risk perception were investigated. What does it mean that risk perceptions are increased and what should be the consequences? In Chapter V it is reported whether the recommendations also induce a general state of anxiety. The last study (Chapter VIII) investigated whether the reception of precautionary recommendations has a profound impact on feelings and perceptions, that is, whether nocebo responses appear in an alleged exposure situation.

The results of the investigated points were discussed profoundly at the end of each corresponding chapter and the reader is referred to each chapter for an in-depth discussion of findings, study limitations and specific implications. This general discussion highlights only the main results and offers an interpretation of the general implications that can be derived when considering the outcomes of all studies together. Implications for risk communication research, the practice of risk communication as well as for research methodology are discussed and recommendations for future research are given. As for all empirical research working with samples, the reader should be aware of the epistemological value of the findings. Rather than interpreting study results as given facts, they should be seen as the best current working hypothesis in the sense of Karl Popper (Popper, 1989). The possibility that the results were influenced by some unknown systematic bias or by random sampling error can never be ruled out completely. Nevertheless, carefully designing research is the best way of generating valid working hypotheses.

1.1 Questionnaire-based risk perception measures should reflect psychological processes as closely as possible

At first, a methodological implication is discussed, which will also be important for other parts of this discussion. The study about message amendments (Chapter VI) was the first to use conditional risk perception measures in the analysis of the effects of precautionary recommendations. 'Conditional' refers to the application of precautionary measures. Two different questions were used: Risk perception under the condition that no precautions are taken ('How dangerous do you think the electromagnetic fields from mobile phones are while talking on the phone without using any precautionary measures?') and risk perception under the condition that precautions are taken ('How dangerous do you think the electromagnetic fields from mobile phones are while talking on the phone if precautionary measures that you deem appropriate are used?'). The idea behind the conditional measurement is that it is very likely that people feel less endangered if they apply precautionary measures (e.g. using a headset for phone calls) than if they do not. The conditional measurement thus intends to tap an important aspect that the traditional, unconditional measurement with questions like 'How dangerous do you think the EMFs emitted by a mobile phone when making a phone call are?' does not take into account.

Using conditional measures, the study reported in Chapter VI yields new insights: People clearly differentiate between RF EMF risk if precautionary measures are taken and if they are not taken. Moreover, risk communication and precautionary recommendations differentially affect the two forms of conditional risk perception (see further discussion below). However, the value of a conditional measurement should be further validated in future research. It might be that the differentiation between conditional risk perception with and without precautionary actions is too 'artificial' because it does not reflect naturally occurring thought processes. In this way, the differences between conditional risk perception with and without precautionary measures found in the study would be indicative of a well-known questionnaire effect (Schwarz, 1999): Participants might have been aware of the questions inherent logic and thus the questions would simply have shaped their answers. Future research regarding the utility of conditional risk perception measures would thus be very useful and is not necessarily limited to the investigation of precautionary recommendations and certainly not to the field of EMFs.

1.2 Precautionary recommendations increase risk perception more in low-anxious than in high-anxious people

As shown in Chapter V and Chapter VII, precautionary recommendations predominantly increase risk perception in low-anxious people. While this effect was only found in women and not in men in the first study with a student sample (Chapter V), the effect was independent of gender in the replication with a general population sample (Chapter VII). In the first study, the precautionary recommendations raised the average risk perception of low-anxious individuals to the level of high-anxious individuals that did not receive precautionary recommendations. This effect is somewhat counterintuitive because one might have expected that especially those with high general anxiety might respond with increased risk perception to precautionary recommendations. Wiedemann and Schütz (2005) have suggested that the effect manifests itself because the recipients apply a logic of 'there is no smoke without fire' (no recommendations without an existing risk). Building on this, one could venture to say that, apparently, low-anxious individuals follow this logic more than high-anxious individuals do, because high-anxious individuals already saw the smoke beforehand. Relating this to the distinction between hazard and risk (see Chapter II section 2), one can say that this group interprets the provision of 'risk-related information' (i.e. the precautionary recommendation, cf. Wiedemann & Schütz, 2005) as an indication of the existence of the hazard.

For individuals with higher trait anxiety, the effects of precautionary recommendations are different. In the study in Chapter V the average risk perception was the same in the two groups that (1) did and (2) did not receive a precautionary recommendation. In the replication with a larger general population sample, this was replicated if participants judged the risks under the condition that no precautions are taken. However, under the condition that precautions are taken, risk perception decreased in participants with high trait anxiety. A plausible interpretation of this effect is that especially high-anxious participants feel empowered by personal means to reduce their exposure.

Keeping in mind that communicator's aims can vary, the findings of this monograph suggest a role for tailored risk communication. For instance, the findings of the current monograph suggest that if it is the communicator's aim to reassure generally anxious people, then precautionary recommendations *should be provided* to this group. If, in addition, it is the aim not to increase risk perception, then people who are generally less worried *should not receive* precautionary recommendations. Tailoring risk communication to such 'target audiences' has been proven to be useful in persuasive risk communication (e.g. Noar, Benac, & Harris, 2007). A key variable that mediates the effect of tailoring messages is the perceived relevance of the message (Jensen, King, Carcioppolo, & Davis, 2012). Implementing tailored communication is, however, a difficult endeavour in many communication scenarios, because knowledge about the recipients has to be available. Potential application scenarios include consultations of physicians or also online contexts in which usage patterns or other user data are available. However, when tailoring risk communication, not only its effectiveness but also other aspects need to be considered, first and foremost ethical aspects: Is it right to hold back some information from some people only?

1.3 It is hard to predict the effects of different message framings

In a further study, it was tested whether precautionary recommendations can be framed[14] so that they do not increase risk perception. The results of that study have to be interpreted with care because the original effect was weaker in this study than in previous studies (see Chapter VI section 4 for a detailed discussion of this). Two types of frames were tested. Firstly, the motives for the recommendations were explained in order to reduce the perceived inconsistency arising from the provision of both information about safe exposure limits and precautionary recommendations. This 'consistency framing' did not have an effect on risk perception. The result fits to previous research in which communicating two other motives did not affect risk perception either (Barnett et al., 2008).

Secondly, the effectiveness of the precautionary measures was explained. For the majority of people, the mobile phone is the primary source of exposure to RF EMFs (cf. Bolte & Eikelboom, 2012; Neubauer et al., 2007). Still, most people underestimate the contribution from their mobile phones to their personal exposure and overestimate that of base stations (Claassen, Bostrom, & Timmermans, 2014; Cousin & Siegrist, 2010b). It was hypothesised that risk perception would decrease when the value of individual precautions targeting the mobile phone was emphasised by this additional explanation. However, the opposite was the case: Risk perception under the condition that no precautions are taken was increased while risk perception under the condition that precautions are taken remained the same. The interpretation of this result involves two different processes. On the one hand, the participants might have corrected their inadequate exposure assessments and subsequently increased their risk perception (which was specifically assessed for the situation of a mobile phone call). On the other hand, a detailed explanation of why the recommended precautionary measures work well in reducing exposure might have been interpreted in the sense of the logic described by Wiedemann and Schütz (2005, see prior paragraph): There is 'no smoke without a fire'. For people following this logic, the communicator's emphasis on the effectiveness of the precaution could mean 'even more smoke'.

For risk communication practice, the example of explaining the measures' effectiveness implies that framing precautionary messages is not an easy endeavour. It does not always have the effects that communicators envision. Therefore, the effects of a specific framing should be evaluated prior to its application whenever possible (cf. Fischhoff et al., 2011). Additionally, communicators have to decide whether correcting misconceptions regarding the contribution by different sources of RF EMFs is their primary goal and if they are willing to accept an increase in risk perception in exchange. In other words, communicators need to be aware of the different effects their communication can have and consciously formulate and pursue their communication aims.

[14] The term framing is used in its common language sense in the current thesis. It is not to be understood as being in relation to the branch of communication research that examines and discusses 'framing' (see e.g. Entman (1993), Cacciatore, Scheufele, and Iyengar (2015)).

1.4 Beyond risk perception: Boundaries of the effect

Renowned scholars have strongly criticised the recommendation of precautionary measures (Burgess, 2004; Sandman, n.d.; Sunstein, 2005). According to these authors, precautionary recommendations give rise to public fears, alarm and outrage. Findings of the current thesis suggest that their criticisms need to be softened. First of all, the increase in risk perception was shown on an individual level. Further social processes are needed for public alarm and outrage to evolve in response to precautionary recommendations. It is currently unknown, whether such processes are initiated by increased risk perception on the individual level. What is more, the current work delineates the boundaries of the effect on the individual level. Precautionary recommendations neither gave way to higher state anxiety nor to more frequent nocebo experiences under sham exposure to an alleged WLAN signal.

The question is then: What does the well-replicated increase in risk perception actually stand for, if it is not related to anxiety and symptoms? What is the practical relevance of it? It could be argued that the practical relevance is low and that risk perception as measured in questionnaires does not correspond with relevant affective or behavioural processes. However, risk perception is generally accepted as an important predictor in models of health behaviour (e.g. Brewer et al., 2007). This is also supported by the results of the study reported in Chapter VIII. Prior risk perception was by far the best predictor of nocebo experiences under sham exposure to an alleged WLAN signal. Integrating all this, the best explanation is that the effect of precautionary messages on risk perception is too small to be related to affective or behavioural effects. This line of thinking can be backed by the following chain of arguments:

1. Risk perception and health behaviour are correlated. According to meta-analyses (e.g. Brewer et al., 2007), the correlation lies in the range of $.20 < r < .30$ and is thus moderate. Explained variances are thus in the range of $.04 < r^2 < .09$.
2. The effect sizes of the impact of precautionary recommendations on risk perception that were reported are small. People rather slightly increase their risk perception in response to the recommendations than strongly.
3. The prior variation in risk perception between different persons is much higher than the variance in risk perception which is correlated to the different experimental conditions in the studies (precaution vs. no precaution).
4. Thus, although risk perception is in general related to affective and behavioural processes, the induced change in risk perception in response to precautionary recommendations is too small to be related to affective or behavioural processes.

Technically, it would also have been possible that the recommendations are related to more nocebo responses and higher state anxiety independently of risk perception. This is not the case, either.

The results reported in Chapter V and Chapter VII can also provide additional arguments. Increases in risk perception mostly occur in those who are generally low-anxious. Wiedemann, Freudenstein et al. (2017) have identified two qualitatively different types of people that are concerned about EMFs. For about 80 percent of those who indicate to be concerned about possible health effects of EMFs in a questionnaire, the issue is not relevant in their everyday life. Only 20% admit that they think about the issue often in their daily life (equalling roughly 10% of all people). It seems likely that low-anxious people who increased their risk perception now belong to the 80% who are concerned but for whom the risk is not an issue in their daily lives. It might be that people with this 'mild' type of risk perception do not experience nocebo responses more frequently than people with low risk perception. As data are lacking on this, the relation to the risk perception types remains speculative, however.

In short, if it is not the communicator's aim to increase risk perception, then recommending precaution is not the best approach. However, the consequences are not as devastating as was suggested by some scholars.

1.5 Can the findings be transferred to other possible risks?

Because possible risks differ widely in many facets (e.g. with respect to characteristics of the hazard, size and characteristics of the affected population, extent and quality of scientific uncertainties etc.) it is difficult to compare them. The question whether the findings can be transferred is thus a very difficult albeit important one. In order to see if the findings can potentially be transferred, it seems reasonable to attempt such a transfer to a very similar risk at first. Extremely low frequency magnetic fields (ELF MFs) share many characteristics of RF EMFs: They are both imperceptible, classified as a 2B 'possible carcinogen' (IARC, 2002), highly present in everyday life worldwide, limit values (including a safety margin) exist in many countries, public risk perception is in a comparable range (Siegrist, Earle et al., 2005), precautionary policies are pursued in many countries. Another similarity is that people tend to overestimate their exposure from far-field sources (such as mobile phone base stations and high-voltage power lines) and to underestimate their exposure from near-field sources (such as mobile phones and hair-dryers). Moreover, precautionary measures that can be applied by the recipients themselves are recommended by health authorities in both cases, e.g. by the German Federal Office for Radiation Protection (Bundesamt für Strahlenschutz, n.d.a, Bundesamt für Strahlenschutz, n.d.d). In both cases, these recommendations aim mostly at an increase of the distance to near-field sources.

Differences exist with regard to the physical properties (i.e. the wavelengths) and the way the fields interact with the body (heating in the case of RF EMFs and induction of currents in the case of ELF MFs). Moreover, ELF MFs also occur naturally while RF EMFs are man-made. However, for the question at hand, it seems more relevant how similar two potential hazards appear in the eye of the recipient. In this vein, an important difference between technologies using ELF MFs and RF EMFs, respectively, is that electrical appliances have been used for a much longer time than modern wireless communication devices (such as mobile phones etc.). It is possible that mechanisms like habituation on the individual level and acceptance on both individual and societal level make people less interested in and less attentive to information about ELF MFs. However, habituation and acceptance change when new power lines are built. For that case, one study has already found a similar effect of information about precaution regarding ELF MFs (Wiedemann, Boerner et al., 2017). Hence, it seems that the effect of precautionary recommendations is at least relevant for similar possible hazards in similar situations. Whether the question is relevant for other possible hazards that are not as similar as ELF MFs and whether some of the findings can be transferred, remains an open question. Cases with similar communication patterns certainly exist. It would be worthwhile for future research to systematically register uncertain hazards for which precaution has been proposed. A good starting point for this would be the list of all IARC 2B classified agents. Hazards could be selected on the basis of similarity to the case of RF EMFs of wireless technologies, and the effects of precautionary recommendations could subsequently be empirically tested.

2 Concluding Remarks and Avenues for Future Research

The current monograph reports in-depth analyses of the effects of precautionary recommendations regarding EMFs of wireless technologies. These recommendations increase risk perception in some people. Still, the deduction of more 'severe' effects is not compatible with the results of the conducted studies. As such, the costs of precautionary recommendations are restrained to a small increase in average risk perception. Risk communicators and risk researchers should both avoid generalising from an increase in risk perception to other concepts like anxiety or symptoms. This is not warranted in the light of the findings of this monograph.

Risk perception plays a key role in health-related behaviour, however, this role needs further clarification. In a similar vein, it is still an open question to what extent the effects of precautionary recommendations on risk perception persist over time. Only one study with a comparably small sample has investigated this and has not found a persistent effect (Cousin & Siegrist, 2011). Furthermore, it is a remaining possibility that an increased risk perception leads to affective responses (e.g. nocebo responses) over time. Both issues could be usefully investigated in future research.

Besides the persistency of the effect, the precise mechanism of how precautionary recommendations lead to increased risk perception also remains unknown. Thought processes like the 'no smoke without a fire' logic (Wiedemann & Schütz, 2005) and psychological theories like dissonance theory (Festinger, 1957) have been proposed as an explanation of the effect, but it is still an open question how well they actually explain it. Related to this, it remains unclear whether certain elements of precautionary recommendations trigger the effect, like for instance the word 'precaution' itself, or the recommendation to minimise exposure. While the current monograph delineated the boundaries of the effect and also the boundaries of changing the effect, future research could usefully focus on these underlying mechanisms.

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Appendix

Appendix A (to study in Chapter V)

Table A1. Questions referring to Threat, Trust and Knowledge regarding Electromagnetic Fields in Mobile Telephony

Measured Construct	Wording
Threat Perception	All in all, how threatened do you feel by electromagnetic radiation emissions from cell phones (base stations)?
Trust in Protection of the Public	Do you trust that the public's health is sufficiently protected against electro-magnetic radiation emissions from cell phones (base stations)?
Belief in Scientific Knowledge	How would you rate the overall state of scientific knowledge about the health effects of electromagnetic radiation emissions from cell phones (base stations)?

Table A2. Means and Standard Deviations of Threat, Trust and Knowledge in the Basic group and the Precautionary Group, both for Mobile Phones and Base Stations

	Text	N	Mean (SD)
MP[1] Threat	BM	153	2.15 (.97)
	PM	145	2.46 (1)
MP Trust	BM	153	3.08 (.91)
	PM	145	2.82 (.95)
MP Knowledge	BM	153	2.77 (1)
	PM	145	2.71 (1.04)
BS Threat	BM	153	2.41 (1.12)
	PM	145	2.52 (1.06)
BS Trust	BM	153	2.99 (.89)
	PM	145	2.96 (.97)
BS Knowledge	BM	153	2.88 (1.08)
	PM	145	2.57 (.96)

[1] MP = Mobile Phone, BS = Base Station, SD = Standard Deviation, BM = Basic Message, PM = Precautionary Message; Samples sizes were N = 153 in the Basic Group and N = 145 in the Precautionary Group

Table A3. Means and Standard Deviations of Threat, Trust and Knowledge for Mobile Phones and Base Stations, Separately for Males and Females

	Gender	Mean (SD)
MP[1] Threat	Male	2.12 (.94)
	Female	2.36 (1.01)
MP Trust	Male	3.04 (1.03)
	Female	2.93 (.91)
MP Knowledge	Male	2.61 (1.02)
	Female	2.79 (1.01)
BS Threat	Male	2.28 (1.10)
	Female	2.53 (1.08)
BS Trust	Male	3.09 (1.01)
	Female	2.93 (.90)
BS Knowledge	Male	2.71 (1.14)
	Female	2.73 (1.00)

[1] MP = Mobile Phone, BS = Base Station, SD = Standard Deviation, Sample sizes were N = 76 for Males and N = 222 for Females

Table A4. Means and Standard Deviations of Threat, Trust and Knowledge for Mobile Phones and Base Stations, Separately for Order of Appearance

	Order	Mean (SD)
MP[1] Threat	MP - BS	2.18 (.94)
	BS - MP	2.42 (1.03)
MP Trust	MP - BS	2.91 (1)
	BS - MP	3.00 (.86)
MP Knowledge	MP - BS	2.75 (1.08)
	BS - MP	2.73 (.95)
BS Threat	MP - BS	2.71 (1.12)
	BS - MP	2.22 (1)
BS Trust	MP - BS	2.78 (.90)
	BS - MP	3.17 (.92)
BS Knowledge	MP - BS	2.72 (1.05)
	BS - MP	2.73 (1.02)

[1] MP = Mobile Phone, BS = Base Station, N = 150 for the order MP – BS and N = 148 for the order BS – MP

Table A5. Means and Standard Deviations of Threat, Trust and Knowledge for the Whole Sample

	Mean (SD)
MP[1] Threat	2.30 (.99)
BS Threat	2.46 (1.09)
MP Trust	2.96 (.94)
BS Trust	2.97 (.93)
MP Knowledge	2.74 (1.02)
BS Knowledge	2.73 (1.03)

[1]MP = Mobile Phone, BS = Base Station, SD = Standard Deviation, N = 298

Appendix B (to study in Chapter VI)

B1. Experimental Material used in the Study in Chapter VI

Basic text module

The International Commission for Non-Ionizing Radiation Protection – a body collaborating with the World Health Organisation (WHO) – has recommended limits of exposure to electromagnetic fields emitted by mobile phones and mobile phone towers (the exposure is the strength of the electromagnetic field that reaches a person). Australia, like most other countries, has adopted these limits in its laws. A large number of studies have been performed to investigate whether mobile phone use poses a potential health risk. It is the assessment of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and other national and international health authorities, including the WHO, that there is no established scientific evidence that the use of mobile phones causes any health effects within these limits.

Precaution text module

However, the possibility of harm cannot be completely ruled out. ARPANSA and other authorities recommend the following measures as highly effective means to minimize your personal overall exposure, and especially the exposure of your head:

- use a headset when talking on the mobile phone.
- limit the duration of mobile phone calls.
- make mobile phone calls where the reception is good. Your phone sends a weaker signal under good reception conditions.
- use a mobile phone with a low SAR value. The SAR value indicates how much electromagnetic energy your head absorbs when you make a phone call.
- use the mobile phone's loudspeaker when talking on the phone.
- do not make calls with a mobile phone when a normal wired phone is available.
- send a text message (SMS, What's App, Email or similar) instead of making a voice call.

Consistency text module

Why does ARPANSA communicate precautionary measures despite the safety of the existing limits?

Despite much research, there has been no established scientific evidence for any health effects of electromagnetic fields within the limits implemented in Australian law. However, ARPANSA also provides information about precautionary measures. Although this may appear contradictory, it is provided for those people who may be concerned (regardless of the science), as a means of assisting them to reduce their exposure.

How do the precautionary measures substantially reduce exposure?

Electromagnetic fields decline very rapidly with increased distance from the source of the field

During phone calls, a mobile phone functions as an antenna and sends signals, just like mobile phone towers do. The most effective way to reduce exposure to electromagnetic fields during mobile communication is to increase the distance between the mobile phone and the user (e.g. by using a headset). People often underestimate the exposure reduction that can be achieved by having the mobile phone even a few centimetres further away from the head, but physics shows us that this reduction is very large. Therefore, using a wired headset or the loudspeaker of the phone reduces the exposure substantially, as it physically moves the exposure source away from the brain. The following table shows the reduction of exposure that can be achieved (as a percentage) by moving the phone away from the ear, compared with having the phone against the ear.

Distance to Source of Electro-magnetic Field	Exposure Reduction (compared with the standard exposure)
Phone at ear (approximately 2.5 cm from the brain)	standard exposure to the brain (at this distance, exposure is within the limits regulated by law and not deemed harmful)
5 cm from ear	89% exposure reduction
10 cm from ear	96% exposure reduction
25 cm from ear	99% exposure reduction

During phone calls, mobile phones are responsible for most of the exposure, not mobile phone towers

Although a mobile phone tower may emit a strong signal, at the distance that mobile phone towers are generally from people these emissions are extremely small and far smaller than those from your mobile phone.

Increasing the distance to the phone (e.g. with a headset), limiting exposure time to it (e.g. via sending text messages, keeping phone calls short and using wired phones when available) or limiting the emissions of your phone (by buying a phone with a low SAR value or by restricting calls to situations with good reception) will lead to the reduction of the largest share of your overall exposure to electromagnetic fields from mobile telecommunication technologies.

Appendix C (to study in Chapter VIII)

Table C1. Means of Symptom Perceptions at T_2 and T_3

Perceived symptom	T_2 Mean (SD)	T_2 % 'markedly'; 'strong'[a]	T_3 Mean (SD)	T_3 % 'markedly'; 'strong'[a]
Ear noise	2.05 (.87)	20.4; 6.6	1.98 (.95)	17.5; 8.8
Fatigue	1.35 (.58)	5.1; 0	1.57 (.76)	11.7; 1.5
Restlesness or irritability	1.28 (.51)	2.9; 0	1.25 (.58)	2.9; 1.5
Sweating	1.23 (.45)	1.5; 0	1.14 (.39)	1.5; 0
Concentration difficul-ties	1.22 (.53)	0.7; 1,5	1.39 (.67)	10.2; 0
Dizziness	1.21 (.43)	0.7; 0	1.39 (.68)	6.6; 1.5
Drowsiness	1.20 (.42)	0.7; 0	1.35 (.58)	5,1; 0
Palpitation	1.20 (.45)	2.2; 0	1.32 (.56)	4.4
Feeling of warmth on skin	1.18 (.44)	2.2; 0	1.26 (.61)	4.4; 1.5
Dryness of mouth	1.17 (.46)	1.5; 0.7	1.28 (.61)	5.8; 0.7
Congestion of nose	1.17 (.52)	2.2; 1.5	1.15 (.51)	2.2; 1.5
Headache	1.14 (.39)	1.5; 0	1.47 (.64)	8; 0
Blurred vision	1.11 (.34)	0.7; 0	1.21 (.56)	2.9; 1.5
Muscle tension or trem-bling	1.10 (.33)	0.7; 0	1.16 (.44)	2.9; 0
Breathlessness	1.10 (.35)	1.5; 0	1.17 (.49)	2.9; 0.7
Breathing difficulties	1.07 (.29)	0.7; 0	1.18 (.50)	2.9; 0.7
Prickling of skin	1.07 (.29)	0.7; 0	1.25 (.55)	5.8; 0
Nausea	1.04 (.21)	4.4; 0	1.18 (.48)	4.4; 0
Itching of skin	1.03 (.21)	0.7; 0	1.12 (.41)	2.9; 0
Stomach ache	1.01 (.09)	0.7; 0	1.14 (.42)	2.9; 0

[a] Answers were given on a on a 4-point scale with labels 'not at ll', 'mildly', 'markedly', and 'strongly'.

Appendix D: Review Article (submitted)

A Systematic Review of Health Risk Communication About EMFs from Wireless Technologies

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Abstract

Over the last two decades, the risk perception and risk communication literature has grown extensively. The current paper provides the results of a systematic review on risk communication regarding potential health effects of radiofrequency electromagnetic fields (RF EMFs) of mobile communication technologies. The following databases were searched in March 2017: EBSCO (PsycInfo, Academic search premier), Medline, SCOPUS, emf-portal.org. Of 1139 unique hits, 28 articles (including 27 studies) remained after full-text eligibility screening. The majority of studies were experiments. The quality of all studies was evaluated against standardised criteria. Studies were assigned to 9 different categories of content. Categories were comprehensibility of information (4 studies), information on existence of the risk (2), information about uncertainty (3), information focussed on different health effects (3), information about the source of the information (2), information about individual risk and exposure aspects (5), information about precautionary measures (14), effects of television reports and audio-visual advertisements (4), miscellaneous (2). For each topic, findings were summarised and, if possible, a recommendation for risk communication practice was derived. Key findings: For information about precautionary measures, the evidence was combined in a meta-analysis. Mean effects showed a significant increase of risk perception regarding mobile phones and mobile phone base stations due to information about precaution (Hedges' $g = .16$, 95% confidence interval (.05; .26) for mobile phone risk perception, $g = .17$ (.10; .24) for base station risk perception). Throughout the topics, many studies did not only analyse main effects but also interactions with recipient characteristics. Interaction analyses suggest that especially prior risk perception shapes the individual evaluation of RF EMF information and has an influence on perceived credibility, interpretation of verbal descriptors of uncertainty, perceived persuasiveness of arguments and the communication's effect on risk perception. Potential avenues for future research are discussed.

Keywords: Risk Communication; EMF, Electromagnetic Fields, Review, Meta-Analysis

Introduction

Over the last few decades, there has been a controversy over possible health effects of radiofrequency electromagnetic fields (RF EMFs; c.f. (Baan et al., 2011; ICNIRP, 1998, ICNIRP, 2009; Swerdlow et al., 2011)).

While most people worldwide use mobile phones, smartphones and/or wireless local access networks (WLAN) nowadays, protests against them (e.g. against the erection of mobile phone base stations) are not as common any more as in the late 1990s and the early 2000s. Nevertheless, concern is still widespread and on a constant level according to survey-based research (e.g. LINK Institut, 2013; TNS Opinion & Social, 2010; Wiedemann, P. & Freudenstein, F., 2014). The value of these findings has, however, been challenged recently (Wiedemann, Freudenstein et al., 2017).

One factor that might contribute to lay people's risk perception is their lack of knowledge about the technical aspects involved in mobile communication. Various studies have shown that misconceptions are common, e.g. regarding personal exposure and the contribution of different RF EMF sources to it (Claassen et al., 2014; Cousin & Siegrist, 2010b).

Having scientific uncertainty on the one side and public concern and misconceptions on the other side, risk communication is a difficult undertaking. The aim of the current paper is to review and systemise the relevant research literature regarding RF EMF risk communication. For some research questions, reviews derive direct recommendations for communication practice from the literature. For instance, in their review about probability information in risk communication, Visschers et al. (2009) derive recommendations regarding the comprehensibility of probability information. Comprehensibility is something that most communicators want to achieve under most circumstances, thus recommendations to improve comprehensibility will be accepted without much debate. In the current review, the main dependent variable across studies is RF EMF risk perception. When it comes to risk perception, aims depend on the specific intentions of the communicator: Is the goal to increase risk perception, to decrease it, or not to change it at all and only raise awareness? It is thus necessary to make an assumption about communicators' intentions prior to giving recommendations. In the current review, we give recommendations under the assumption that public risk perception about RF EMFs should not be fuelled by risk communication (e.g. by public health authorities). This assumption mirrors our opinion, which in turn is based on three key arguments: Firstly, the general reasoning of the WHO is that the current exposure limits are sufficient for health protection. Secondly, scientific uncertainties regarding potential health effects have been reduced by means of scientific studies over the past two decades (Swerdlow et al., 2011). And thirdly, evidence exists that risk and exposure perception itself can lead to the perception of symptoms (see e.g. Baliatsas et al., 2011; Baliatsas et al., 2015).

Purpose

Many guidelines have been published on risk communication in general. However, a closer look reveals that they are rather built on general assumptions and not on systematic research. Evidence-based risk communication – like in the field of clinician-patient-communication – is the exception rather than the rule (Fischhoff et al., 2011). For RF EMFs in wireless telecommunication, to our knowledge, no systematic review covers the literature on EMF risk communication. The scope of the current review is limited by a narrow definition of risk communication, similar to that applied elsewhere (Visschers et al., 2009). Risk messages and their effects on recipients are examined. Broader issues that are important in risk communication, such as context, policy issues or two-way risk communication will not be discussed.

Materials and Methods

Search Terms and Data Collection

Literature search was performed in March 2017. No language or date restrictions were imposed. The following databases were searched: EBSCO (PsycInfo, Academic search premier), Medline, SCOPUS, emf-portal.org. Search terms were combinations of one term of

a) base station OR Bluetooth OR cell phone OR cellular phone OR cordless phone OR DECT OR electromagnetic energy OR electromagnetic field OR electromagnetic radiation OR EMF OR mobile phone OR Wi-Fi OR wireless LAN OR WLAN

and one term of

b) risk communication OR risk information OR risk message.

The search resulted in 3671 hits (1037 hits in Medline, 200 hits in Scopus, 360 hits in Academic Search Premier (EBSCOhost), 111 hits in PsycInfo and 1963 hits in emf-portal.org databases). The hits from all searches were transferred to a literature management program. The program automatically detected and excluded double entries so that 1139 entries remained in the database.

Title and Abstract Screening

The study selection process is depicted in Figure D1. At first, titles and abstracts of these entries were subsequently screened for concordance with the following inclusion criteria

- The article had to be about EMF risk communication, especially in contrast to only being about risk perception (1086 articles excluded)
- The article had to be a peer-reviewed journal publication (7 additional articles excluded)
- It had to be in English, German or French (1 additional article excluded)

46 articles remained after title and abstract screening.
Subsequently, the full-texts of all of the remaining 44 articles were obtained.

Full-Text Screening

Full-text inclusion criteria were:

(1) The article had to be at least in part about a test of RF EMF risk communication (7 articles excluded; formulation changed 9 Nov 2017. Prior formulation: "The article had to be at least in part about RF EMF risk communication", change due to a media content analysis (Claassen et al., 2012). Several media content analyses about RF EMF coverage exist and we considered this to be a different topic.)
(2) The article had to provide new empirical data (8 articles excluded)

(3) The article had to suffice methodological criteria (2 articles excluded; understandable description of methods, comprehensible procedure, sample size and analysed variables)

When necessary, the corresponding authors of the articles were contacted and asked to provide the experimental material used in the study. For two articles (one study), it remained unclear whether they were only about EMFs in general or whether they contained information on RF EMFs specifically (McMahan & Meyer, 1997; McMahan, Witte, & Meyer, 1998). Because the authors did not reply to repeated requests, these two articles were excluded. 25 articles remained after this step. During the full-text screening, 3 additional articles were included that were not part of the original sample of articles. 2 had been published after the literature search (Bräscher et al., 2017; Witthöft et al., 2017), and one was provided by an author that was asked to provide the experimental material of another study (Niederdeppe et al., 2014). The final sample of eligible articles thus consisted of 28 articles.

Articles with Multiple Studies and Multiple Articles About one Study

There were two pairs of articles reporting on the same sample. In this case, the two articles were only counted as one study (Wiedemann & Schütz, 2008; Wiedemann, Schütz, Sachse, & Jungermann, 2006 and Kim et al., 2015; Niederdeppe et al., 2014). One article reported on two studies with two separate samples (Wiedemann & Schütz, 2005) and one article reported results from 8 different samples (Wiedemann et al., 2013). As Wiedemann et al. (2013) used the exact same methodology for each of their samples, this article will be treated as one study. In some articles, multiple studies were conducted but only one of the studies was relevant for the current review (Niederdeppe et al., 2014; Wiedemann & Schütz, 2008). Ruddat et al. (2010) report a focus group study and a survey. The focus group study is not included in this review, because it insufficiently reports the study's methods (e.g. no sample size for focus groups reported). The survey is included. The number of included studies was 27.

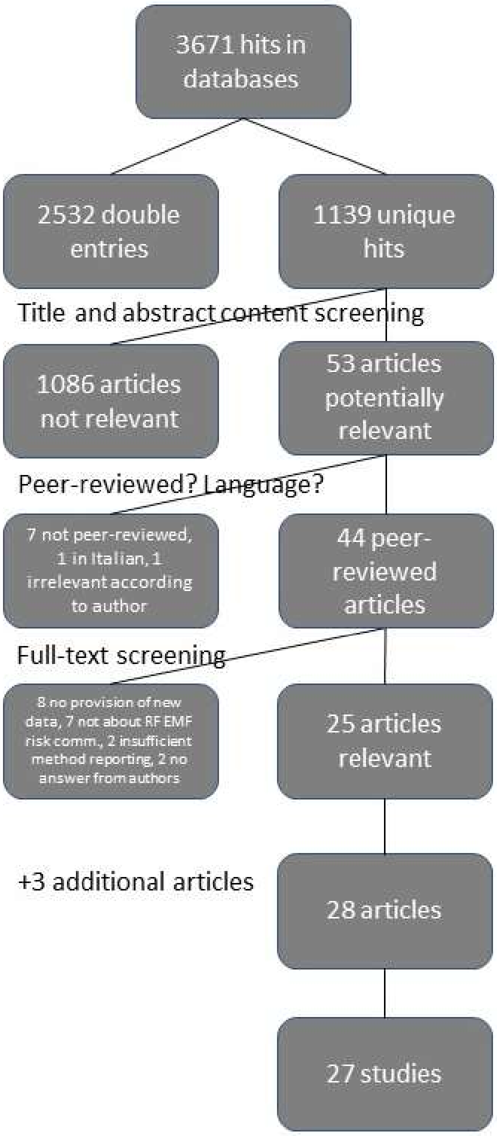

Figure D1. The study selection process.

Quality Assessment

Eligible studies with an experimental design were assessed using the Cochrane Collaboration's Risk of Bias tool (Higgins & Green, 2011). For qualitative studies, separate criteria were applied (Mayring, 2016). The quality of survey studies was assessed using an amended version of the Total Survey Error (TSE; Groves & Lyberg, 2011). In principle the TSE differentiates between representation and measurement errors. The former covers possible problems with respect to sampling, if the target population is covered and if information about non-response is given. The latter evaluates the validity of the construct (specification), possible errors during the measurement and progressing errors when data is edited. The error rate for all studies was assessed using a 3-point scale for 'low', 'medium' and 'high' risk. For experiments and survey studies we additionally assessed if statistical power calculations were reported.

Results

Study Quality Assessment

As shown in Figure D2, the experimental studies performed well against some of the criteria and rather bad against others (see Appendix E4 for the complete assessment). In contrast to some experiments in e.g. medical research, the studies reviewed here were not at risk for blinding of outcome assessment or allocation concealment (one could also argue that these criteria are not useful in evaluating research in which the experimental manipulation immediately follows the allocation and in which outcome measures are self-reported). Bias of selective reporting was assessed by comparing the measures mentioned in the method section with the measures reported in the results section of each article. About half of the studies did not report results for at least one measure used in the study according to the method section. Risk of bias introduced by inadequate blinding of personnel and random sequence generation was largely unclear due to insufficient reporting. Only 22 percent of the experimental studies and none of the survey studies reported power calculations.

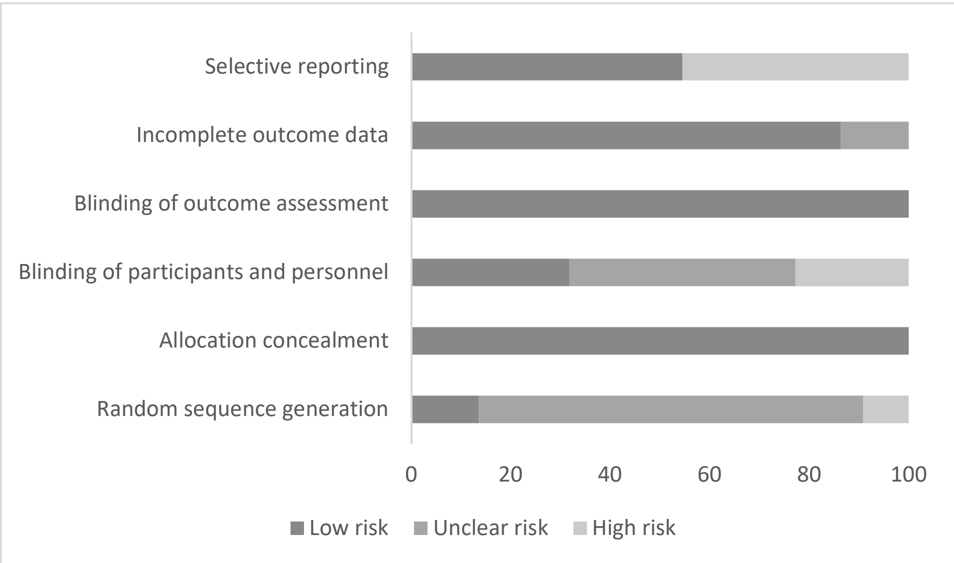

Figure D2. Risk of bias in the 22 experimental studies.

The two qualitative studies performed rather well against Mayring's quality criteria (Mayring, 2016). One of the studies (Collins, 2010) partly lacked justification of its research methodology (see Appendix E5). The three survey studies' (Barnett et al., 2007; Ruddat et al., 2010; Wiedemann et al., 2014) performance against the TSE was mixed to bad. The study by Barnett et al. (2007) showed a low risk for errors in all categories except for the non-response subclass, which was evaluated as 'medium' due to a high rate and a lack of explanation. As Wiedemann et al. 2014 used a student sample and no information about non-response was given, the risk for representation errors is 'high', whereas the risks for all measurement errors are 'low'. In the third survey study (Ruddat et al., 2010), sampling, non-response and measurement errors were 'high', mainly because the method changed from respondents participating via mail to a telephone survey and due to a high non-response rate (complete evaluation for all studies, see Appendix E6).

Study Categorisation by Content

During the course of the review, we identified nine different aspects of RF EMF risk communication that studies had been focussing on, i.e.

(1) Comprehensibility of information (4 studies)
(2) Information on existence of the risk (2 studies)
(3) Information about uncertainty (3 studies)
(4) Information focussed on different health effects (3 studies)
(5) Information about the source of the information (2 studies)
(6) Information about individual risk and exposure aspects (5 studies)
(7) Information about precautionary measures (14 studies)
(8) Effects of television reports and audio-visual advertisements (4 studies)
(9) Miscellaneous (2 studies)

While some of the reviewed studies address one aspect only, others address multiple aspects. The results section will be structured in accordance with the nine identified aspects. An overwhelming majority of the studies used textual risk communication stimuli. If not otherwise specified, the communication materials used in the studies were texts.

In many of the studies described below, the perception of EMFs as a danger (e.g. Boehmert et al., 2016) or health concerns about EMFs (e.g. Cousin & Siegrist, 2011) or health worries (e.g. Witthöft & Rubin, 2013) are important dependent variables. In the current review, these similar and correlated concepts will all be termed 'risk perception' in order to facilitate the description of and the comparisons between studies. This was especially important in the meta-analysis carried out for 'information about precautionary measures', as it would have been impossible to find more than two studies using the exact same wording for their dependent variables. However, treating concerns and risk perceptions alike is not to say that differences between these concepts do not exist (c.f. Sjöberg, 1998), and in studies where several constructs were assessed (e.g. Cousin et al., 2011), these will be taken into account separately.

Some studies analysed the interplay of risk communication and recipient variables (e.g. personality variables or prior attitudes). For instance, there is considerable evidence for the importance of prior risk perceptions. Studies using indirect change measurement (one measurement before experimental manipulation and one thereafter, Gollwitzer & Jäger, 2009) report substantive proportions of participants that do not change their risk perceptions in response to the risk communication. For instance, in one study (Nielsen et al., 2010), averaged across all groups, 50 percent of participants did not change their prior risk perception after receiving RF EMF risk messages. Study results on the influence of recipient variables will be described in a separate subsection for each risk communication aspect.

If not otherwise mentioned, all results reported in the current review were statistically significant ($p < .05$).

Each section will begin with a brief summary, followed by recommendations for better EMF risk communication, in case recommendations could be derived. Subsequently, individual studies will be described in detail. Each section is concluded by a paragraph about the influence of recipient variables.

1. Comprehensibility of Information (4 studies)

Summary

Two out of two studies report that information containing less technical terms, intended to be understood easily, is in fact understood better by the recipients (Cousin & Siegrist, 2011; Nielsen et al., 2010). Importantly, the indicators for understanding differed between the two studies, with one study reporting an increase in 'objective' understanding (i.e. increased knowledge, Cousin & Siegrist, 2011) and one study reporting an increase in the subjectively rated comprehensibility (Nielsen et al., 2010). A third study (Ruddat et al., 2010) points at the possibility of attitude-congruent judgments of comprehensibility, while a fourth study documents the difficulties in the understanding of the International Agency for Research on Cancer's classification of mobile phone RF EMFs as 'possibly carcinogenic' (Wiedemann et al., 2014).

Cousin and Siegrist (2011) amended an information booklet issued by a public health authority with the aim to make it more understandable for its target audience (i.e. the public). Technical terms and complex formulations were replaced by simpler expressions and sentences. Also, the authors changed the booklet's structure by integrating precautionary recommendations in the corresponding text passages in the form of textboxes. Participants reading the amended booklet showed higher gains of knowledge compared to participants reading the original booklet. The amended version of the booklet was also better understood (i.e. gains in knowledge were higher) if it contained precautionary information than if it did not.

Nielsen et al. (2010) assigned their participants to one of three groups: One group received a brief summary about the existing knowledge around RF EMFs and health; a second group received 'more comprehensive, detailed and technical' information and a third group received information on 'simple measures that reduce the exposure'. Participants reading the more technical text rated the comprehensibility of the text lower than the groups reading the brief summary and the text about exposure reduction measures. There was no difference between brief summary and the technical text regarding participant's judgements of usefulness, information value and trustworthiness.

Wiedemann et al. (2014) gave their participants parts of the IARC 2011 press release stating that RF EMFs from mobile phones are 'possibly carcinogenic'. The authors were interested in the understanding of this qualitative expression of likelihood. They found that the term was translated to a probability of 30% (median), with 50% of participants assigning probabilities between 18 and 50%.

Influence of Recipient Variables

The experimental studies in this section did not test any interactions with recipient variables. In their survey study, Wiedemann et al. (2014) report that the interpretations of the term 'possibly carcinogenic' are shaped by prior risk perceptions. Participants with high prior risk perceptions gave higher estimates for the degree of certainty implied in this statement.

Ruddat et al. (2010) report differential results of participants with high prior concerns, low prior concerns and ambivalent participants. While all three groups judged the comprehensibility of a text summarising the position of the telecommunication industry in a similar way, differences existed between their judgements of the comprehensibility of a text summarising the position of mobile telephony opponents. Those with high concerns found that text easier to understand than those with low concerns. Ambivalent participants' judgment of comprehensibility was on average between the high and the low concern groups.

2. Information on Existence of the Risk (2 studies)

Summary

The two studies in this section show that if it is a communicator's aim to convince people that there are no health effects, this aim is not easily achievable. Especially participants with an already high risk perception seem to be a group that cannot easily be targeted. Motivated information processing seems to play a role in the uptake of information (Siegrist et al., 2008).

Recommendation

If risk managers conclude that the remaining uncertainties about RF EMF health effects are small enough to warrant the dissemination of an all-clear message, communicators will face a credibility problem. Especially those recipients with high existing risk perceptions are unlikely to be reassured by an all-clear message. We suggest that a thorough explanation of how the risk evaluation was achieved would be the best approach then. A recent research project has explored possible ways of presenting information on the risk assessment process (Högg & Dürrenberger, 2017). However, this suggestion is (a) not based on empirical evidence and (b) neglects the affective dimension of risk perception. More research is needed regarding the effects of different all-clear messages.

Siegrist et al. (2008) experimentally varied several factors of a text about mobile communication. One of the factors varied was that according to the text, a large study either did or did not find a health effect. There was a main effect of this factor on credibility of the results. A higher credibility was generally ascribed to the study that found a health effect.

Hartung et al. (2013) investigated the effects of an all-clear message including a risk comparison ('we know that even for people living close to mobile phone masts, the risk to get sick because of electro-smog is still lower than to be struck by lightning'). On average, self-perceived change of concern about base stations in response to the message was close to zero and not significant.

Influence of Recipient Variables

Siegrist et al. (2008) found an interaction between prior risk perception and the study outcome reported in their experimental text. Those who already had a high prior risk perception found the study that reported the existence of a risk more credible than the study that reported no risk. The same was true for participants with moderate prior risk perception. For participants with low prior risk perception the opposite picture emerged. They assigned higher credibility to the study that did not find a health effect.

In Hartung et al. (2013), perceived change of risk perception in response to the all-clear message was related to participants' pre-existing concerns. That is, people with low pre-existing concerns rather said the all-clear message diminished their risk perception while those with high pre-existing concerns said the all-clear message increased their risk perceptions.

3. Information About Uncertainty (3 studies)

Summary

Effects of information about scientific uncertainty have been studied in three experiments (Wiedemann & Schütz, 2005, studies 1 and 2, Wiedemann, Thalmann et al., 2006) and one survey study that assessed lay understanding of expressions of uncertainty (Wiedemann et al., 2014). The experimental findings do not indicate an important effect of information about uncertainty. However, all three studies manipulated uncertainty solely with one single sentence (which was, on top, the very same sentence in all studies). Uncertainties might affect recipients if communicated in different ways.

Wiedemann and Schütz (2005), study 1 manipulated uncertainty by either adding or not adding a sentence stressing scientific uncertainty to a statement about the safety of the existing exposure limits ('Some scientists argue that substantial uncertainties exist as to whether current protection from electrosmog is sufficient.'). They did not find an effect of this manipulation on risk perception.

Wiedemann and Schütz (2005), study 2 manipulated uncertainty in the same way as in study 1. The uncertainty factor did not affect any of the three dependent variables risk perception, appraisal of scientific knowledge and trust in public protection.

In Wiedemann, Thalmann et al. (2006), the same experimental variation was used, again. No effects were found on risk perception and on trust in public protection. There was, however, an effect on appraisal of scientific knowledge. Scientific knowledge was perceived to be higher if uncertainties were mentioned, which is a somewhat counterintuitive result.

The survey study (Wiedemann et al., 2014) showed that recipients' understanding of terms expressing uncertainty of potential adverse effects vary widely.

Influence of Recipient Variables

Not reported in the studies in this section.

4. Information Focussed on Different Health Effects (3 studies)

The discourse about potential RF EMF health risks often focusses on potential cancer risks. However, other endpoints haven been and still are discussed. Two experimental studies systematically varied the negative outcome focussed by the risk message (Siegrist et al., 2008; Thalmann & Wiedemann, 2006). It has been assumed that compared to information about relatively 'harmless' outcomes, information about 'severe' outcomes induces a higher degree of emotionality (Thalmann & Wiedemann, 2006). A study reporting on the effects of an emotionally charged newspaper article is also included in this paragraph (Cousin et al., 2011).

Summary

Recipients recognise the emotional character of risk information. However, in all three studies, risk perception was not affected by texts that manipulated the health outcome and were supposed to give rise to emotions. Because affective and emotional processes are known to be an important aspect of risk perception (see e.g. 'risks as feelings' perspective, Loewenstein et al., 2001 or the 'affect heuristic', Finucane et al., 2000), it seems unlikely that they do not contribute to RF EMF risk perception. Instead, it seems more likely that simply focussing on a different outcome does not influence affective or emotional responses.

Cousin et al. (2011) conducted an experimental study with three different groups. One group read 'an authentic, emotionally charged newspaper article about a base station siting conflict in a Swiss neighbourhood, which had appeared […] several years before the study was conducted,' while two other groups read either a neutral text unrelated to electromagnetic fields and mobile communication technology or an information booklet about mobile communication. The newspaper article was rated as less informative and as having a greater emotional touch than the other two texts. The 'newspaper group' had lower positive affect towards base stations than the 'EMF booklet group'. The 'newspaper group' did not differ from the other groups regarding positive affect towards mobile phones, risk perception, benefit perception, health concerns regarding base stations and health concerns regarding mobile phones.

Thalmann and Wiedemann manipulated the 'degree of terribleness of possible health effects' to induce emotionality in a 2x4 factors experimental study. The first factor pertained to two different outcomes (cancer vs. effect on $Ca2+$ flux) and had no main effect on risk perception.

A study with a similar experimental variation was conducted by Siegrist et al. (2008). The researchers used a 2x2x2 design in which they manipulated the existence of a risk (risk vs. no risk), the source of the EMF (mobile phone vs. base station) and the outcome (cancer vs. effect on well-being). Like Thalmann and Wiedemann (2006), they did not find a main effect of outcome manipulation.

Influence of Recipient Variables

While Thalmann and Wiedemann did not find a main effect of outcome manipulation, they report an interaction of this factor with prior concerns. Participants with prior concerns about potential health effects had higher risk perceptions in the high emotionality condition (health effect: cancer) than in the low emotionality condition (health effect: $Ca2+$ Flux). The opposite was true for participants with low prior concerns. This interaction, however, was also analysed but not found by Siegrist et al. (2008).

5. Information About Source of the Information (3 studies)

Summary

Three out of three studies did not find an effect of the variation of the source of information on risk/ safety perception. However, the source of information might exert a more complex influence on recipients.

Cousin and Siegrist (2011) divided their sample into four different experimental groups (of which two are relevant in the current section). The booklets received by two of these groups only differed on the first and last page, where either no information about the source was given, or the Swiss mobile communication providers were indicated as the source. There were no differences between these two groups regarding their health concerns about base stations and mobile phones, neither directly after reading the booklet, nor two weeks later. Cousin and Siegrist (2011) discuss that their experimental approach might have oversimplified real-life conditions.

Hartung et al. (2013) analysed the effects of an all-clear message regarding EMF health effects on self-perceived change in risk perception. The source of the message was either a university, a public health authority, an activist group or the mobile phone industry. The variation of the source did not have any effects on self-perceived change in risk perception.

Wiedemann et al. (2008) examined whether safety perception is influenced by the disclosure of a precautionary SAR value. In one of the experimental groups, the precautionary SAR value was introduced by the German Federal Office for Radiation Protection (BfS), in another group by consumer protection advocacy groups. The precautionary SAR (specific absorption rate) value used in the study is the so called 'Blue Angel', which is in use in Germany since 2002 and refers to aSAR of ≤ 0.6 W/kg. Safety perception did not differ for the different sources of the information.

Influence of Recipient Variables

Wiedemann et al. (2008) did not find an interaction between prior risk perception and information about the source of information.

6. Information About Individual Risk and Exposure Aspects (5)

Summary

Two out of two studies found information about individual risk and exposure to increase participants' knowledge about RF EMF exposure issues, which, however, is not a surprising result (Claassen et al., 2015; Cousin & Siegrist, 2011). Moreover, there is evidence exists for an increase in risk perception due to the provision of such information. This effect could be due to a better understanding of the contribution of the distance-exposure relationship and of the contribution of various EMF sources to personal exposure (Boehmert et al., 2016; Cousin & Siegrist, 2011; Nielsen et al., 2010). These studies specifically report higher risk perceptions for mobile phone EMFs. In contrast, risk perception of base station EMFs decreases in two studies (Cousin et al., 2011; Cousin & Siegrist, 2011) and is not reported in two other studies (Boehmert et al., 2016; Nielsen et al., 2010). One study did not find an effect on risk perception (Claassen et al., 2015). This might have been due to its low statistical power. However, the explanations of the distance-exposure relationship were combined with other technical information in all of these studies, which leaves some uncertainty with regard to what exactly caused the change in risk perception. Combining the findings on knowledge and risk perception, it seems plausible that participants gained new insights about RF EMFs and adjusted their risk perceptions accordingly.

Recommendation

Risk communicators should explain exposure patterns. It is our opinion that, regardless of the question whether detrimental health effects exist or not, it is better when risk perceptions reflect the actual exposure conditions.

Claassen et al. (2015) used a 2x2x2 experimental design, with each factor standing for the provision of information about a certain EMF related aspect. One of these texts provided technical information about (1) the distance-exposure relationship and (2) the relative contribution of mobile phones and base stations to overall exposure (related to the distance). There was a main effect of this factor on knowledge. Participants who had received the information about exposure patterns achieved better results in an exposure assessment task. There was no effect on risk perception.

The design of the study by Nielsen et al. (2010) has already been described in the section about comprehensibility (see above). The 'more technical text' focussed on the following aspects of individual risk and exposure: (1) distance-exposure relationship; (2) strength of emission from mobile phone depends on distance to receiving antenna (base station); (3) difference between ionising and non-ionising radiation, with the latter not yet proven to be a hazard for human health; (4) determinants of potential health effects: SAR value of the mobile phone, distance to source, duration of exposure, potentially higher susceptibility of children; (5) uncertainty whether 3G signal has a different effect on human health as 2G and GSM.

Compared with the brief summary that basically stated the safety of the current exposure limits, a significantly higher proportion of participants increased their risk perceptions about the use of mobile phones in response to the information about individual risk and exposure. There was no effect on the acceptance of the erection of a 3G mast. Change in risk perception about base stations were not reported, although they had been assessed.

Boehmert et al. (2016) studied the effect of explaining technically how precautionary measures, such as using a headset while talking on the phone, reduce personal exposure. They explained (1) the distance-exposure relationship and (2) the relative contribution of mobile phones and base stations to personal exposure. Compared to a group with the precautionary information only, the group receiving the additional technical information had increased risk perceptions of mobile phones. This, however, was only true if participants rated the risk under the condition that no precautions are taken.

Two further studies tested the effect of information booklets that contained, among other information, information about individual risk and exposure aspects (Cousin et al., 2011; Cousin & Siegrist, 2011).

A study by Cousin et al. (2011) compared the effects of an EMF information booklet to those of a text unrelated to EMF and an emotionally charged newspaper article. The authors found lower risk perceptions for base stations and for mobile phones in the EMF booklet group than in the 'unrelated text group', and more positive affect towards base stations than in the two other groups. Risk perception, benefit perception and positive affect towards mobile phones did not differ.

Another study (Cousin & Siegrist, 2011) also tested the effect of information booklets. In that study, however, all of the experimental conditions contained the same information on individual risk and exposure aspects. The overall sample had a higher risk perception of mobile phones and a lower risk perception of base stations at the follow-up two weeks later. It seems unlikely that this specific pattern emerged due to a 'mere exposure effect'. It rather seems that participants adjusted their risk perception in accordance with their new knowledge about the relative contribution of mobile phones and base stations provided in all the booklets. Cousin and Siegrist (2011) also found that reading the booklets improved participant's knowledge about technical aspects.

Influence of Recipient Variables

None of the studies reported analysed the interplay of technical information and recipient variables.

7. Information About Precautionary Measures (14 studies)

A total of fourteen studies contained analyses of the effects of precautionary information. Compared to other risk communication aspects, researchers have thus clearly focussed on this topic. One of the fourteen publications in this section is a multinational, experimental study that analysed nine different samples (Wiedemann et al., 2013). Because of the high number of studies dealing with the issue, a meta-analytical approach was chosen. In a first step, the studies' eligibility for the meta-analysis was checked.

Summary

The meta-analysis shows that precautionary recommendations increase risk perceptions of the general public. It has to be noted, though, that the effect size is small. In our view, it is hard to estimate the practical, societal implications of a certain effect size. The framing of the recommendations seems to be of minor importance. Results regarding the influence of recipient variables are somewhat inconclusive, more research is needed here.

Recommendation

Precautionary recommendations should not be disseminated with the intention to reassure the public. However, the recommendations are probably important means to reduce exposure for people really seeing themselves as being at risk. Ideally, communicators would reach these individuals without targeting the general public.

Meta-Analysis

Selection According to Methodological Criteria

Only experimental studies with at least one group that received precautionary recommendations and at least one control group without these recommendations are considered. Two studies were excluded because they were not experiments (Barnett et al., 2007; Timotijevic & Barnett, 2006) and two studies were excluded because they had no control groups without precautionary information (Barnett et al., 2008 and Chandran & Menon, 2004, study 2).

Selection According to our Definition of 'Precautionary Recommendation'

In order to define the term precautionary recommendation in this meta-analysis, we provide a differentiation between precaution and protection on the one hand and refer to speech act theory (Searle, 2012) on the other hand. Regarding the first point, we only consider communication to be about precaution if it was stated that there is 'no conclusive evidence' or that 'no scientific proof' exists or a similar statement clarifying that harmful effects of RF EMFs have not (yet) been proven. If recommendations are given without this piece of information, then we consider it a recommendation of protective measures and not as precaution. Secondly, the precautionary character of the information had to be stated explicitly and/or the speech act of the statement had to be a recommendation/advice (c.f. Searle, 2012). For example, the speech act of 'in order to minimise personal exposure, we strongly encourage people to use a headset while talking on the phone' is a recommendation while it is not a recommendation in 'in order to minimise personal exposure, a headset can be used while talking on the phone'. It is important to note that for our selection, the source of information (e.g. an activist group, a governmental agency etc.) and the addressee (e.g. the public, risk regulators etc.) of the recommendation is not relevant.

Of the identified studies, we excluded two studies (Kim et al., 2015; Niederdeppe et al., 2014; Nielsen et al., 2010) from the subsequent analyses, as they did not contain any information that health effects have not been proven. The studies not selected for the meta-analysis are summarised at the end of this section.

Choice of Comparison Groups

To minimise performance bias (i.e. bias due to other differences than the precautionary recommendation), we only compared groups where the precautionary recommendation was the sole difference between the two groups. For instance, in Cousin and Siegrist (2011), there was one group that read a booklet with precautionary recommendations, one group that read the same booklet with the only difference that it did not contain the recommendations and another group that also received the recommendations but that was additionally informed about the source of the information (the Swiss mobile communication providers). We only compared the first two groups to avoid any confounding.

This rationale led us to include more than one group comparison in studies with a complete factorial design (4 group comparisons in Claassen et al., 2015 and in Wiedemann et al., 2013, 2 group comparisons in Wiedemann & Schütz, 2005, study 1 and in Wiedemann & Schütz, 2005, study 2). Wiedemann et al. (2013) conducted the exact same experiment with eight different samples in eight different countries. We combined these samples for the meta-analysis.

Choice of Dependent Variables

All of the included studies used multiple dependent variables. Five studies assessed mobile phone risk perception (Boehmert et al., 2016; Boehmert, Wiedemann et al., 2017; Claassen et al., 2015; Cousin & Siegrist, 2011; Wiedemann et al., 2013), four studies base station risk perception (Boehmert, Wiedemann et al., 2017; Claassen et al., 2015; Cousin & Siegrist, 2011; Wiedemann et al., 2013), and four studies general EMF risk perception (Claassen et al., 2015, Wiedemann & Schütz, 2005, studies 1 and 2, and Wiedemann, Thalmann et al., 2006). All dependent variables were single item measurements. It is important to note that the wording of the items differed between studies. For instance, regarding general EMF risk perception, Wiedemann and Schütz (2005) speak of 'electrosmog' while Claassen et al. (2015) use the expression 'electromagnetic radiation', a difference that will be discussed in the light of the findings later on. As mentioned earlier, we termed variables as risk perception that were termed differently in the original study, for instance, some authors use the expression 'health concerns' (Cousin & Siegrist, 2011). The study by Wiedemann et al. (2008) was excluded from the meta-analysis because it did not assess risk perception as a dependent variable.

Data Analysis

In all studies, post-test values in groups with precautionary recommendations and groups without precautionary information were compared. For each comparison, Hedges' g, which is a sample size corrected version of the standardised mean difference (Hedges & Olkin, 1985), was calculated as a measure of effect size in a spreadsheet. Inverse variance weights were calculated in the same spreadsheet. Means, standard deviations and sample sizes of the respective groups were requested from study authors if they had not been reported in the articles. Mean effect size calculation and moderator analysis (method of moments approach) were conducted using SPSS 24 and David Wilson's meta-analysis macro for SPSS (the macro can be downloaded on http://mason.gmu.edu/~dwilsonb/ma.html). The random effects model coefficients are reported.

Results

The Forrest Plots for the meta-analyses are depicted in Figures D3, D4 and D5. Mean effect sizes were small but significant for mobile phone risk perception (Mean Hedges' g = .16, 95% CI (0.05, 0.26), Homogeneity parameter $Q_{df=10}$ = 22.35, p = .01) and for base station risk perception (Mean Hedges' g = .17, 95% CI (0.10, 0.24), Homogeneity parameter $Q_{df=9}$ = 7.76, p = .56) and small but not significant for general EMF risk perception (Mean Hedges' g = .15, 95% CI (-0.04, 0.34), Homogeneity parameter $Q_{df=9}$ = 16.97, p = .049). Effect sizes were heterogenous for mobile phone risk perception and EMF risk perception in general. We analysed 'research group' as a moderating factor for mobile phone risk perception and general EMF risk perception (due to significant deviation from homogeneity). Three research groups conducted the studies that were part of the meta-analysis. A Dutch group around Michelle Timmermans, a Swiss group around Michael Siegrist and a German group around Peter Wiedemann. For mobile phone risk perception, the variance component that could be attributed to differences between the research groups was not significant (Q = 2, p = .37). For general EMF risk perception, the variance component that could be attributed to differences between the studies was significant (Q

= 9.74, p = .002). As can be seen in Figure D5, the effect of precautionary recommendations was higher in the studies conducted in the Wiedemann group than in the studies conducted by the Timmermans group. This can in turn be due to various factors which cannot be untangled: a) differences in the wordings of the assessed variables (risk perception of ‘electrosmog’ vs. ‘EMFs in general’), b) year of publication (2005 and 2006 vs. 2015), c) differences in the recommendations. The first two factors might lead to higher or lower risk perception. However, we do not see a straightforward explanation of why they should interact with the effect of a precautionary recommendation. Hence, in our eyes, it is most likely the different formulation of the recommendations (i.e. the experimental material itself) that causes the differences. A possible reason is that in the study conducted by the Timmermans group, the experimental material was not exclusively focussed on precaution and also not exclusively on RF EMFs (fields from high-voltage power lines were also mentioned in the text).

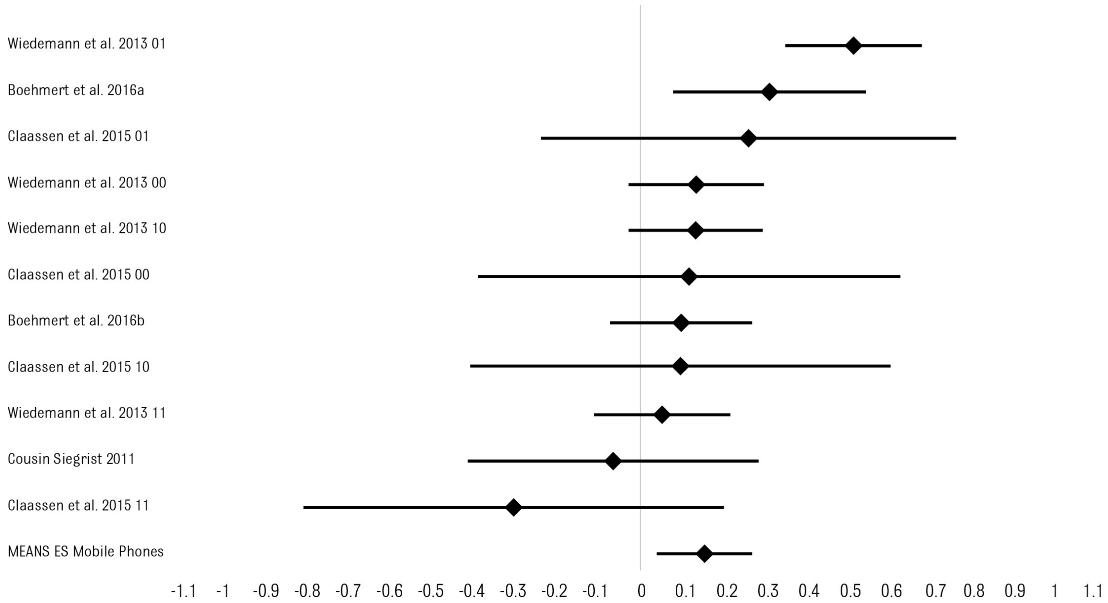

Figure D3. Effect sizes d' of precautionary recommendations on mobile phone risk perception. Note. Explanation of suffices. Claassen et al. 2015 first number: 1 = exposure-distance information included (0 = not included). Second number: 1 = exposure management options included (0 = not included). Wiedemann et al. 2013 first number: 1 = risk framing, 0 = safety framing. Second number: 1 = base station text first, 0 = mobile phone text first.

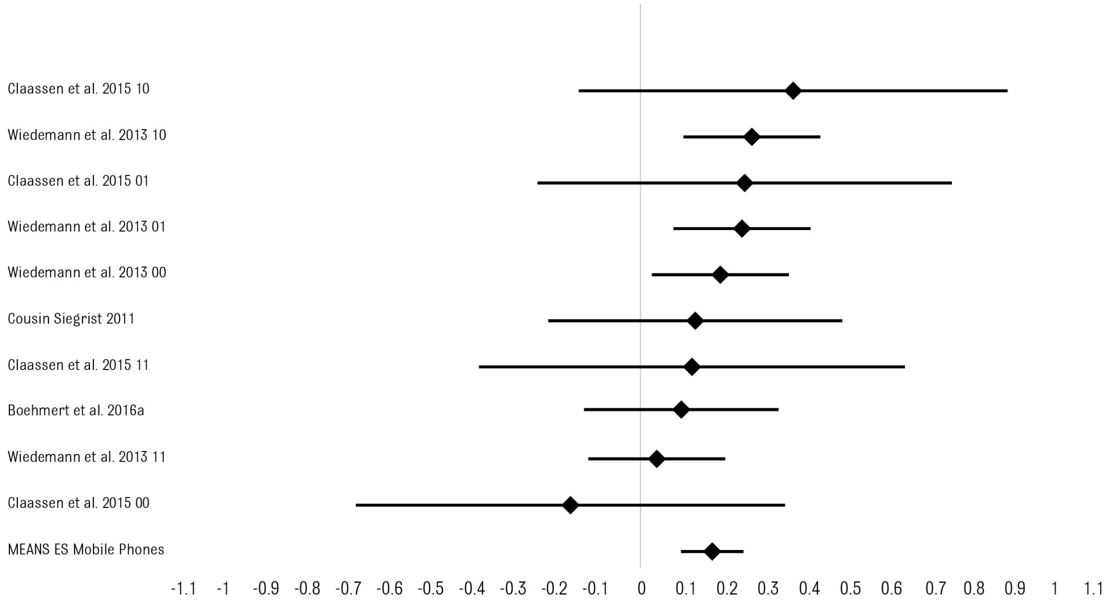

Figure D4. Effect sizes d' of precautionary recommendations on base station risk perception. Note. Explanation of suffices. Claassen et al. 2015 first number: 1 = exposure-distance information included (0 = not included). Second number: 1 = exposure management options included (0 = not included). Wiedemann et al. 2013 first number: 1 = risk framing, 0 = safety framing. Second number: 1 = base station text first, 0 = mobile phone text first.

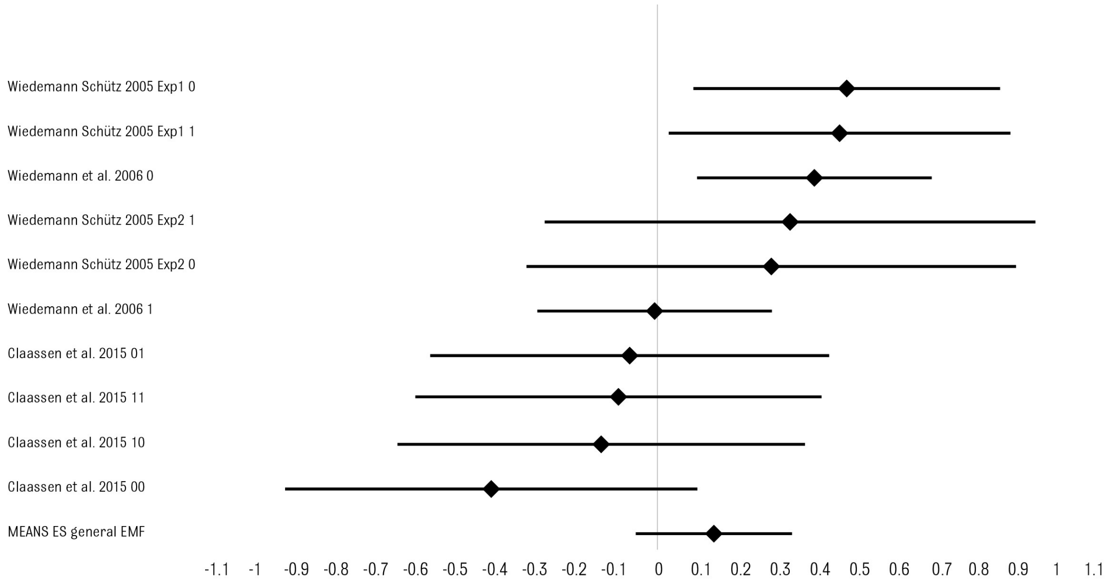

Figure D5. Effect sizes d' of precautionary recommendations on general EMF risk perception. Note. Explanation of suffices. Claassen et al. 2015 first number: 1 = exposure-distance information included (0 = not included). Second number: 1 = exposure management options included (0 = not included). Wiedemann & Schütz 2005, studies 1 and 2: 1 = uncertainty information included, 0 = uncertainty information not included).

An analysis of the funnel plots for all three dependent variables showed some variation between the effect sizes of studies with smaller standard errors. There was no sign of the typical pattern of publication bias (i.e. large effect sizes of studies with large standard error, no effect among studies with small standard error; c.f. Hartung & Knapp, 2008, pp. 171–174)

Other Dependent Variables

Some of the studies in the meta-analysis also reported results for other dependent variables. Cousin and Siegrist (2011) report that after receiving precautionary information, more participants tended to change their mobile phone usage towards more precaution within the next two weeks than after the reception of a booklet without precautionary recommendations (54% vs. 35%).

Three of the studies analysed the effects on trust in public health protection. Two of these studies found a detrimental effect on trust (Boehmert, Wiedemann et al., 2017; Wiedemann & Schütz, 2005), while one did not find an effect (Wiedemann, Thalmann et al., 2006).

Effect of Precautionary/Protective Information vs. no information: Studies not Included in the Meta-Analysis

Barnett et al. (2007) conducted a survey among the British general population. The survey 'explored public responses to a leaflet issued by the Department of Health (DoH) in 2000' that contained precautionary recommendations regarding the use of mobile phones. Data were assessed by means of face-to-face interviews in November 2004. Recognition rate of the recommendations in the leaflets were below one third. On a measure of self-perceived change, the percentage of participants saying the precautionary recommendations by the DoH increased their risk perceptions was higher (between 40% and 50% for each precautionary measure) than the percentage saying it decreased their risk perception (between 20% and 30% for each precautionary measure). However, inferential statistics regarding this difference were not provided.

In an experiment with 15 groups, 8 groups received information about '[a]nother study [linking] cell phone use to an increased risk of cancer' (Niederdeppe et al., 2014). The other 7 groups only received information about another hazard or were control groups). Of these eight groups, four received additional exposure reduction information (by use of a hands-free headset). In a multiple regression analysis, this information did neither have an effect on cancer prevention fatalism (i.e. the belief that nothing can be done to prevent cancer), nor on cancer information overload (i.e. feeling of being overwhelmed by the volume of cancer information). For the same dataset, an effect of exposure reduction information on self-efficacy regarding the precautionary behaviour was reported (Kim et al., 2015).

Nielsen et al. (2010) assigned their participants to one of three groups: One received short facts about RF EMFs used in mobile communication, a second one received extensive technical information and a third group received information about how to reduce personal exposure to RF EMFs from mobile phones. The information about options of personal exposure reduction was evaluated more positively than the other two information types in terms of trustworthiness and usefulness. Compared to the group that received the short facts, a higher percentage of participants in the exposure reduction condition had increased risk perceptions about mobile phone use after reading the message and showed less acceptance for the placement of a base station in the vicinity of their homes. Behavioural intentions regarding the application of precautionary measures did not differ between the groups.

Wiedemann et al. (2008) investigated the effects of information about a precautionary SAR value (‘Blue Angel’, introduced in Germany in 2002 for mobile phones with a SAR < 0.6, see also section ‘Information about the source of information’). Safety perception of four different SAR values (0.16 W/kg, 0.59W/kg, 1,14 W/kg, and 1.63 W/kg) served as the dependent variable. The authors did not find differences between participants that either received only basic information about the SAR value or received additional information about the ‘Blue Angel’).

Framing Precautionary Recommendations

In an experiment by Barnett et al. (2008), all groups received precautionary information regarding mobile telephony. The framing of the precautionary information was varied in a 2x2 design, with the first factor pertaining to additional benefit information (risks vs. risks and benefits) and the second factor pertaining to the reason for providing the information (scientific uncertainties vs. public concern). No effects of the experimental variation were found. However, assuming an effect size of $f = .05$ which would be in line with other effect sizes reported in this area, the study was underpowered with a statistical power of $1\text{-}\beta = .10$ for a main effect in a 2x2 ANOVA.

Chandran and Menon (2004) conducted an experiment with 64 students. All participants read a text that stressed the risk of cancer due to mobile phone use. In a 2x2 experimental design, the temporal framing of this text (day vs. year) was varied, as well as the type of precautionary measures described afterwards (easy to implement (e.g. use of hands-free device) vs. hard to implement (e.g. using phones as little as possible in a car)). Risk perception was greater in response to the day framing, but the type of precautions mentioned had no effect on risk perception.

There was an interactional effect of temporal framing and type of precaution on behavioural intentions to inform oneself about the risk. While in the day frame the type of precautions did not make a difference, in the year frame participants who had read the easy to implement precautions indicated higher intentions to inform themselves about the risk.

Boehmert et al. (2016) tested if explaining that precautionary recommendations are disseminated ‘for those people who may be concerned (regardless of the science), as a means of assisting them to reduce their exposure’ had an effect on recipients’ risk perception. There was no difference of that group to a group receiving the recommendations without a reason for their dissemination.

Influence of Recipient Variables

Timotijevic and Barnett (2006) conducted a study with 9 focus groups. In an initial discussion, a very low awareness of the British government’s precautionary approach became apparent throughout all focus groups. Subsequently, the researchers introduced the governmental approach to the groups. The authors speak of a ‘complex picture’ of their results and report that already concerned participants tended to have concerns about the precautions, whereas ‘[f]or those people less attentive to possible health risks […] precaution did seem to provide some reassurance.’

Experimental results somewhat contradict this assessment (Boehmert, Wiedemann et al., 2017). The authors analysed the interaction between three personality variables and the reception of a precautionary message vs. a message stating the safety of the current exposure limits. Risk perception, trust in public protection and perceived scientific knowledge of EMFs served as the dependent variables. They found no interaction between personal need for structure as well as personal fear of invalidity with message reception. Trait anxiety, the third personality trait, interacted with message type and gender (three-way-interaction): The precautionary message mainly led to an increased threat perception and to less trust in public protection in women low in trait anxiety.

Wiedemann et al. (2008) did not find differences in safety perceptions in reaction to information about a precautionary SAR value between people with low prior risk perception, high prior risk perception and unsure people.

8. Effects of Television Reports and Audio-Visual Advertisements (4 studies)

While all other studies used textual communication material, the four studies in this section used video clips as experimental material (Bräscher et al., 2017; Köteles et al., 2016; Witthöft et al., 2017; Witthöft & Rubin, 2013). The video clips were all original material that had been broadcasted on TV or on the internet. The clips strongly suggested health effects of RF EMFs. In all four studies the effects of these clips were contrasted with the effects of some sort of control video.

Summary

Three out of four studies found increased risk perception regarding EMFs in response to short video clips suggesting a health effect (Bräscher et al., 2017; Köteles et al., 2016; Witthöft et al., 2017). In the fourth study (Witthöft & Rubin, 2013), no main effect was found, but an interaction between the experimental condition and state anxiety. It can thus reasonably be assumed that video clips that (strongly) suggest health effects of EMFs elevate peoples' risk perceptions, a finding that does not surprise much, however. There is mixed evidence for the moderating influence of personality variables. Whether the changes in risk perception are persistent, has not yet been investigated. The findings on symptom perception and the intensity of tactile perceptions have been discussed as indicators of the potential role of media reports in the development of idiopathic environmental intolerance. Although this is plausible, more research is needed to provide further evidence regarding this hypothesis.

Recommendation

Media coverage about potential health effects of RF EMFs should be more balanced, because it has effects on recipients' risk perceptions. Some of the experimental material in this section was taken from publicly financed TV broadcasters. Especially for these, it should be an obligation to draw an adequate picture of potential RF EMF health risks.

In a study by Witthöft and Rubin (2013), participants were exposed to a sham EMF after watching the TV report. The TV report neither had a main effect on symptom perception under sham exposure nor on risk perception.

Bräscher et al. (2017) investigated the effect of a TV report suggesting a health effect on the intensity perception of tactile stimuli under sham exposure. A main effect of the report condition existed: The experimental video increased participants' perceived intensity of tactile stimuli under sham Wi-Fi exposure. Moreover, participants reported higher risk perceptions after watching the experimental video, compared to participants watching the control video.

Similarly, in Witthöft et al. (2017), study 2, an increase on two different EMF health worry scales was demonstrated in response to a video clip suggesting EMF health effects (entitled 'When the phone makes you ill'), compared to a control video.

Köteles et al. (2016) compared respondents' reactions to (a) a video clip from a company offering radiation protection equipment that strongly suggested a health effect of EMFs and (b) a nature documentary. Both heart rate and risk perception were elevated in participants that had just watched the EMF clip, compared to those that had just watched the nature documentary. The findings, especially regarding the heart rate, should be interpreted with care. The data of that study show that the difference in change in heart rate can be attributed in part to a decrease in the heart rate after watching the nature documentary (and not only an increase in heart rate after watching the EMF video).

Influence of Recipient Variables

Witthöft and Rubin (2013) report an interaction between the experimental condition and state anxiety after watching the TV report, i.e. participants who reported higher state anxiety after the experimental report subsequently reported more symptoms under sham exposure and had a higher risk perception. Also, perceived symptoms under sham exposure to an RF EMF were more present in people with high prior risk perception as well.

In Bräscher et al. (2017), the strength of the effect of the TV report on tactile perception was moderated by somatosensory amplification (a personality trait characterised by increased body awareness, interpretations of sensations as pathological and reactions of fear to these sensations). The experimental report had a greater effect on tactile perception in participants with higher levels of somatosensory amplification.

Witthöft et al. (2017), study 2, and Köteles et al. (2016) did not find any significant interactions between the type of video and several personality variables.

9. Miscellaneous (2 studies)

In a focus group study by Collins (2010), 37 participants, divided into six groups, read critical articles about the placement of base stations near schools and discussed the topic within the groups. The study focussed on the discursive roles of (a) 'non-mediated knowledge' and (b) risk comparisons. Several sources of information were referenced by the participants, e.g. general practitioners, family, friends or acquaintances. Participants compared the possible risks of base stations to a multitude of other risks (e.g. microwaves, mobile phones, road safety, smoking, food allergies). According to the author, these two strategies are 'not, however, employed uncritically or in order to entirely replace 'scientific rationality', but rather as part of a negotiation of understandings within what is perceived as a situation of uncertainty.'

Wiedemann and Schütz (2008) analysed the impact of various information and participation strategies for the base station siting process. Two factors were varied experimentally, with the first varying the level of public information and the second the level of participation. The three information strategies tested were (1) no information of citizens and coordination with the local authorities, (2) coordination with the local authority representatives and information about the proposed action on the local authority's Internet webpages, and (3) coordination with the local authority representatives, webpage information and a public information meeting with right to public input (3). The three participation strategies tested were (1) coordination with the local authority representatives, (2) consensus-finding at a round table and (3) binding poll of the residents of the house where the antenna is to be installed. After the subjects had read their text module, they had to evaluate the described information and participation strategies with regard to the following depended variables: (1) transparency of the approach, (2) consideration of concerns of the local residents, (3) applicability of the strategies for conflict avoidance, (4) trust in health protection, (5) applicability for the reduction of conflicts and (6) acceptance of the siting decision. The three information strategies did not have different effects on any of the dependent variables. More participation led to higher ratings of transparency, 'consideration of concerns' and 'resolution of existing conflicts.' The round table participation format was evaluated best on these variables, whereas the binding poll and coordination with the local authority were not evaluated differently. Interestingly, the level of prior concerns did not influence these results.

Discussion

This paper systematically reviewed research on communication about potential risks from radiofrequency electromagnetic fields (RF EMFs). 27 Studies were classified in nine different categories according to their content.

We will first summarise the main research topics that have been covered. Subsequently, the the main practical recommendations given in the sections above will be discussed from a theoretical as well as a practical perspective. Then, we will discuss the relevance of recipient variables, especially that of prior risk perception on a theoretical base. The limitations of this review will be outlined afterwards, followed by brief suggestions for future research endeavours.

Research about the communication of precautionary recommendations was by far the most researched aspect. In contrast, communication about exposure limits has been poorly investigated thus far. There are only two studies (Nielsen et al., 2010; Wiedemann et al., 2008) on communication regarding SAR-values, and only one study (Nielsen) on exposure limits related to base stations (Nielsen et al., 2010). Other studies only speak of exposure limits in a general way which is non-specific with respect to the source of the EMF. There are five studies dealing with risk assessment issues (Boehmert et al., 2016; Claassen et al., 2015; Cousin et al., 2011; Cousin & Siegrist, 2011; Nielsen et al., 2010), such as distance to the base stations as a proxy for exposure strength, comparisons of the strength of various RF EMF exposure sources, and the difference between ionizing and non-ionizing radiation. Three studies cover uncertainty regarding the sufficiency of the existing exposure limits. All other studies referred to generic topics of risk communication such as text comprehensibility, the effect of the communication of different health outcomes, and interpretation of qualitative uncertainty expressions.

A meta-analysis showed that precautionary recommendations increase risk perceptions. Different reasons for communicating precautions exist, but reassurance of the general public should not be among them, as the opposite is actually achieved. One might try to make a case for providing recommendations in order to reassure – if not the general public – at least those who are already concerned, by making them feel safer if they follow the recommendations. We did not find any quantitative study investigating this effect specifically for already concerned individuals. However, a qualitative study yielded first evidence that also for this group, precautionary recommendations are not reassuring (Timotijevic & Barnett, 2006).

We also recommend that information about exposure patterns should be communicated. Mental model studies (Claassen et al., 2015; Cousin & Siegrist, 2010b) have shown that people typically underestimate their exposure from near-field sources (especially from the mobile phone) and overestimate the exposure from far-field sources (e.g. mobile phone base stations). Apparently, a correction of this evaluation also leads to a shift in risk perceptions, away from base stations and towards mobile phones – a pattern that is actually more in line with the actual share of exposure from both sources for most people (Bolte & Eikelboom, 2012; Neubauer et al., 2007).

Several other message properties have been investigated. Neither information about the source of the information, nor about uncertainty, nor messages that state that there are no risks have any effect on the mean level of risk perception. Focussing messages on different potential health effects that vary in the degree of severity did not have a main effect on risk perception, either. These variables do not exert a direct influence on risk perception, still they might be of some importance. It could be that their interplay with other variables, be it characteristics of the communication product or of the recipient, is too complex to result in main effects.

The differentiation of the concepts hazard and risk has not been part of any of the communication material used in the studies. In our opinion, investigating this could be a useful step to foster understanding. In terms of comprehensibility, the most important issue is, in our opinion, the development of a risk communication format that clarifies what the International Agency for Research on Cancer's assessment 'possibly carcinogenic to humans' means.

A considerable portion of the studies analysed how risk messages affected different 'target groups'. There were two ways this was done. Most studies divided their samples into subgroups of participants with low, medium (sometimes also ambivalent) and high prior risk perception. Other studies looked at interactions of risk communication and continuous recipient variables in multiple regression analyses. Regarding the role of prior risk perception, a strong, uniform picture emerged: People process and interpret risk communication in ways that are congruent with their existing view. This is particularly the case with people with high prior risk perception (see Table D1). We see this as a case of motivated information processing (Kruglanski, 1996) or what has been called more specifically 'motivated science perception' (Rothmund, Gollwitzer, Nauroth, & Bender, 2017). Possibilities for future research in this area are suggested at the end of this paper.

Table D1. The influence of prior risk perception on the reception process of risk messages.

Information processing aspect	Differential effect in people with high risk perception (compared to people with low risk perception)	Studies reporting on this
Perceived credibility/ trustworthiness	- Information that risk exists is more credible - Information from activist groups is more trustworthy	Siegrist et al., 2008, Ruddat et al., 2010
Interpretation of verbal descriptions of uncertainty	- 'Possibly carcinogenic' is assigned a higher likelihood in numbers	Wiedemann et al., 2014
Perceived persuasiveness of arguments	- Information from activist groups is more persuasive	Ruddat et al., 2010
Effect on perception of risk	- Different types of information increase risk perception	Hartung et al., 2013, Timotijevic & Barnett, 2006, Thalmann & Wiedemann, 2006

The influence of the recipient's personality on the reception of RF EMF risk communication has also been looked at. The majority of studies investigating this used video clips that strongly suggested a health effect as experimental material. Regarding the influence of personality traits, a mixed picture emerged, with one study finding a moderating influence of somatosensory amplification, whereas two other studies did not find interactions between different video clips and various personality traits. However, it is important to note that personality variables such as somatosensory amplification or trait anxiety exert an important influence on RF EMF risk perception in the form of main effects. However, if they also lead to a different uptake of risk communication (interaction effect) is currently uncertain due to the mixed results.

Limitations

Firstly, the recommendations derived in this literature review are our best conclusions drawn from the existing body of research. Still, they should not be treated as 'strict rules' and risk communicators will probably face occasions and situations where it might be best to deviate from them. Secondly, and related to the first point, it has to be remembered that situational factors are crucial in risk communication. For instance, reading a text at home when participating in an online study is one thing, receiving the same information in a public panel discussion is another. Only carefully planned field studies could overcome this problem, but usually these are associated with lower internal validity, and generalisability can also be an issue. Thirdly, 44% of the studies were conducted with student samples and the validity of the results of these studies for the general population might be limited. However, 41% of the studies used samples drawn from the general population, hence, this limitation is probably not as grave as in other research fields (c.f. Henrich, Heine, & Norenzayan, 2010 plus commentaries for a discussion about this issue).

Perspectives for Future Research and Communication Practice

Only four studies have focussed on comprehensibility of RF EMF risk communication so far. In our eyes, there is clearly a need for more research here, because recipients' understanding of risk information is a prerequisite of whatever effect a communicator might want to achieve. Regarding physics related aspects (e.g. exposure), research on the comprehensibility of physics education (e.g. school books) might provide some insights useful for designing risk communication materials.

Reviewing the relevant research, we also came to the conclusion that there is room for improvement regarding the collaboration between risk communication researchers and the EMF research community. The core messages tested in the social science studies should always aim to correctly reflect risk and exposure assessments[15]. Unfortunately, there are problems in this respect. To give only one example: Measurement campaigns (Bornkessel, Schubert, Wuschek, & Schmidt, 2007) indicate that the mere distance to mobile phone base stations is not a reliable proxy for the strength of RF EMF exposure. Still, among risk communication researchers, it seems to be a common assumption that the distance-exposure relationship for the far-field follows the same rules as for the near-field.

In terms of the communication format, researchers have almost exclusively investigated the effects of textual risk communication. Future research could usefully direct the focus more towards audiovisual media. Moreover, no field research regarding the evaluation of e.g. public panel discussions has been published, yet. Such an approach could also be useful with regard to the introduction of other EMF sources like high-voltage power transmission lines.

Psychological research has identified methods to overcome misinformation and motivated information processing (see Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012 for an overview). In line with Steele's self-affirmation theory (Steele, 1988), motivated information processing occurs when conflicting information poses a threat and people defend their own standpoints. One method of making people more receptive to conflicting information is by affirming their self (Cohen et al., 2007; Cohen, Aronson, & Steele, 2000). At this point, we would like to stress that we do not propose to persuade people that risks related RF EMFs in mobile communication do not exist. Rather, we think that people should come to an informed decision regarding the risk on their own, but that this decision should be made under consideration of valid information. Planning and evaluating communication that incorporates self-affirmation would be a challenging but useful next step in RF EMF risk communication research.

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[15] We refer to research that aims to provide evidence for best practice communication e.g. by health authorities. Of course, research can and should also test the effects of obviously distorted risk messages, as for instance the studies about effects of video clips which are reviewed in this paper do.

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Wiedemann, P. M., Schütz, H., Boerner, F., Clauberg, M., Croft, R., Shukla, R.,. . . Barnett, J. (2013). When precaution creates misunderstandings: the unintended effects of precautionary information on perceived risks, the EMF case. *Risk Analysis*, *33*(10), 1788–1801. https://doi.org/10.1111/risa.12034

Wiedemann, P. M., Thalmann, A., Grutsch, M., & Schütz, H. (2006). The Impacts of Precautionary Measures and the Disclosure of Scientific Uncertainty on EMF Risk Perception and Trust. *Journal of Risk Research*, *9*(4), 361–372. https://doi.org/10.1080/13669870600802111

Witthöft, M., Freitag, I., Nußbaum, C., Bräscher, A.-K., Jasper, F., Bailer, J., & Rubin, G. J. (2017). On the origin of worries about modern health hazards: Experimental evidence for a conjoint influence of media reports and personality traits. *Psychology & Health*, 1–20. https://doi.org/10.1080/08870446.2017.1357814

Witthöft, M., & Rubin, G. J. (2013). Are media warnings about the adverse health effects of modern life self-fulfilling? An experimental study on idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF). *Journal of Psychosomatic Research*, *74*(3), 206–212. https://doi.org/10.1016/j.jpsychores.2012.12.002

Appendix E: Supplementary Material to Review Article

Appendix E1: Abstract Screening

Article Number	**Authors**	**Title**	**Peer-Reviewed Journal /Article?**	**Provides Empirical Data?**	**Full-text Available?**	**Screening Result**	**Remarks**
			0 = no, 1= yes, 2 = unclear			0 = ineligibile, 1 = proceed to full-text screening	
1	Barnett, Timotijevic, Shepherd & Senior, 2007	Public responses to precautionary information from the Department of Health (UK) about possible health risks from mobile phones	1	1	1	1	
2	Barnett, Timotijevic, Vassallo & Shepherd, 2008	Precautionary advice about mobile phones: Public understandings and intended responses	1	1	1	1	
3	Bedini, Giliberti & Salerno, 2008	Information and communication on the electromagnetic fields: Analysis of the Italian Internet sites	2	1	1	0	Discard because in Italian
4	Boehmert, Wiedemann, Pye & Croft, 2016	The Effects of Precautionary Messages about Electromagnetic Fields from Mobile Phones and Base Stations Revisited: The Role of Recipient Characteristics	1	1	1	1	

Article Number	Authors	Title	Peer-Reviewed Journal /Article?	Provides Empirical Data?	Full-text Available?	Screening Result	Remarks
			0 = no, 1= yes, 2 = unclear			0 = ineligibile, 1 = proceed to full-text screening	
5	Boehmert, Wiedemann & Croft, 2016	Improving Precautionary Communication in the EMF Field? Effects of Making Messages Consistent and Explaining the Effectiveness of Precautions	1	1	1	1	
6	Bräscher, Raymaekers, van den Bergh & Witthöft, 2017	Are media reports able to cause somatic symptoms attributed to WiFi radiation? An experimental test of the negative expectation hypothesis	1	1	1	1	
7	Chandran & Menon, 2004	When a Day Means More than a Year - Effects of Temporal Framing on Judgments of Health Risk	1	1	1	1	
8	Claassen, Bostrom & Timmermans, 2016	Focal points for improving communications about electromagnetic fields and health: a mental models approach	1	1	1	1	
9	Claassen, Smid, Woudenberg & Timmermans, 2012	Media coverage on electromagnetic fields and health: Content analysis of Dutch newspaper articles and websites	1	1	1	1	

Article Number	Authors	Title	Peer-Reviewed Journal /Article?	Provides Empirical Data?	Full-text Available?	Screening Result	Remarks
			0 = no, 1= yes, 2 = unclear			0 = ineligibile, 1 = proceed to full-text screening	
10	Claassen, van Dongen & Timmermans, 2015	Improving lay understanding of exposure to electromagnetic fields; the effect of information on perception of and responses to risk	1	1	1	1	
11	Collins, 2010	Mobile phone masts, social rationalities and risk: Negotiating lay perspectives on technological hazards	1	1	1	1	
12	Cousin, Dohle & Siegrist, 2011	The impact of specific information provision on base station siting preferences	1	1	1	1	
13	Cousin & Siegrist, 2010a	The public's knowledge of mobile communication and its influence on base station siting preferences	1	1	1	1	
14	Cousin & Siegrist, 2010b	Risk perception of mobile communication: A mental models approach	1	1	1	1	
15	Cousin & Siegrist, 2011	Cell phones and health concerns: impact of knowledge and voluntary precautionary recommendations	1	1	1	1	
16	Farag, Cheng & Penn, 1999	Development of an electromagnetic fields risk communication plan	1	2	1	1	

Article Number	Authors	Title	Peer-Reviewed Journal /Article?	Provides Empirical Data?	Full-text Available?	Screening Result	Remarks
			0 = no, 1= yes, 2 = unclear			0 = ineligibile, 1 = proceed to full-text screening	
17	Foster, 2002	The Precautionary Principle – Common Sense or Environmental Extremism?	1	2	1	1	
18	Frick, Rehm & Eichhammer, 2002	Risk perception, somatization, and self report of complaints related to electromagnetic fields - A randomized survey study	1	1	1	1	
19	Hom, Plaza & Palmén, 2011	The framing of risk and implications for policy and governance: the case of EMF	1	2	1	1	
20	Hartung, Schulz & Keller, 2014	A Boomerang Effect of an All-Clear Message on Radiation Risk	1	1	1	1	
21	Huiberts, Hjørnevik, Mykletun & Skogen, 2013	Electromagnetic hypersensitivity (EHS) in the media - a qualitative content analysis of Norwegian newspapers	1	1	1	1	
22	Ikeda, 2014	Interdisciplinary Framework of Risk Communication as an Integral Part of Environmental Risk Analysis in Postindustrial Risk Society : Three Case Studies of the 1999 Amendment of Air Pollution Control Law, Dioxins, and the EMF Risks	1	1	1	1	

Article Number	Authors	Title	Peer-Reviewed Journal /Article?	Provides Empirical Data?	Full-text Available?	Screening Result	Remarks
			0 = no, 1= yes, 2 = unclear			0 = ineligibile, 1 = proceed to full-text screening	
23	Kim, Kim & Niederdeppe, 2015	Scientific uncertainty as a moderator of the relationship between descriptive norm and intentions to engage in cancer risk-reducing behaviors	1	1	1	1	
24	Köteles, Tarjan & Berkes, 2016	Artificial concerns. Effects of a commercial advertisement on modern health worries and sympathetic activation	1	1	1	1	
25	McMahan & Meyer, 1997	Reducing exposure to electromagnetic fields: the effects of low- and high-threat risk messages on behavior change	1	1	1	1	
26	McMahan, Witte & Meyer, 1998	The Perception of Risk Messages Regarding Electromagnetic Fields: Extending the Extended Parallel Process Model to an Unknown Risk	1	1	1	1	Same study (both n = 251) as McMahan & Meyer 1997
27	Nielsen, Elstein, Gyrd-Hansen, Kildemoes, Kristiansen & Støvring, 2010	Effects of alternative styles of risk information on EMF risk perception	1	1	1	1	
28	Pölzl, 2009	German mobile telecommunication research programme - Findings on risk communication	1	2	0	1	Author contacted via email on 2017-11-08; full-text received 4 days later

Article Number	Authors	Title	Peer-Reviewed Journal /Article?	Provides Empirical Data?	Full-text Available?	Screening Result	Remarks
			0 = no, 1= yes, 2 = unclear			0 = ineligibile, 1 = proceed to full-text screening	
29	Pölzl, 2011 a	Mobile telecommunication: Current knowledge on risk perception and risk communication: Results gained within the German Mobile Telecommunication Research Programme	0	2	0	0	
30	Pölzl, 2011 b	EMF recommendations specific for children?	1	2	0	1	Author contacted via email on 2017-11-08; full-text received 4 days later
31	Ruddat, Sautter & Renn, 2007	Abschlussbericht zum Forschungsprojekt "Operationalisierung des Leitbildes 'Risikomündigkeit' unter Berücksichtigung von Lebensstil und Wertorientierung als Grundlage für die Risikokommunikation im Strahlenschutz"	0	1	1	0	
32	Ruddat, Sautter, Renn, Pfenning & Ulmer, 2010	Communication about a communication technology	1	1	1	1	
33	Salvatore, 1993	Information Sought on Human Health Effects of Nonionizing Electromagnetic Radiation	2	2	0	0	Author contacted via researchgate on 2017-11-08; author replied that "paper will not be of any use for review"

Article Number	Authors	Title	Peer-Reviewed Journal /Article?	Provides Empirical Data?	Full-text Available?	Screening Result	Remarks
			0 = no, 1= yes, 2 = unclear			0 = ineligibile, 1 = proceed to full-text screening	
34	Schweikardt, Rosentreter & Gross, 2012	Discourse and policy making on consumer protection in the areas of mobile telecommunication and tanning	1	2	1	1	
35	Siegrist, Cousin & Frei, 2008	Biased Confidence in Risk Assessment Studies	1	1	1	1	
36	Thalmann & Wiedemann, 2006	Beliefs and emotionality in risk appraisals	1	1	1	1	
37	Timotijevic & Barnett, 2006	Managing the possible health risks of mobile telecommunications	1	1	1	1	
38	Valberg, 1992	A Public-Health Framework for Addressing a Layperson's Perception of EMF Health Risks	0	2	0	0	
39	van Deventer & Foster, 2008	Risk Assessment and Risk Communication for Electromagnetic Fields: A World Health Organization Perspective	0	2	0	0	
40	van Dijk, van Rongen, Eggermont, Lebret, Bijker & Timmermans, 2011	The role of scientific advisory bodies in precaution-based risk governance illustrated with the issue of uncertain health effects of electromagnetic fields	1	2	1	1	

Article Number	Authors	Title	Peer-Reviewed Journal /Article?	Provides Empirical Data?	Full-text Available?	Screening Result	Remarks
			0 = no, 1= yes, 2 = unclear			0 = ineligibile, 1 = proceed to full-text screening	
41	WHO, 2002	Establishing a Dialogue on Risks from Electromagnetic Fields	0	0	1	0	
42	WHO Office Europe, 2013	Health and environment: communicating the risks	0	0	1	0	
43	Weinhold, 2005	A precautionary tale: Mental health and risk communication	0	0	1	0	Is the editorial to Wiedemann & Schütz 2005
44	Wiedemann, Börner & Repacholi, 2014	Do people understand IARC's 2B categorization of RF fields from cell phones?	1	1	1	1	
45	Wiedemann & Schütz, 1999	Risk communication for environmental health hazards	1	2	1	1	
46	Wiedemann & Schütz, 2005	The precautionary principle and risk perception: experimental studies in the EMF area	1	1	1	1	
47	Wiedemann & Schütz, 2008	Informing the public about information and participation strategies in the siting of mobile communication base stations	1	1	1	1	

Article Num-ber	Authors	Title	Peer-Re-viewed Journal /Article?	Provi-des Em-pirical Data?	Full-text Available?	Screening Result	Remarks
			0 = no, 1= yes, 2 = unclear			0 = ineligi-bile, 1 = pro-ceed to full-text screen-ing	
48	Wiedemann, Schütz & Clauberg, 2008	Influence of information about specific absorption rate (SAR) upon customers' purchase decisions and safety evaluation of mobile phones	1	1	1	1	
49	Wiedemann, Schütz, Sachse & Jungermann, 2006	SAR values of mobile phones. Safety eval-uation and risk perception	1	1	1	1	Same study as Wiede-mann, Schütz & Clauberg 2008?
50	Wiedemann, Thalmann, Grutsch & Schütz, 2006	The impacts of precautionary measures and the disclosure of scientific uncer-tainty on EMF risk perception and trust	1	1	1	1	
51	Wiedemann, Schuetz, Bo-erner, Clauberg, Croft, Shukla, Kikkawa, Kemp,Gutteling, Villiers, da Silva Medeiros & Bar-nett, 2013	When precaution creates misunderstand-ings: the unintended effects of precau-tionary information on perceived risks, the EMF case	1	1	1	1	
52	Wu, Shao, Yang, Qi, Lin & Yu, 2013	A large-scale measurement of electro-magnetic fields near GSM base stations in Guangxi, China for risk communication	1	1	1	1	methodological problems

Article Number	Authors	Title	Peer-Reviewed Journal /Article?	Provides Empirical Data?	Full-text Available?	Screening Result	Remarks
			0 = no, 1= yes, 2 = unclear			0 = ineligibile, 1 = proceed to full-text screening	
53	Zaryabova & Israel, 2015	Dynamics of the public concern and risk communication program implementation	1	2	1	1	

Appendix E2: Full-Text Screening

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
1	Barnett, Timotijevic, Shepherd & Senior, 2007	Public responses to precautionary information from the Department of Health (UK) about possible health risks from mobile phones	1	1	1	1	
2	Barnett, Timotijevic, Vassallo & Shepherd, 2008	Precautionary advice about mobile phones: Public understandings and intended responses	1	1	1	1	
3	Bedini, Giliberti & Salerno, 2008	Information and communication on the electromagnetic fields: analysis of the Italian Internet sites					Discard because in Italian
4	Boehmert, Wiedemann, Pye & Croft, 2016	The Effects of Precautionary Messages about Electromagnetic Fields from Mobile Phones and Base Stations Revisited: The Role of Recipient Characteristics	1	1	1	1	

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
5	Boehmert, Wiedemann & Croft, 2016	Improving Precautionary Communication in the EMF Field? Effects of Making Messages Consistent and Explaining the Effectiveness of Precautions	1	1	1	1	
6	Bräscher, Raymaekers, van den Bergh & Witthöft, 2017	Are media reports able to cause somatic symptoms attributed to WiFi radiation? An experimental test of the negative expectation hypothesis	1	1	1	1	
7	Chandran & Menon, 2004	When a Day Means More than a Year - Effects of Temporal Framing on Judgments of Health Risk	1	1	1	0	media content analysis
8	Claassen, Bostrom & Timmermans, 2016	Focal points for improving communications about electromagnetic fields and health: a mental models approach	1	0	1	0	mental model study, no test of RC

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
9	Claassen, Smid, Woudenberg & Timmermans, 2012	Media coverage on electromagnetic fields and health: Content analysis of Dutch newspaper articles and websites: Health risks in the media	1	0	1	0	excluded because media content analysis
10	Claassen, van Dongen & Timmermans, 2015	Improving lay understanding of exposure to electromagnetic fields; the effect of information on perception of and responses to risk	1	1	1	1	
11	Collins, 2010	Mobile phone masts, social rationalities and risk: Negotiating lay perspectives on technological hazards	1	1	1	1	
12	Cousin, Dohle & Siegrist, 2011	The impact of specific information provision on base station siting preferences	1	1	1	1	
13	Cousin & Siegrist, 2010	The public's knowledge of mobile communication and	1	0	1	0	mental model study, no test of RC

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
		its influence on base station siting preferences					
14	Cousin & Siegrist, 2010	Risk perception of mobile communication: A mental models approach	1	0	1	0	survey study, no test of RC
15	Cousin & Siegrist, 2011	Cell phones and health concerns: impact of knowledge and voluntary precautionary recommendations	1	1	1	1	
16	Farag, Cheng & Penn, 1999	Development of an electromagnetic fields risk communication plan	0			0	
17	Foster, 2002	The Precautionary Principle – common sense or environmental extremism?	0			0	
18	Frick, Rehm & Eichhammer, 2002	Risk perception, somatization, and self report of complaints related to electromagnetic fields - A randomized survey study	1	0	1	0	about EMFs in general not specific about RF EMF

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
19	Hom, Plaza & Palmén, 2011	The framing of risk and implications for policy and governance: the case of EMF	0			0	
20	Hartung, Schulz & Keller, 2014	A Boomerang Effect of an All-Clear Message on Radiation Risk	1	1	1	1	
21	Huiberts, Hjørnevik, Mykletun & Skogen, 2013	Electromagnetic hypersensitivity (EHS) in the media - a qualitative content analysis of Norwegian newspapers	1	0	1	0	Paper is on media reports about IEI-EMF. The term radiofrequency does not occur, nor is this risk communication about RF

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
22	Ikeda, 2014	Interdisciplinary Framework of Risk Communication as an Integral Part of Environmental Risk Analysis in Postindustrial Risk Society : Three Case Studies of the 1999 Amendment of Air Pollution Control Law, Dioxins, and the EMF Risks	0			0	
23	Kim, Kim & Niederdeppe, 2015	Scientific uncertainty as a moderator of the relationship between descriptive norm and intentions to engage in cancer risk-reducing behaviors	1	1	1	1	Authors provided experimental material on 15 Nov 2017; Contacted authors on 14 Nov 2017 and asked to provide experimental material in order to judge eligibility
24	Köteles, Tarjan & Berkes, 2016	Artificial concerns. Effects of a commercial advertisement on modern health worries and sympathetic activation	1	1	1	1	

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
25	McMahan & Meyer, 1997	Reducing exposure to electromagnetic fields: the effects of low- and high-threat risk messages on behavior change	1	?	1	0	Contacted author in March 2917 and again on 14 Nov 2017 and asked for experimental material; no reply. Exclude because not RF EMF specific but EMF in general (see items; unclear how experimental texts are formulated, no mention of EMF source)
26	McMahan, Witte & Meyer, 1998	The Perception of Risk Messages Regarding Electromagnetic Fields: Extending the Extended Parallel Process Model to an Unknown Risk	1	?	1	0	Same study (both n = 251) as McMahan & Meyer 1997
27	Nielsen, Elstein, Gyrd-Hansen, Kildemoes, Kristiansen & Støvring, 2010	Effects of alternative styles of risk information on EMF risk perception	1	1	1	1	
28	Pölzl, 2009	German mobile telecommunication research programme	0			0	

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
		- Findings on risk communication					
29	Pölzl, 2011a	Mobile telecommunication: Current knowledge on risk perception and risk communication: Results gained within the German Mobile Telecommunication Research Programme				0	
30	Pölzl, 2011b	EMF recommendations specific for children?	0			0	
31	Ruddat, Sautter & Renn, 2007	Abschlussbericht zum Forschungsprojekt "Operationalisierung des Leitbildes 'Risikomündigkeit' unter Berücksichtigung von Lebensstil und Wertorientierung als Grundlage für die Risikokommunikation im Strahlenschutz"				0	

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
32	Ruddat, Sautter, Renn, Pfenning & Ulmer, 2010	Communication about a communication technology	1	1	1	1	Only survey study reported; Focus group study excluded because it does not fulfill methodological criteria (sample size not reported)
33	Salvatore, 1993	Information Sought on Human Health Effects of Nonionizing Electromagnetic Radiation				0	
34	Schweikardt, Rosenpreter & Gross, 2012	Discourse and policy making on consumer protection in the areas of mobile telecommunication and tanning	1	1	0	0	Article is a description of policy-making and actions of relevant actors in the emf and tanning field. It has no clear methodology and does not describe a method of document selection.
35	Siegrist, Cousin & Frei, 2008	Biased Confidence in Risk Assessment Studies	1	1	1	1	
36	Thalmann & Wiedemann, 2006	Beliefs and emotionality in risk appraisals	1	1	1	1	

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
37	Timotijevic & Barnett, 2006	Managing the possible health risks of mobile telecommunications	1	1	1	1	
38	Valberg, 1992	A Public-Health Framework for Addressing a Layperson's Perception of EMF Health Risks				0	
39	van Deventer & Foster, 2008	Risk Assessment and Risk Communication for Electromagnetic Fields: A World Health Organization Perspective				0	
40	van Dijk, van Rongen, Eggermont, Lebret, Bijker & Timmermans, 2011	The role of scientific advisory bodies in precaution-based risk governance illustrated with the issue of uncertain health effects of electromagnetic fields	0			0	Article is rather a statement that is derived from analyses of a couple of policy documents. Has no method section and does not fulfull any of the other method criteria

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
41	WHO, 2002	Establishing a Dialogue on Risks from Electromagnetic Fields				0	
42	WHO Office Europe, 2013	Health and environment: communicating the risks				0	
43	Weinhold 2005	A precautionary tale: Mental health and risk communication				0	
44	Wiedemann, Börner & Repacholi, 2014	Do people understand IARC's 2B categorization of RF fields from cell phones?	1	1	1	1	went through peer-review according to the main author
45	Wiedemann & Schütz, 1999	Risk communication for environmental health hazards	0			0	
46	Wiedemann & Schütz, 2005	The precautionary principle and risk perception: experimental studies in the EMF area	1	1	1	1	consists of two separate studies
47	Wiedemann & Schütz, 2008	Informing the public about information and participation strategies in the siting of	1	1	1	1	

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
		mobile communication base stations					
48	Wiedemann, Schütz & Clauberg, 2008	Influence of information about specific absorption rate (SAR) upon customers' purchase decisions and safety evaluation of mobile phones	1	1	1	1	Two studies with the same participants; study 1 is not a risk communication but about people ranking different mobile phone attributes, study 2 can be used
49	Wiedemann, Schütz, Sachse & Jungermann, 2006	SAR values of mobile phones. Safety evaluation and risk perception	1	1	1	1	same data as in Wiedemann & Schütz 2008
50	Wiedemann, Thalmann, Grutsch & Schütz, 2006	The impacts of precautionary measures and the disclosure of scientific uncertainty on EMF risk perception and trust	1	1	1	1	
51	Wiedemann, Schuetz, Boerner, Clauberg, Croft, Shukla, Kikkawa,	When precaution creates misunderstandings: the unintended effects of	1	1	1	1	consists of 9 separate studies

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
	Kemp,Gutteling, Villiers, da Silva Medeiros & Barnett, 2013	precautionary information on perceived risks, the EMF case					
52	Wu, Shao, Yang, Qi, Lin & Yu, 2013	A large-scale measurement of electromagnetic fields near GSM base stations in Guangxi, China for risk communication	1	1	0	0	insufficient description of methods and materials
53	Zaryabova & Israel, 2015	Dynamics of the public concern and risk communication program implementation	1	0		0	Article provides Bulgarian data of RF EMF exposure measurements in areas where health complaints have been voiced. Data is not on risk communication.
						24	

Article No	Authors	Title	Provides new Empirical Data?	At least in part about a test of RF EMF Risk Commmunication or about RF EMF Communication	Methodological Requirements (have a Method Section, Decribe Data acquisition, Describe Sample, Describe Analysis)	Full-Text Eligibility Result	Remarks
			0 = ineligible, 1 = include in review				in grey: already in abstract screening excluded
54	Niederdeppe, Lee, Robbins, Kim, Kresovich, Kirshenblat, Standridge, Clarke, Jensen & Fowler, 2013 **(Article added after literature search)**	Content and effects of news stories about uncertain cancer causes and preventive behaviors	1	1	1	1	Only study 2 is relevant; same sample as Kim, Kim & Niederdeppe 2015
55	Witthöft, Freitag, Nußbaum, Bräscher, Jasper, Bailer & Rubin, 2017 **(Article added after literature search)**	On the origin of worries about modern health hazards: Experimental evidence for a conjoint influence of media reports and personality traits	1	1	1	1	Only study 2 is relevant; study 1 is about a film on IEI and chemicals
56	Witthöft & Rubin, 2013 **(Article added after literature search)**	Are media warnings about the adverse health effects of modern life self-fulfilling? An experimental study on idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF)	1	1	1	1	

Appendix E3: Study Summaries

Art. No.	Authors	Study design	EMF Source	Country	Sample (participants/size/mean age/percent female)	Form of Communication	Outcome Measures	Relevant Results
1	Barnett, Timotijevic, Shepherd & Senior, 2007	Survey (face-to-face-interviews)	MP	UK	GP/1742/47/53	Government Leaflet information with precautionary advice (year 2000)	Awareness of leaflet Identification of precautionary advice Perception of Concern/Reassurance by precautionary advice	Awareness of leaflet about mobile phones is 15% after four years base station leaflet 10%; Recognition rates of 3 pieces of advice all below one third Precautionary advice is, on average, thought to increase concerns.
2	Barnett, Timotijevic, Vassallo & Shepherd, 2008	Experiment 2x2 factors, all groups get precautionary advice, but framing of it differs; achieved power = .10 for f = .05 for main effects of group	MP	UK	GP/173/43/61	First factor: Rationale for providing precautions (scientific uncertainty vs. public concern) Second Factor: Context (mobile phone risks vs. mobile phone risks and benefits	Concern about uncertainty Trust Concern/reassurance due to precautionary advice	No effects of experimental manipulation
4	Boehmert, Wiedemann, Pye & Croft, 2016	Experiment with mixed 2 (between) x 2 (within) factorial design	MP, BS	Australia	Stud/298/n.a./75	Basic text or basic text plus precautionary message (phone use by children; siting near locations of potentially sensitive people	- Threat perception, - Trust in the public's protection, - Opinion about scientific knowledge	- Main effect of Precautionary Message and of Order (BS vs. MP); - Interaction of trait anxiety with precautionary message: females low in

Art. No.	Authors	Study design	EMF Source	Country	Sample (participants/size/mean age/percent female)	Form of Communication	Outcome Measures	Relevant Results
		with explorative survey						anxiety with increase threat perception and reduced trust
5	Boehmert, Wiedemann & Croft, 2016	Experiment (incomplete factorial design with six different groups)	MP	Australia	GP/1717/43/54	One group without information and 5 different groups with different types of texts about RF EMF health effects and precautionary measures	Unconditional and conditional risk perception	Only conditional risk perception without precautions is influenced by Effectiveness information (+)
6	Bräscher, Raymaekers, van den Bergh & Witthöft, 2017	Experiment with two groups	Wi-Fi	Germany	Stud/63/25/70	One group ‚Wifi film' (EMF exposure measurement and EMF and multiple sclerosis), 'Control film' (illegal trade of mobile phones) Afterwards two types of exposure conditions: sham exposure to Wifi on and off	- Modern health worries radiation subscale -State anxiety - Modern health worries total - Perception of film - Intensity ratings of tactile stimuli	- Increase in radiation worries in both groups, larger increase in 'wifi-group' - No effects on state anxiety - Wifi-film perceived as more relevant and worrisome - No effects on MHW total score - intensity ratings correlate with personality variables - Wifi-film leads to higher intensity ratings of tactile stimuli under sham Wifi signal compared with no sham exposure. No difference between ratings under sham/no sham in control group

Art. No.	Authors	Study design	EMF Source	Country	Sample (participants/size/mean age/percent female)	Form of Communication	Outcome Measures	Relevant Results
								- Interaction between somatosensory amplification and film: Wifi film leads to greater difference in tactile experiences between sham on/off in subjects with high somatosensory amplification
7	Chandran & Menon, 2004, study 2	Experiment (2x2 between-subjects design)	MP	USA	Stud/64/n.a./n.a.	Factor 1: Precautionary behaviours mentioned are (1) easy to implement (2) hard to implement Factor 2: Temporal framing (1) year frame (2) day frame	Risk perception Intention to show precautionary behaviour	Risk perception: - No effect of ease of implementation of precautions - Large Effect of temporal framing Intention to show precautionary behaviour: - interaction effect: type of behaviour does not make a difference in day frame, easy to implement precautionary behaviours generate higher intentions in the year frame (intentions towards other (!) precaution related behaviours that were not mentioned in the experimental manipulation)

Art. No.	Authors	Study design	EMF Source	Country	Sample (participants/size/mean age/percent female)	Form of Communication	Outcome Measures	Relevant Results
11	Claassen, van Dongen & Timmermans, 2015	Experiment, 2x2x2 factorial design	MP, BS, HVPL, EMF-G	Netherlands	GP/245/50/44	(1) Explanation of distance-exposure relationship (2) Information on government policy (3) Information on exposure management (= ways to reduce exposure, similar to precautionary message)	- Risk perception, - Knowledge, - Evaluation of information	- Knowledge is specifically improved by each text module - Risk perception about BS and power lines lowered - No effects of specific groups (potentially underpowered)
12	Collins, 2010	Focus groups study	BS	UK	GP/37/n.a./n.a.	Two articles about base station placement near schools with similar content, one published in the Daily Mail and one published in the Evening Standard	Qualitative quotes of (a) Use of own knowledge (b) risk comparisons made by participants	(a) Non-mediated knowledge is frequently used, sources like the GP, family, friends, acquaintances are quoted; (b) base station risks were compared to a multitude of other risks (e.g. microwaves, mobile phones, road safety, smoking) both strategies are 'not, however, employed uncritically or in order to entirely replace 'scientific rationality', but

Art. No.	Authors	Study design	EMF Source	Country	Sample (participants/size/mean age/percent female)	Form of Communication	Outcome Measures	Relevant Results
								rather as part of a negotiation of understandings within what is perceived as a situation of uncertainty.
13	Cousin, Dohle & Siegrist, 2011	Experiment (questionnaire)	MP, BS	Switzerland	GP/228/36/n.a.	(1) Neutral text (2) Information booklet on mobile communication (focus: explanation of interaction MP-BS) (3) emotionally charged newspaper article	- Knowledge - Siting preference (= task for transfer of exposure knowledge) - Risk perception and health concerns (for MP and BS separately) - Benefit perception - Affect	- Booklet increases knowledge compared to both other groups - Siting preference of base stations: Solutions with lower radiation are selected after reading the booklet - Booklet reduces health concerns compared to neutral text - More positive affect for base stations
16	Cousin & Siegrist, 2011	Experiment (test-retest); 'hidden aim'	MP, BS	Switzerland	GP/408/35/n.a.	4 Information booklets with and without precaution recommendations & with or without a specific sender (Swiss mobile communication providers) dealing with knowledge gaps.	- Knowledge - Health concerns - Behaviour at follow-up	- All booklets increase knowledge - Concerns: no differences between booklets, increased concern in all groups together for MP after booklet and at follow-up, decreased for BS at follow-up - Booklets without precautionary rec. with less precautionary behaviour reported at follow-up

Art. No.	Authors	Study design	EMF Source	Country	Sample (participants/size/mean age/percent female)	Form of Communication	Outcome Measures	Relevant Results
23	Hartung, Schulz & Keller, 2014	Experiment with four groups	BS	Switzerland	GP/240/50/53	Same all-clear message for all groups, variation of the source (a university researcher, public health authority, activist group, mobile phone industry)	- Self-perceived change of concern about health risks from base stations - Interaction of prior risk perception (groups) and message reception	- No influence of experimental manipulation - Message is overall not perceived as changing concerns - People with high prior risk perception report an increase their concerns in response to the message; no effect for people with moderate or low prior risk perception
26	Kim, Kim & Niederdeppe, 2015	see Art. No. 32	see Art. No. 32	see Art. No. 32	see Art. No. 32	see Art. No. 32	- self-efficacy in relation to six cancer related risks	self-efficacy is increased by efficacy information (= precautionary information)
27	Köteles, Tarjan & Berkes, 2016	Experimental study (1 factor with 2 factor levels)	Various sources	Hungary	Stud/100/21/72	Conspiracy film from company offering radiation protection equipment vs. control nature documentary (potential BIAS: control condition might induce calmness) Moderation hypothesised by personality variables: - Somatosensory Amplification - PANAS - Health Anxiety	- Heart rate - Modern Health Worries EMF subscale (actually assessing "concern"), after the film and 3 weeks follow-up	- Heart rate and MHW increased in experimental group only. MHW still higher in follow-up after three weeks. - no interactions with personality variables

Art. No.	Authors	Study design	EMF Source	Country	Sample (participants/size/mean age/percent female)	Form of Communication	Outcome Measures	Relevant Results
						-Subjective somatic symptoms - Spiritual and alternative medicine beliefs		
32	Niederdeppe, Lee, Robbins, Kim, Kresovich, Kirshenblat, Standridge, Clarke, Jensen & Fowler, 2013	Experiment with 15 groups	MP	USA	GP/601/29/52	Short texts about "cell phone radiation" risk or bisphenol A risk + information about precaution ("efficacy") + no info about prevention or uncertain or established prevention (unrelated to both cell phones and BPA)	- Cancer information overload - Prevention fatalism - Intention to	Cancer information overload and fatalism are not influenced by efficacy information (= precautionary information)
33	Nielsen, Elstein, Gyrd-Hansen, Kildemoes, Kristiansen & Støvring, 2010	Experiment (internet-based survey)	MP, BS	Denmark	GP/1687/43/50	3 types of information about radiation from mobile phones and masts (short facts, longer technical explanation & health effects, guidance to reduce radiation)	- Evaluation of risk information - Acceptance (BS) - Change in Concern (MP) - Change in Concern (BS) - Intention to show precautionary behaviour	- Precautionary information judged as more trustworthy and more useful than other two; technical info judged as less comprehensive - Precautionary info leads to less acceptance of BS in vicinity compared to the short facts condition - Increased concern (MP) after precautionary info and after technical info compared to short facts condition

Art. No.	Authors	Study design	EMF Source	Country	Sample (participants/size/mean age/percent female)	Form of Communication	Outcome Measures	Relevant Results
								- No significances reported regarding behavioural intention - Change in concern (BS) not reported although assessed
38_2	Ruddat, Sautter, Renn, Pfenning & Ulmer, 2010	5 Focus groups & survey ((only survey study reported in review))	MP, BS	Germany	N of focus groups is unclear, not found in original project report, either GP/814/n.a./n.a. in survey subsample (n = 347) from written survey: confronted with 4 texts; subsample (n = 467) from telephone survey: confronted with short messages of the 4 actors	Information: 4 texts (written)/ 4 short messages with typical arguments by (a) activist groups, (b) industry, (c) political authorities and (d) scientists Psychometric variables (voluntariness, personal control)	- Participants split into 3 groups (1) low concern, (2) unsure/ambiguous, (3) high concern - Survey: Eight-item evaluation of information	- Opinion-contingent evaluation of material: concerned favour activist information, unconcerned favour industry information - Almost no differences on mean evaluation of authority info - In focus groups, all groups are sceptical about activist information
42	Siegrist, Cousin & Frei, 2008	Experiment (2x2x2x3 design)	MP, BS	Switzerland	Stud/670/23/61	Texts about a risk assessment study. Factors varied: - existence of risk vs. no risk - base station vs. mobile phone - risk: cancer vs. well-being	- Confidence in study results - Knowledge	- Main effect of outcome on confidence: More confidence in existing risk - Interaction: Low prior RP with more confidence in no risk; medium and high prior RP with more confidence in high risk

Art. No.	Authors	Study design	EMF Source	Country	Sample (participants/size/mean age/percent female)	Form of Communication	Outcome Measures	Relevant Results
						additional variable: low vs. medium vs. high prior risk perception		- no other main effects or interactions
43	Thalmann & Wiedemann, 2006	Experiment (2x4x3 design)	MP, BS	Austria	GP/197/22/n.a.	Risk information: "emotionality of information" operationalised by severity of consequences; type of argument (only pro, only con, con and pro, pro and con); Prior concern (concerned, unconcerned, undecided)	Risk Perception	- Main effect for prior concern: RP is higher for higher prior concern - Interaction of prior concern and severity of consequences: Difference between risk perception of prior concern groups only in the severe consequences condition - No effect of type of argument
44	Timotijevic & Barnett, 2006	Focus groups	MP, BS	UK	GP+parents+BS opponents/59/n.a./n.a.	Explorative discussions about different topics of mobile communication. Phase 1 Phase 2: It is introduced that the government pursues a precautionary approach	- Benefits, - Risk Regulation - Awareness of precautionary approach - Concern	- Awareness of governmental precautionary approach very low - 'The benefits of mobile phones (particularly in relation to personal safety), were perceived as far outweighing potential health costs.' - Different effect of precaution depending on prior concern: Concern about precaution was often expressed by already concerned people, 'For

Art. No.	Authors	Study design	EMF Source	Country	Sample (participants/size/mean age/percent female)	Form of Communication	Outcome Measures	Relevant Results
								those people less attentive to possible health risks […] precaution did seem to provide some reassurance.'
52	Wiedemann, Börner & Repacholi, 2014	Online survey	MP	Austria	Stud/2013(subsample 532)/25/66	Parts of IARC 2011 press release	Correct understanding of IARC press release, especially "40% risk increase in heavy users" and "possibly carcinogenic"	- interpretation of "possibly carcinogenic" median: 30% certainty, box between 15 and 50 - interaction: the higher the prior risk perception, the greater the estimated certainty - Understanding of 40% risk increase: vast majority understands it as 4 in 10 additional sufferers
54_1	Wiedemann & Schütz, 2005, study 1	Experiment 4x2 design	MP, BS	Austria	Stud/246/24/62	Factor 1: Basic text vs. basic text + one of three precautionary recommendations Factor 2: no information about uncertainty vs. information about high uncertainty	- Risk perception - Perception of scientific knowledge	- higher risk perception in precautionary groups - no effect of uncertainty info - no effects on perception of scientific knowledge
54_2	Wiedemann & Schütz, 2005, study 2	Experiment 2x2 design	MP, BS	Austria	N.a./84/median=23/76	Factor 1: Basic text vs. basic text + precautionary information (participation)	- Risk perception - Perception of scientific knowledge - Trust in public protection	- Risk perception no effect - Perception of scientific knowledge no effect

Art. No.	Authors	Study design	EMF Source	Country	Sample (participants/size/mean age/percent female)	Form of Communication	Outcome Measures	Relevant Results
						Factor 2: no information about uncertainty vs. information about high		- Trust in public protection lower in precautionary group - no effect of uncertainty info
55	Wiedemann & Schütz, 2008	Experiment (3x3 design)	BS	Germany	GP/225/30/53	Factor 1: level of public information Factor 2: level of public participation in the decision-making process	- Risk perception - Acceptance of site - Trust in safety - Transparency of siting process - Perception of consideration of public concerns - Conflict resolution Avoidance of conflicts	Only effect of participation (especially of round table format) on estimation of transparency, consideration and conflict resolution
56+57	Wiedemann, Schütz & Clauberg, 2008 Study 2; Wiedemann, Schütz, Sachse & Jungermann, 2006	Experiment	MP	Germany	Stud/240/median=27/51	Three text modules: (1) Basic text Plus SAR precautionary recommendation of 0,6 W/kg SAR-value either by (2) BfS or (3) advocacy group	Safety perception of SAR-values	No group differences in safety perception (in percent) for four different SAR values
58	Wiedemann, Thalmann, Grutsch & Schütz, 2006	Experiment 5x2 design	BS	Switzerland	Stud/639/22/42	Factor 1: Basic text vs. basic text + one of four types of precautionary information	- Risk perception - Trust in risk regulation/public health protection	- Risk perception higher in protection of sensitive areas condition - no effect on trust

Art. No.	Authors	Study design	EMF Source	Country	Sample (participants/size/mean age/percent female)	Form of Communication	Outcome Measures	Relevant Results
						Factor 2: no uncertainty information vs. high uncertainty	- perceived scientific knowledge	- no effect on perceived scientific knowledge - higher perceived scientific knowledge after uncertainty disclosure
59	Wiedemann et al., 2013	Experiment 5x2x2 design	MP, BS	8 countries	Stud/3902/21/59	Factor 1: Basic text vs basic text + one of four types of precautionary Information Factor 2: safety vs. risk framing, Factor 3: bas station or mobile phone text first	- Base station risk perception - Mobile phone risk perception	For both risk perception variables: - order effect in some countries - effect of precautionary recommendations in some countries
60_2	Witthöft, Freitag, Nußbaum, Bräscher, Jasper, Bailer & Rubin 2017, study 2	Experiment 1 factor with two levels	MP	Germany	Stud/82/26/70	Experimental film "When the phone makes you ill" vs. control film about mobile phone theft	- Mental health worries regarding radiation - Electromagnetic Fields Health Worries Scale	- Experimental film increases worry about EMF on both scales - No interactions of film with absorption or with negative affectivity
61	Witthöft & Rubin, 2013	Experiment (one factor with 2 levels) plus explorative survey	Wi-Fi	UK	CS/147/30/67	Alarming BBC documentary vs. control film	- Symptom perception under sham EMF exposure - Risk perception	- No main effect, - Interaction with state anxiety prior to sham exposure on risk perception and symptom perception

Note. MP = mobile phone, BS = base station, EMF-G = EMF in general, HVPL = high-voltage powerline, CS = community sample, Stud = students, GP = general population

Appendix E4: Quality of Experimental Studies

Criteria ‘Random Sequence Generation’, ‘Allocation Concealment’ and ‘Blinding of Participants and Personell’

			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)				
Study No.	**Art. No.**	**Authors**	**Random sequence generation**	**Random sequence genera-tion reasons**	**Allocation concealment**	**Allocation concealment reasons**	**Blinding of participants and personnel**
2	2	Barnett, Timotijevic, Va-ssallo & Shepherd, 2008	3	No information about as-signment at all	1	Questionnaires including experimental texts were sent by mail	1
4	4	Boehmert, Wiedemann, Pye & Croft, 2016	3	No information about ran-domisation procedure	1	Online study, unknown to researchers who the partici-pants were	1
5	5	Boehmert, Wiedemann & Croft, 2016	3	No information about ran-domisation procedure	1	Online study, unknown to researchers who the partici-pants were	1
6	6	Bräscher, Raymaekers, van den Bergh & Witt-höft, 2017	1	“Participants were assigned to the experimental or con-trol group by a computer-ized random allocation process."	1	Very likely not a problem, because motivation to as-sign a person to one spe-cific group should be low for experimenters	3
7	7	Chandran & Menon, 2004	3	No information about ran-domisation procedure	1	Very likely not a problem, because it is a university ex-periment (motivation to as-sign a person to one specific group should be low for experimenters)	1
10	10	Claassen, van Dongen & Timmermans, 2015	3	No information about ran-domisation procedure	1	Online study, unknown to researchers who the partici-pants were	1
12	12	Cousin, Dohle & Siegrist, 2011	3	"The computer randomly assigned participants to one	1	Immediately after the allo-cation, the experimental	2

			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)				
Study No.	**Art. No.**	**Authors**	**Random sequence generation**	**Random sequence generation reasons**	**Allocation concealment**	**Allocation concealment reasons**	**Blinding of participants and personnel**
				Of three experimental conditions while controlling for gender."		Manipulation was handed out by experimenters	
15	15	Cousin & Siegrist, 2011	3	No information about randomisation procedure	1	Very likely not a problem, because motivation to assign a person to one specific group should be low for experimenters	2
20	20	Hartung, Schulz & Keller, 2014	2	"Subjects were randomly assigned to experimental conditions by systematic alternation."	1	Very likely not a problem, because motivation to assign a person to one specific group should be low for experimenters	2
23+54	23	Kim, Kim & Niederdeppe, 2015	see Art. No. 54				
24	24	Köteles, Tarjan & Berkes, 2016	3	No information about randomisation procedure	1	Very likely not a problem, because motivation to assign a person to one specific group should be low for experimenters	2
23+54	54	Niederdeppe, Lee, Robbins, Kim, Kresovich, Kirshenblat, Standridge, Clarke, Jensen & Fowler 2013	3	No information about randomisation procedure	1	Study on computer	1
27	27	Nielsen, Elstein, Gyrd-Hansen, Kildemoes, Kristiansen & Støvring, 2010	3	"The website was programmed to randomly assign respondents to three types of information"	1	Online study, unknown to researchers who the participants were	1

			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)				
Study No.	**Art. No.**	**Authors**	**Random sequence generation**	**Random sequence generation reasons**	**Allocation concealment**	**Allocation concealment reasons**	**Blinding of participants and personnel**
35	35	Siegrist, Cousin & Frei, 2008	3	No information about randomisation procedure	1	Very likely not a problem, because motivation to assign a person to one specific group should be low for experimenters	2
36	36	Thalmann & Wiedemann, 2006	1	"Participants were randomly assigned, by drawing"	1	Very likely not a problem, because motivation to assign a person to one specific group should be low for experimenters	3
46_1	46	Wiedemann & Schütz, 2005, study 1	3	No information about randomisation procedure	1	Very likely not a problem, because motivation to assign a person to one specific group should be low for experimenters	3
46_2	46	Wiedemann & Schütz, 2005, study 2	3	No information about assignment at all	1	Very likely not a problem, because motivation to assign a person to one specific group should be low for experimenters	3
47	47	Wiedemann & Schütz, 2008	3	No information about randomisation procedure	1	Very likely not a problem, because motivation to assign a person to one specific group should be low for experimenters	3
48+49	48	Wiedemann, Schütz & Clauberg, 2008, study 2	2	"The subjects were assigned alternately to one of the three experimental conditions in the order of their recruitment"	1	Very likely not a problem, because motivation to assign a person to one specific group should be low for experimenters	3

			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)				
Study No.	**Art. No.**	**Authors**	**Random sequence generation**	**Random sequence generation reasons**	**Allocation concealment**	**Allocation concealment reasons**	**Blinding of participants and personnel**
48+49	49	Wiedemann, Schütz, Sachse & Jungermann, 2006	see Art. No. 48				
50	50	Wiedemann, Thalmann, Grutsch & Schütz, 2006	3	"The subjects were distributed over the 10 conditions in a balanced and randomized way"	1	Very likely not a problem, because motivation to assign a person to one specific group should be low for experimenters	3
51	51	Wiedemann et al., 2013	3	No information about randomisation procedure	1	Very likely not a problem, because motivation to assign a person to one specific group should be low for experimenters	3
55_2	55	Witthöft, Freitag, Nußbaum, Bräscher, Jasper, Bailer & Rubin, 2017, study 2	3	No information about randomisation procedure	1	Very likely not a problem, because motivation to assign a person to one specific group should be low for experimenters	3
56	56	Witthöft & Rubin, 2013	1	"Randomisation was performed using a computerised random number generator"	1	Very likely not a problem, because motivation to assign a person to one specific group should be low for experimenters	3

Criteria 'Blinding of Participants and Personell' (continued), 'Blinding of outcome assessment' and 'Incomplete outcome data'

			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)				
Study No.	**Art. No.**	**Authors**	**Blinding of participants and personell reasons**	**Blinding of outcome assessment**	**Blinding of outcome assessment reasons**	**Incomplete outcome data**	**Incomplete outcome data reasons**
2	2	Barnett, Timotijevic, Vassallo & Shepherd, 2008	No administering personell, participants did not know it was an experiment	1	Self-report by participants, no other persons involved	3	Attrition and exclusion not reported
4	4	Boehmert, Wiedemann, Pye & Croft, 2016	No administering personell, participants did not know it was an experiment	1	Self-report by participants, no other persons involved	1	Attrition of 18%, exclusion justified
5	5	Boehmert, Wiedemann & Croft, 2016	No administering personell, participants did not know it was an experiment	1	Self-report by participants, no other persons involved	3	Attrition not reported, exclusion justified
6	6	Bräscher, Raymaekers, van den Bergh & Witthöft, 2017	Unclear whether administering personell knew about assignment (rather likely, or did participants use headphones while watching the exp. film?); participants do not know the text is an experimental stimulus	1	Self-report by participants, no other persons involved	1	No attrition, exclusion justified and only 3%

			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)				
Study No.	**Art. No.**	**Authors**	**Blinding of participants and personell reasons**	**Blinding of outcome assessment**	**Blinding of outcome assessment reasons**	**Incomplete outcome data**	**Incomplete outcome data reasons**
7	7	Chandran & Menon, 2004	No administering personell, participants probably did not know it was an experiment	1	Self-report by participants, no other persons involved	1	No attrition or exclusion reported
10	10	Claassen, van Dongen & Timmermans, 2015	No administering personell, participants did not know it was an experiment	1	Self-report by participants, no other persons involved	3	Attrition and exclusion not reported
12	12	Cousin, Dohle & Siegrist, 2011	Personnel handed out the experimental texts, was thus unblinded	1	Self-report by participants on laptop, no other persons involved	1	No attrition or exclusion reported
15	15	Cousin & Siegrist, 2011	Personell administering questionnaires not blinded	1	Self-report by participants	1	No attrition at T2, attrition to follow-up: 38% (254/408)
20	20	Hartung, Schulz & Keller, 2014	Personell not blinded	1	Self-report by participants	1	No attrition reported, no exclusion reported
23+54	23	Kim, Kim & Niederdeppe, 2015					
24	24	Köteles, Tarjan & Berkes, 2016	Experimenters can probably see the movie that participants are watching. 4-6 participants	1	Self-report by participants; heartrate assessed with computer	1	No attrition reported, no exclusion reported

			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)				
Study No.	**Art. No.**	**Authors**	**Blinding of participants and personell reasons**	**Blinding of outcome assessment**	**Blinding of outcome assessment reasons**	**Incomplete outcome data**	**Incomplete outcome data reasons**
			tested in the lab at a time.				
23+54	54	Niederdeppe, Lee, Robbins, Kim, Kresovich, Kirshenblat, Standridge, Clarke, Jensen & Fowler, 2013	Study on computer	1	Self-report by participants	1	No attrition reported, no exclusion reported
27	27	Nielsen, Elstein, Gyrd-Hansen, Kildemoes, Kristiansen & Støvring, 2010	No administering personell, participants did not know it was an experiment	1	Self-report by participants	1	No attrition reported, no exclusion reported
35	35	Siegrist, Cousin & Frei, 2008	"Data collection lasted about 10 minutes and took place at the beginning of class lectures." It is likely that participants, talking to each other, realised that there were different experimental conditions.	1	Self-report by participants	1	No attrition reported, no exclusion reported

			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)				
Study No.	**Art. No.**	**Authors**	**Blinding of participants and personell reasons**	**Blinding of outcome assessment**	**Blinding of outcome assessment reasons**	**Incomplete outcome data**	**Incomplete outcome data reasons**
36	36	Thalmann & Wiedemann, 2006	Participants likely to be blinded; Personnel unclear because procedure of administration of questionnaire not reported	1	Self-report by participants	1	Exclusion of 10% due to classification in risk perception groups; no attrition
46_1	46	Wiedemann & Schütz, 2005, study 1	Participants likely to be blinded; Personnel unclear because procedure of administration of questionnaire not reported	1	Self-report by participants	1	No attrition reported, no exclusion reported
46_2	46	Wiedemann & Schütz, 2005, study 2	Participants likely to be blinded; Personnel unclear because procedure of administration of questionnaire not reported	1	Self-report by participants	1	No attrition reported, no exclusion reported
47	47	Wiedemann & Schütz, 2008	Participants likely to be blinded; Personnel unclear because procedure of administration of questionnaire not reported	1	Self-report by participants	1	No attrition reported, no exclusion reported

			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)				
Study No.	Art. No.	Authors	Blinding of participants and personell reasons	Blinding of outcome assessment	Blinding of outcome assessment reasons	Incomplete outcome data	Incomplete outcome data reasons
48+49	48	Wiedemann, Schütz & Clauberg, 2008, study 2	Participants likely to be blinded; Personnel unclear because procedure of administration of questionnaire not reported	1	Self-report by participants	1	No attrition, exclusion justified and below 1%
48+49	49	Wiedemann, Schütz, Sachse & Jungermann, 2006					
50	50	Wiedemann, Thalmann, Grutsch & Schütz, 2006	Participants likely to be blinded; Personnel unclear because procedure of administration of questionnaire not reported	1	Self-report by participants	1	No attrition reported, no exclusion reported
51	51	Wiedemann et al., 2013	Participants likely to be blinded; Personnel unclear because procedure of administration of questionnaire not reported	1	Self-report by participants	1	No attrition reported, no exclusion reported
55_2	55	Witthöft, Freitag, Nußbaum, Bräscher, Jasper, Bailer & Rubin, 2017, study 2	Blinding of personell unclear did they seen which film the participants watched?)	1	Self-report by participants	1	Low attrition from first (online questionnaire) to second part (experiment), no exclusion reported

			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)				
Study No.	**Art. No.**	**Authors**	**Blinding of participants and personell reasons**	**Blinding of outcome assessment**	**Blinding of outcome assessment reasons**	**Incomplete outcome data**	**Incomplete outcome data reasons**
56	56	Witthöft & Rubin, 2013	Blinding of personell unclear did they seen which film the participants watched?)	1	Self-report by participants	1	Attrition of 2%, justified

Criterion ‘Selective Reporting’ and General Criteria ‘Power Calculations’, ‘Sample Size’ and ‘Number of Experimental Groups’

Study No.	Art. No.	Authors	Selective reporting	Selective reporting reason	Power calculations provided	Sample size (valid N) in calculations	No. of experimental groups
			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)		0 = no, 1 = yes		
2	2	Barnett, Timotijevic, Vassallo & Shepherd, 2008	2	The measures pertinent to the research questions of the present study are summarized in Table 1.	0	173	4
4	4	Boehmert, Wiedemann, Pye & Croft, 2016	2	Several assessed measures not reported (see Figure 1)	0	298	4
5	5	Boehmert, Wiedemann & Croft, 2016	2	Several assessed measures not reported (see Figure 1)	0	1717	6
6	6	Bräscher, Raymaekers, van den Bergh & Witthöft, 2017	1	State version of STAI, SSA MHWS, SSAS in methods; All reported in results	0	63	2
7	7	Chandran & Menon, 2004	1	Results are reported for all dependent variables described in the methods ('We then collected dependent measures, manipulation checks, and background information about cell phone ownership, usage, familiarity, gender, and age. The background variables did not affect our measures and are therefore not discussed any further.')	0	64	4
10	10	Claassen, van Dongen & Timmermans, 2015	2	277 participants 'assigned to conditions containing information on the transparency of	1	245	

Study No.	Art. No.	Authors	Selective reporting	Selective reporting reason	Power calculations provided	Sample size (valid N) in calculations	No. of experimental groups
			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)		**0 = no, 1 = yes**		
				government policy' were excluded			
12	12	Cousin, Dohle & Siegrist, 2011	1	Results are reported for all dependent variables described in the methods	0	228	3
15	15	Cousin & Siegrist, 2011	2	"First, a short questionnaire containing different scales measured attitudes and beliefs (not reported here)"	0	408 (253 at follow-up)	4
20	20	Hartung, Schulz & Keller, 2014	2	"The only independent variable looked at here is risk perception of NIR before the experiment."	0	240	4
23+54	23	Kim, Kim & Niederdeppe, 2015			0		
24	24	Köteles, Tarjan & Berkes, 2016	1	Results are reported for all dependent variables described in the methods	1	100	2
23+54	54	Niederdeppe, Lee, Robbins, Kim, Kresovich, Kirshenblat, Standridge, Clarke, Jensen & Fowler, 2013	2	Results reported in two different articles, with first article not mentioning the variables reported in the second article	0	601	15
27	27	Nielsen, Elstein, Gyrd-Hansen, Kildemoes, Kristiansen & Støvring, 2010	2	Many items of the questionnaire are lacking in Table 1	0	1687	3
35	35	Siegrist, Cousin & Frei, 2008	2	"First, a short questionnaire containing different scales	0	670	8

Study No.	Art. No.	Authors	Selective reporting	Selective reporting reason	Power calcu-lations provi-ded	Sample size (valid N) in calculations	No. of experi-mental groups
			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)		0 = no, 1 = yes		
				measured attitudes and beliefs (not reported here)"			
36	36	Thalmann & Wiede-mann, 2006	1	Only control variables not re-ported	0	178	8
46_1	46	Wiedemann & Schütz, 2005, study 1	1	Results are reported for all de-pendent variables described in the methods	0	246	8
46_2	46	Wiedemann & Schütz, 2005, study 2	1	Results are reported for all de-pendent variables described in the methods	0	84	4
47	47	Wiedemann & Schütz, 2008	1	Results are reported for all de-pendent variables described in the methods	0	225	9
48+49	48	Wiedemann, Schütz & Clauberg, 2008, study 2	1	only safety perception is men-tioned and reported	0	239	3
48+49	49	Wiedemann, Schütz, Sachse & Jungermann, 2006			0		
50	50	Wiedemann, Thalmann, Grutsch & Schütz, 2006	1	Results are reported for all de-pendent variables described in the methods	1	639	10
51	51	Wiedemann et al., 2013	2	Results for trust variable are not reported	1	3902	20
55_2	55	Witthöft, Freitag, Nuß-baum, Bräscher, Jasper, Bailer & Rubin, 2017, study 2	1	Results are reported for all de-pendent variables described in the methods	0		

Study No.	Art. No.	Authors	Selective reporting	Selective reporting reason	Power calculations provided	Sample size (valid N) in calculations	No. of experimental groups
			Cochrane Risk of Bias Asssessment (1 = low risk, 2 = high risk, 3 = unclear risk)		0 = no, 1 = yes		
56	56	Witthöft & Rubin, 2013	1	Results are reported for all dependent variables described in the methods	1	147	2

Appendix E5: Quality of Qualitative Studies

Criteria 'Documentation' and 'Interpretation Backed by Arguments'

Study No.	Art. No.	Authors	Quality criteria for qualitative research (Mayring 2016)		
			Documentation	**Documentation reason**	**Interpretation backed by arguments**
11	11	Collins, 2010	Relevant theoretical assumptions and method are properly documented	Theoretical assumptions: individual RP of RF EMFs insufficiently modeled in quantitative studies;	Interpretation is partly backed by quotes from participants
37	37	Timotijevic & Barnett, 2006	Relevant theoretical assumptions and method are properly documented	Theoretical assumptions and practical research question (originating in a communication pattern that the government pursues) are sufficiently documented. Methods are described in sufficient detail.	Interpretation is fully backed by quotes from participants

Criteria 'Interpretation Backed by Arguments' (continued), 'Conformity with Rules', 'Proximity to Object of Research' and 'Validation by Participants

Study No.	Art. No.	Authors	Interpretation backed by arguments reason	Conformity with rules	Cnformity reason	Proximity to object of research	Proximity reason	Validation by participants	Validation reason
11	11	Collins, 2010	Role of non-mediated contextual knowledge is supported by various citations; role of different risk comparisons is only supported by one citation each	Decisions regarding research design are insufficiently justified	Instruments of analysis: no justification of focus group approach (as compared to other qualitative methods), no justification why participants were confronted with these specific newspaper articles; data analysis: no justification of "focus on just two of the themes" (p. 626);	Given in focus group design	Group discussions with similar people are probably a good simulation of discussions participants have in their lives	Not reported	
37	37	Timotijevic & Barnett, 2006		Decisions regarding research design are sufficiently justified	Pros and cons of chosen focus group design are explained and potential drawbacks addressed (e.g. for the influence of the group facilitator on the participants "We endeavoured to address this primarily by the use of the clear three stage structure outlined in the Procedure below")	Given in focus group design	Participants are well chosen (base station oponents, general public and parents)	Not reported	

Criterion 'Triangulation'

Study No.	Art. No.	Authors	Triangulation	Triangulation reason
11	11	Collins, 2010	Not reported	
37	37	Timotijevic & Barnett, 2006	Not reported	

Appendix E6: Quality of Survey Studies

Study No.	Art. No.	Author	Total Survey Error (Groves and Lyberg 2011)		
1	1	Barnett, Timotijevic, Shepherd & Senior, 2007	**Representation**	**Evaluation (risk of error)**	**Description**
			Coverage	Low	Possible undercoverage for people not listed in pool of Office of National Statistics
			Sampling	Low	Representative sample for British adults ("The Office of National Statistics (ONS) Omnibus Survey provides nationally representative data on adults aged 18 and over living in private households in Great Britain")
			Non-response	Medium	35% non-response ("The survey achieved an overall response rate of 65%"), no additional information
1	1	Barnett, Timotijevic, Shepherd & Senior, 2007	**Measurement**		
			Specification	Low	Obvious key variables, using different scales e.g. Likert-scales
			Measurement	Low	No indication for errors, face to face interviews with survey ("Face to face interviews were conducted..."), low risk interviewer influenced answers
			Processing	Low	No online tool was used, low risk of data input errors
31	31	Ruddat, Sautter & Renn, 2007 (survey only)	**Representation**	**Evaluation (risk of error)**	**Description**
			Coverage	Medium	Undercoverage as using mail and telephone ("... (as) the original mailing was ... low ... the research team added a telephone survey")
			Sampling	High	Doubts if sample is representative, not explained in detail ("Unfortunately, the response rate to the original mailing was so low (n = 347) that the research team added a telephone survey (n = 467). In total the sample included 814 respondents roughly representing the German public.")
			Non-response	High	High non-response, not explained

31	31	Ruddat, Sautter & Renn, 2007 (survey only)	**Measurement**		
			Specification	Medium	Overall and group specific analysis, clear variables ("The processing of the results was done in two ways. First, the whole sample was analysed; second, the sample was divided into three subsamples representing the three major response groups...")
			Measurement	High	Strategy not clear, mixture of mail and telephone prone to error, different influence of used method, ("... (as) the original mailing was ... low ... the research team added a telephone survey")
			Processing	Low	Low risk of data input errors
44	44	Wiedemann, Börner & Repacholi, 2014	**Representation**	**Evaluation (risk of error)**	**Description**
			Coverage	High	Undercoverage possible
			Sampling	High	Not representative for general population, non-randomized student sample ("was made available to all 27,000 students of the University of Innsbruck in Austria. A total of 2,013 students ... participated...") ("we have to be cautious about extrapolating the findings from the student population to the general public without additional evidence from a representative sample")
			Non-response	High	No information about non-response evaluated; Unit-/Item unknown ("A total of 2,013 students ... participated...") ("...we cannot exclude the occurrence of a sampling bias because we have no information about the non-responders in our survey.")
44	44	Wiedemann, Börner & Repacholi, 2014	**Measurement**		
			Specification	Low	Questionnaire designed by researcher, Likert-scales were used, original text excerpt was used ("using a Likert-scale") ("instructed to read the text from the original IARC press release")
			Measurement	Low	No indication for errors, online survey was used
			Processing	Low	Well known online survey tool was used low risk of processing errors ("Using Survey Monkey (Palo Alto, CA), an online survey consisting of 13 questions was conducted in April 2012.")