



Case report

An idiographic approach to idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF) part I. Environmental, psychosocial and clinical assessment of three individuals with severe IEI-EMF

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ABSTRACT

IEI-EMF refers to an environmental illness whose primary feature is the occurrence of symptoms that are attributed to exposure to weak electromagnetic fields (EMFs). There is a growing evidence that this condition is characterized by marked individual differences thus a within-subject approach might add important information beyond the widely used nomothetic method. A mixed qualitative/quantitative idiographic protocol with a threefold diagnostic approach was tested with the participation of three individuals with severe IEI-EMF. In this qualitative paper, the environmental, psychosocial, and clinical aspects are presented and discussed (results of ecological momentary assessment are discussed in Part II of this study). For two participants, psychopathological factors appeared to be strongly related to the condition. Psychological assessment indicated a severe pre-psychotic state with paranoid tendencies, supplemented with a strong attentional focus on bodily sensations and health status. The psychological profile of the third individual showed no obvious pathology. Overall, the findings suggest that the condition might have uniformly been triggered by serious psychosocial stress for all participants. Substantial aetiological differences among participants with severe IEI-EMF were revealed. The substantial heterogeneity in the psychological and psychopathological profiles associated with IEI-EMF warrants the use of idiographic multimodal assessments in order to better understand the different ways of aetiology and to facilitate person-tailored treatments.

1. Introduction

Idiopathic environmental intolerances (IEIs) such as multiple chemical sensitivity or electromagnetic hypersensitivity are characterised by non-specific symptoms that are attributed to various environmental factors by the affected individuals (Dantoft et al., 2015; IPCS (WHO), 1996). However, the vast majority of the general population is not impacted by these factors (Haanes et al., 2020), and the symptoms reported by IEI sufferers cannot be explained from a biomedical point of view (Baliatsas et al., 2014). Thus, a paradigm shift and a new term (symptoms associated with environmental factors, SAEF) were proposed recently by Haanes et al. (2020). This new paradigm approaches IEIs from the viewpoint of symptom perception and associations with

environmental factors rather than that of environmental exposure and/or intolerance.

Electromagnetic hypersensitivity (aka IEI-EMF) is characterised by symptoms attributed to weak non-ionizing electromagnetic fields (EMF) (WHO, 2005). Aetiology of IEI-EMF was approached in different ways. Empirical results have revealed no conclusive association between exposure to EMF and symptom reports of people with IEI-EMF (Baliatsas et al., 2012a,b; Köteles et al., 2013; Levallois, 2002; Röösl, 2008; Röösl et al., 2010; Rubin et al., 2005, 2010, 2011; Schmiedchen et al., 2019; Seitz et al., 2005; Szemerszky et al., 2015a,b; van Moorselaar et al., 2017; Verrender et al., 2018). Moreover, a large body of empirical evidence indicates the involvement of psychophysiological factors in the development and maintenance of the condition (Dieudonné, 2016, 2019; Dömötör

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et al., 2016; Oftedal et al., 2007; Regel et al., 2006; Szemerszky et al., 2010; Van den Bergh et al., 2017a,b; Witthöft and Rubin, 2013). Based on these findings, psychophysiological models were proposed that primarily focus on the interplay between perceptual, cognitive, and behavioural factors (Dieudonné, 2020; Van den Bergh et al., 2017a,b). Although these theories do not necessarily rule out the existence of biophysical effects of EMF (Röösli, 2008; Röösli et al., 2010), they suppose that such effects are not directly related to the symptom perceptions (Rubin et al., 2006; Szemerszky et al., 2015a,b). It is important to emphasize that the distinction between biophysical (aka toxicological or bottom-up) and purely psychological (aka psychogenic, top-down) factors or causes, although frequently made in the literature (Rubin et al., 2011; Staudenmayer et al., 2003a, 2003b), reflects the naive concepts of the sufferers rather than the recent scientific approach to the problem. Existing scientific models, most importantly those based on the predictive processing framework, attempt to include and integrate all known factors (Van den Bergh et al., 2017a,b).

Despite the attempts made to establish a definition and measurement protocol (Belpomme et al., 2015; Bergqvist et al., 1997; Eltiti et al., 2007; Hillert et al., 1999, 2002), accepted diagnostic criteria for IEI-EMF, apart from the subjective reports of patients, are yet to be developed (Baliatsas et al., 2012a,b; Meg Tseng et al., 2011). Thus, the primary inclusion criterion of participants in IEI-EMF related research is self-reported sensitivity. In consequence, there is a considerable heterogeneity within the IEI-EMF groups in studies with respect to the severity of the condition, which can partly explain inconsistencies in empirical findings (Baliatsas et al., 2012a,b).

It is possible that psychophysiological and physical environmental factors (i.e. exposure to EMFs) contribute to the IEI-EMF in an additive manner or in interaction (at least such an interaction cannot be excluded). Also, different mechanisms may play the dominant role for different individuals. In consequence, each patient with IEI-EMF may have a unique pathogenesis (Foster and Rubin, 2014). This questions the validity of conventional (i.e. group-based, nomothetic) study designs, and delineates the importance of in-depth exploration of the underlying factors through case studies. Such qualitative investigations may provide us with novel concepts for further large-scale studies (Henningsen and Priebe, 2003). In addition, the necessary treatment should always be determined relying on the individual aetiology. Although therapy for the IEI-EMF patients should be based on a comprehensive evaluation of all possible contributing factors (Baliatsas et al., 2012a,b; Brand et al., 2009; Dantoft et al., 2015; Hillert et al., 1998), no such complex diagnostic procedure has been developed for IEI-EMF to date.

As the phenomenon at hand appears to be quite complicated, its scientific investigation should also be complex. The aim of the current explorative study was to test the feasibility of a multimodal approach to IEI-EMF that involves physical environmental, psychosocial and clinical evaluation, as well as the exploration of the association between IEI-EMF symptoms and ambient EMF exposure in real-time, real-life conditions, at the individual level. Results of the latter, i.e., a 21-day-long ecological momentary assessment (EMA), are reported in detail in Part II of this study. Theoretically, such a sophisticated approach may be able to assess the phenomenon in its complexity. In the present paper (i.e. in Part I of the study), we attempt to present a detailed picture on the actual medical, psychosocial, and physical environmental conditions of our participants. Although conclusions with respect to the causal background of IEI-EMF cannot be drawn from these profiles, considering the lack of published case studies in this area, our findings may contribute to a better understanding of the complexity of the phenomenon, including the existence of substantial individual differences among individuals with IEI-EMF.

2. Materials and methods

2.1. Participants

Participants were three individuals with self-diagnosed IEI-EMF who voluntarily applied to the *National Research Institute for Radiobiology and*

Radiohygiene for help with their condition, as well as for participation in the present study. Inclusion criteria were (1) self-diagnosed IEI-EMF, (2) regular occurrence of symptoms attributed to EMF exposure, and (3) a considerable impact of their condition on everyday functioning (Szemerszky et al., 2019). The only exclusion criterion was the diagnosis of recent psychotic disorder. Participants were not given any financial compensation for their participation. The study was performed in accordance with the guidelines of the 4th revision of the Declaration of Helsinki. Participants received detailed information about the purpose of the measurements and signed an informed consent form. All procedures performed in the study were approved by the Research Ethics Board of the Faculty of Education and Psychology, Eötvös Loránd University, Hungary.

2.2. Procedure and study design

As first step, before entering the study, severity of IEI-EMF, suspected EMF source(s) and EMF-related complaints of the applicants were assessed in a brief questionnaire (for more details, see Part II). Based on their self-ratings, all three participants were characterized by severe IEI-EMF. Upon entry to the study, subjects participated in an exploratory clinical interview conducted by a clinical psychologist. Participants' condition was also assessed using the Minnesota Multiphasic Personality Inventory (MMPI; see below). Subsequently, participants completed a battery of self-report questionnaires that assessed the assumed causes and impact of their condition on their everyday life, their physical and mental health, lifestyle, features of their living and working environment, and psychological characteristics. Finally, a 21-day-long ecological momentary assessment (EMA) were carried out (this part of the study is reported in Part II). The components of the multimodal analysis are presented in Table 1.

2.3. Clinical interview

For each participant, a non-structured clinical interview was conducted in order to (1) identify and exclude individuals with acute psychotic condition and (2) explore the participant's actual psychological status. Before the interview, participants completed the MMPI (Bagdy et al., 1986; Hathaway and McKinley, 1942). (Graham, 2006) The exploratory clinical interviews were conducted by one of two clinical psychologists. Participants' self-reports on their psychiatric anamnesis and the results of MMPI were evaluated by the two clinical psychologists independently. Beyond psychological state, clinical interviews explored the participants' narratives about their IEI-EMF, impact of the condition on their quality of life, and social environment.

2.4. Self-report questions and questionnaires

Participants' demographic characteristics, physical and mental health status (current medication; medical and psychiatric examinations and diagnoses in the past 10 years; other sensitivities), lifestyle (general and

Table 1. Overview of the multimodal assessment.

Modality	Assessed factors
Environmental evaluation	<ul style="list-style-type: none"> physical characteristics of the living and working environment (self-reported) self-reported and measured EMF exposure at the typical habitations of participants (see Part II) ecological momentary assessment (see Part II)
Psychosocial evaluation	<ul style="list-style-type: none"> psychiatric state: psychiatric anamnesis (self-reported), clinical interview, MMPI life events, life conditions, social environment (self-reported) trait and health anxiety, somatic symptom distress, somatosensory amplification, symptom attribution style, modern health worries (self-report questionnaires) subjective sleep quality (self-report questionnaire)
Medical evaluation	<ul style="list-style-type: none"> medical anamnesis (self-reported)

Notes. MMPI = Minnesota Multiphasic Personality Inventory.

leisure activities), social environment (quality of relationships; social support; cohabitation; reaction given by the social environment to their EMF-hypersensitivity), earlier and current living and working environment (perceived EMF exposure), and history of the self-reported IEI-EMF were assessed using open questions. Beyond these, the following questionnaires were completed. Questionnaire scores were compared to the mean values of respective national populations reported in previous studies (see Figure 2).

The *Minnesota Multiphasic Personality Inventory (MMPI)* (Bagdy et al., 1986; Hathaway and McKinley, 1942) is a comprehensive test designed to assist differential diagnosis of mental disorders. It consists of 338 yes-or-no questions, which compose 10 clinical scales and validity scales. Evaluation of the MMPI is a complex procedure which considers the overall pattern and aspects of validity beyond scale total scores. For the interpretation of MMPI profiles (shown in Figure 1), the high point pair approach was used (Graham, 2006).

Health anxiety, i.e. the fear of having a serious illness, was assessed using the short version of *Health Anxiety Inventory (SHAI-S)* (Köteles et al., 2011a,b; Salkovskis et al., 2002). The SHAI-S consists of 18 items that are rated on a 4-point scale. Higher scores refer to higher levels of health anxiety.

The *Somatosensory Amplification Scale (SSAS)* (Barsky et al., 1988; Köteles et al., 2009) was used to assess the proneness to experience somatic sensation as intense, noxious, and disturbing. It consists of 10 items rated on a 5-point scale; higher scores indicate higher amplification tendency.

Somatic symptoms distress was measured with the *Patient Health Questionnaire Somatic Symptom Severity Scale (PHQ-15)* (Kroenke et al., 2002; Stauder et al., 2021). Participants are asked to rate the bothersomeness of 15 somatic symptoms with respect of the last four weeks on a 3-point scale. Higher scores refer to higher levels of somatic symptom distress.

Worries about possible harmful effects of modern technologies (modern health worries) were assessed using the *Modern Health Worries Scale (MHWS)* (Köteles et al., 2011a,b; Petrie et al., 2001). It consists of 25 items that are rated on a 5-point scale. High scores indicate more worries.

Attribution style was measured using the *Symptom Interpretation Questionnaire (SIQ)* (Robbins and Kirmayer, 1991; Rózsa et al., 2008). It consists of 13 statements referring to possibly pathological conditions which are evaluated with respect to three attribution styles (i.e. normalizing, psychological, and somatic) on a 4-point scale.

Finally, the *Groningen Sleep Quality Scale (GSQS)* (Mejiman et al., 1988; Simor et al., 2009) was used to assess subjective sleep quality. It consists of 14 yes-or-no statements referring the perceived sleep quality with respect to the preceding night. High scores refer to worse sleep quality. The GSQS was completed by each participant right after awakening for 21 consecutive mornings during EMA.

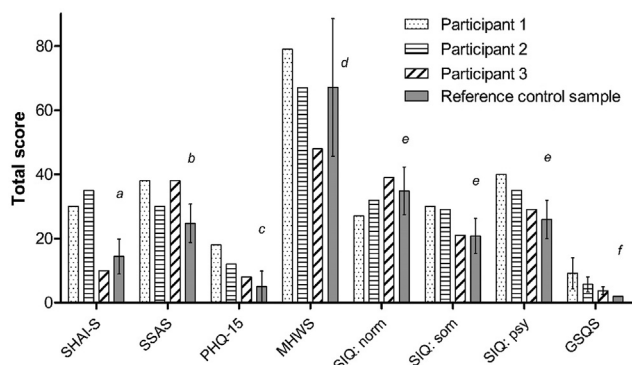


Figure 2. Participants' questionnaire scores and mean values of reference national non-patient samples (error bars represent SDs). a, d: community sample, n = 186 (Köteles et al., 2015); b: community sample of an online questionnaire study, n = 16152 (Köteles & Simor, 2014); c: female, age matched community sample, n = 514 (Stauder et al., 2021); e: female community sample, n = 660 (Rózsa et al., 2008); f: threshold of good subjective quality of sleep (Simor et al., 2009). GSQS: Groningen Sleep Quality Scale; MHWS: Modern Health Worries Scale; PHQ-15: Patient Health Questionnaire Somatic Symptom Severity Scale; SHAI-S: short Health Anxiety Inventory; SIQ: Symptom Interpretation Questionnaire, norm: normalizing attribution, som: somatic attribution, psy: psychological attribution; SSAS: Somatosensory Amplification Scale.

2.5. EMA

For 21 days, participants carried a measurement kit consisting of a portable personal dosimeter for measuring RF EMF bands, a small mobile holter ECG monitor and a paper-based "diary" with a series of short questions. The dosimeters and the ECG device registered the momentary strength of the electric field and the momentary physiological data, respectively, 24 h a day for the entire duration of the EMA (sampling frequency was one value per 30 s). The mobile ECG device recorded heart rate (HR), high frequency (HF; 0.04–0.14 Hz) domain of heart rate variability representing parasympathetic activation, and respiratory rate (RR). The diary was used by participants to record somatic symptoms they attributed to EMF exposure, the assumed intensity of actual EMF exposure, mood, and contextual variables (location, social environment, and the type of activity in which they were engaged in right before the actual assessment.) They were prompted for recording 8 times a day with 90+/-30 min between alarms (see Part II of this study for a more detailed description).

3. Results

3.1. Psychosocial analysis

3.1.1. Social context and subjective aetiology of IEI-EMF

Participant #1 was a 64-year-old woman with secondary education, who retired and widowed, and lived at the time of the study together with her eldest adult son. She frequently felt minor electric shocks and tingling sensations on her whole body in the proximity of electrical appliances and power sources, and often experienced tingle, whisper, chirp, growl, pain, and pressing in and around her ears. She attributed these perceptions to a claimed device emitting EM radiation, installed by the neighbours to persecute her and take possession of her property. Her EMF-related symptoms had first appeared two years before entering the study. Partly because of her narrowed range of interest, which focused on the complaints, and of her beliefs on being intentionally exposed to EMF by the neighbours, she lost the majority of her social relations. Her younger son moved away two years earlier, which nearly coincided with the appearance of her EMF-related symptoms. This event was interpreted by the participant as a betrayal, i.e., as part of the neighbours' conspiracy.

Participant #2 was a 40-year-old, higher educated woman, who was unemployed, divorced, and lived together with her mother and 4-year-

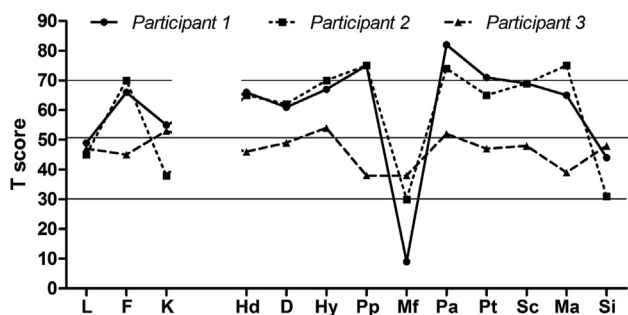


Figure 1. MMPI profiles. L = Lie, F = Infrequency, K = Correction, Hd = hypochondriasis, D = depression, Hy = hysteria, Pp = psychopathic deviate, Mf = masculinity/femininity, Pa = paranoia, Pt = psychasthenia, Sc = schizophrenia, Ma = hypomania, Si = social introversion.

old son at that time. She complained about pain experienced on various areas of her head, face and neck, headache, toothache, and neurasthenic (dizziness, fatigue, concentration problems, etc.) problems in the proximity of mobile phones. Simultaneously with the increasing appearance of her complaints (4 years before the study), she was under considerable chronic psychosocial stress, including work overload, as well as loss of her job and her partner due to her extremely high health worries and severe somatic symptoms during her pregnancy. To avoid contagious diseases and harmful environmental factors, she escaped from the capital city to an isolated rural area, and became disabled for years due to the aggravation of her complaints. The EMF-related attribution emerged during her pregnancy, when she started to associate her symptoms with the frequent 30-40 min-long telephone conversations in connection with her work and partner-relationship. Her symptoms were attributed exclusively to the radiation of mobile phones.

Participant #3 was a 52-year-old, higher educated woman, who was employed and lived alone. She had minimal social support, her relationship with her siblings was fractured due to their offensive behaviour after their parents' long sickness and death. She never had a spouse or domestic partner. She only had one close acquaintance and met friends rarely. Her EMF-associated symptoms had started to appear six years before the study (during her parents' sickness). She experienced the first disturbing complaints when a lodger regularly listened to loud music in the house. At the same time, the neighbouring school was renovated, and she regularly heard very loud machine sounds and babble, which often resulted in trembling and shaking of her body. According to her belief, the new furnace in the school generated infrasound, which was partly responsible for her symptoms. Later, her symptom attribution became generalized to smartphones, laptops, Wi-Fi, and certain types of loudspeakers.

3.1.2. Interpretation of the MMPI profiles

MMPI profiles of Participant #1 and #2 were surprisingly similar. Paranoia (Pa, Scale 6) and Psychopathic Deviate (Pd, Scale 7) with T scores above 70 are indicative of individuals in a pre-psychotic state with the dominance of paranoid symptoms. Individuals with this high point pair may exhibit poor adaptive functions, are likely to be self-dramatic, hysteroid, and tend to be sensitive to criticism. In contrast, the MMPI profile of Participant #3 can be considered clinically normal, with no score above average (it is worth noting that low T score on F scale suggests a tendency to minimize psychological problems though).

3.1.3. Further psychological characteristics

Participant #1 and #2 scored higher than the M + SD of the reference national non-patient sample on health anxiety (SHAI-S), somatosensory amplification (SSAS), somatic symptom distress (PHQ-15), and somatic and psychological attribution style (SIQ) (Figure 2). Their PHQ-15 score was 18 and 12, respectively. PHQ-15 scores of 10 and 15 represents cut-off points for medium and high somatic symptom severity (Kroenke et al., 2002). In both cases, health anxiety reached the threshold of clinical hypochondriasis. GSQS scores indicated impaired subjective sleep quality in all cases (>2: impaired sleep quality). For Participant #3, only the SSAS score was higher than the M + SD of the reference control sample.

3.2. Assessment of physical environments

Participant #1 and #2 lived in a quiet countryside area during their childhood, and Participant #1 has been living there ever since. As an adult, Participant #2 lived in the capital city for five years, and then returned to a rural area during her pregnancy (her first EMF-related symptoms appeared at that time). Participant #3 lived in an old tenement house in the capital city, even so, in a peaceful environment. She worked as a secretary. Participant #1 and #2 previously also worked in an office environment. None of them reported being exposed to extremely high EMF in the past. None of the participants had wireless network in their homes; Participant #1 had no mobile phone. Exposure

levels measured by the personal dosimeters during the 21-day long EMA were of the same order of magnitude or lower as measured in other European countries in earlier studies (Gajšek et al., 2015; Joseph et al., 2010; Thuróczy et al., 2008; Tomitsch and Dechant, 2015) (for further details, see Part II of this study).

3.3. Highlights of the EMA results

Individual time series analyses of EMA data showed that the associations between different EMF frequency bands and HR and RR were consistently negative, while the direction of the association on HRV-HF was rather inconsistent, across both individuals and frequencies of EM radiation. GSM900 downlink EMF had a negative partial association with symptom score for Participant #1 and Participant #2, i.e., higher exposure was associated with less symptoms. A path analysis indicated that this association was partially mediated by the believed intensity of EM radiation in case of Participant #1, however not for Participant #2. Concerning Participant #3, UMTS downlink EMF had a substantial positive association with the symptom score, i.e., higher exposure predicted more symptom reports, after controlling for all measured intra- and extra-person control variables too. Partial effects were statistically non-significant for all other EMF variables (i.e. frequency bands). The statistical analyses and the results of EMA are presented in detail in Part II of this study.

3.4. Medical analysis

3.4.1. Anamneses

Participants' medical history was reconstructed from their consultants' diagnostic reports from the previous 10 years.

Several years before the first appearance of IEI-EMF, Participant #1 was diagnosed with angina pectoris, essential hypertension, chronically elevated serum sugar-, cholesterol- and triglyceride-levels, and degenerative cervical disc disease. Following the death of her mother (7 years before the appearance of the EMF-symptoms), reactive depression was diagnosed, which had remained untreated. Neurological, rheumatological, and otolaryngological examinations were carried out to assess her frequent tinnitus and headache; results indicated no organic disease. No other diagnosed sensitivity than a penicillin allergy was known to the participant, although she frequently perceived a reaction to household cleaning supplies. She took antihypertensive, vasodilator, pacesetter, anticoagulant, and sedative medication on a daily basis.

Participant #2 was diagnosed with lactose intolerance shortly before she diagnosed herself with IEI-EMF, and with hyperthyroidism 4 years later. To assess her permanent tinnitus and pain in the head, ears, neck, lymph nodes and throat, otolaryngological and neurological examinations and head MRI were carried out, with negative results. Lactose intolerance was her only diagnosed sensitivity, although she experienced reactivity (respiratory complaints) to certain chemicals (NaOH, fungicides). She did not use any medication on a regular basis.

Participant #3 was diagnosed with hypothyroidism. She had a cardiac pacemaker which was checked up annually and did not affect her life quality. She was also diagnosed with arthrosis, spondylosis, olisthesis of vertebrae, osteophytas, and mediolateral discus hernia. She often reported low back pain and obdormition during the EMA, but she did not attribute these symptoms to EMF exposure. Allergological investigation revealed nickel allergy. According to the otorhinolaryngological investigation, her threshold of hearing was lower than average. She took medicine to maintain the serum level of thyroid stimulating hormone.

4. Discussion

This paper presents Part I of a multimodal assessment procedure which could provide us with a deeper understanding of the complexity of IEI-EMF at the individual level. As expected, considerable differences, along with some similarities, among our three participants were revealed.

4.1. Interpretation of the aetiology

4.1.1. EMF exposure

Regarding environmental illnesses, the first important question is whether there are factors in the physical environment which are associated with the appearance of the symptoms. Although even a single-extremely high environmental exposure might serve as a triggering stimulus to IELs in certain cases (Bornschein et al., 2001; Redmayne and Reddel, 2021), our participants had not been aware of past or present permanent or short-term extreme EMF exposure in their everyday environment. Participant #1 and #2 had lived in the countryside for most of their lives, and all of them worked in office environments (earlier or at the time of the study), which were supposedly characterized by low-level or common EMF exposure well below the security threshold. Also, exposure levels measured by the 21-day personal dosimetry were of similar order of magnitude as measured in European countries (Gajšek et al., 2015; Joseph et al., 2010; Thuróczy et al., 2008; Tomitsch and Dechant, 2015), and were well below the international exposure limits (for details, see Part II of this study). These findings do not support our participants' core belief that exposure to EMF might have played the primary role in the development and maintenance of their condition. It is important to note at this point that conditioning and/or nocebo effects can also trigger the development of IEL-EMF beyond actual exposure to EMF (Van den Bergh et al., 2017a,b).

Nevertheless, the possibility remains that the common ambient EMF exposure caused their symptoms, perhaps because of their above average sensitivity to EMF. The findings of the ecological momentary assessment (for details, see Part II), however, do not support this idea for Participant #1 and #2, for whom higher exposure to GSM900 downlink frequency EMF was significantly associated with lower symptom scores. For Participant #3, however, a significant positive association was shown between symptom perception and UMTS downlink frequency EMF exposure, even after controlling for several intra-person (e.g. mood, perception of EMF exposure) and contextual (e.g. social setting, activity, location) control factors. Thus, for all three participants, the genuine biophysical effects of suspected EMF frequencies (i. e. causation of less or more symptoms) could not be excluded. It is important to note, however, that actual exposure to RF EMF in the suspected domain (i.e. what was perceived as a trigger) was not consistently associated with symptoms and physiological activation for any of the participants (see Part II).

4.1.2. Medical factors

It is possible that our participants' complaints - partly or completely - belonged to another medical condition and were just misattributed to EMF exposure. Based on their medical diagnostic reports from the previous 10 years, though, we could not identify conditions that can satisfactorily explain their symptomatology. However, as all of them were characterized by a number of different medical problems before and during the study, it is possible that their non-specific symptoms were concomitants of their poor health status, and were mistakenly ascribed to EMFs. Based on the findings of qualitative studies, it was suggested that IEL-EMF individuals use their self-diagnosed hypersensitivity as a narrative to explain their medically unexplained symptoms to make their condition more reasonable and acceptable (Dieudonné, 2016, 2019). Thus, mistaken attribution of symptoms evoked by other (i.e. non EMF-related) medical problems cannot be excluded for our participants.

4.1.3. Psychosocial factors

The most prominent common characteristic of our participants was the presence of traumatic life event(s) that might have caused remarkably high psychological distress at the time of their occurrence. Trauma and long-term psychosocial stress may initiate the chronic activation of physiological stress responses (Brosschot et al., 2005). Sustained sympathetic arousal may in turn lead to a cognitive-emotional sensitization and distress intolerance (Brosschot, 2002; Ursin and Eriksen, 2001, 2004). This way, stressful life events can generate symptoms through

misattribution of the physiological activation and aroused state; over time, these symptoms mistakenly (see below) might be attributed to EMFs.

For Participant #1 and #2, questionnaire scores indicated above average somatic symptom distress, an elevated tendency to experience somatic sensations as intense, disturbing, and noxious (somatosensory amplification), a tendency to interpret emotional distress as bodily symptoms (somatic attribution style), and fear of having a serious illness (health anxiety), which are in accordance with the findings of Staudenmayer and Phillips (2007). These trait-like, temporally stable psychological characteristics involve increased attentional focus on bodily sensations and health status which can favour the interpretation and labelling of autonomic arousal or even normal bodily processes as symptoms (Barsky et al., 2002; Petrie et al., 2005; Szemerszky et al., 2015a,b). Although the casual role of the aforementioned processes in the development of IEL-EMF is not completely empirically confirmed (Van den Bergh et al., 2017a,b), it is possible that they, most importantly an above-average tendency to monitor the body for symptoms, might have contributed to the reported symptoms. Taking into consideration the design of the present study, however, these associations are clearly speculative. They show that alternative explanations of the condition of our participants exist but do not indicate the priority of these alternative options.

The strongly impaired subjective sleep quality of our participants might also be caused by biopsychosocial factors that are unrelated to EMF exposure. Although disturbances in sleep quality belong to the most frequent complaints related to IEL-EMF (Röösli et al., 2004), most of the studies have not found an association between impaired sleep quality and actual EMF exposure (Andrianome et al., 2016; Mohler et al., 2010, 2012). Nevertheless, subjective quality of sleep has been associated with poor self-rated health, low level of social support and perceived stress in previous studies, while objective sleep efficiency was unrelated to subjective sleep quality, psychosocial characteristics or affect (Jackowska et al., 2011; Tworoger et al., 2005).

Moreover, elevated (although still sub-clinical) levels of hysteria, psychasthenia, hypomania, and schizophrenia were found for Participant #1 and #2. These characteristics are often associated with hyperactive, compulsive, nervous, and distressed states. Negative affect generally causes attentional deployment, emotional reasoning, and biased information processing with respect to threatening stimuli, i.e., selective retrieval of negative memories and drawing invalid conclusions on the basis of the subjective emotional response (Aronson et al., 2001, 2006; Clark, 1999; Mogg and Bradley, 1998; Watson and Pennebaker, 1989). These cognitive-emotional processes may be strengthened by their pre-psychotic state with paranoid tendencies and with projection as the dominant defence mechanism. Henningsen and Priebe (2003) and Staudenmayer et al. (2003b) argue that the central feature of different IELs is a strong and fixed belief of being threatened from the outside, and they assert that only the content of the attribution is syndrome specific. In psychopathological terms, this qualifies as an overvalued idea, or even a delusion. In line with this, the participants rejected the psychosocial explanation for their condition after receiving feedback on null findings (i.e. lack of claimed association between symptoms and EMF exposure; see in Part II), and Participant #1 changed the subject of her conspiracy theory (government and science). These findings, in accordance with the results of Kjellqvist et al. (2016) and Szemerszky et al. (2021), indicate that psychotic and pre-psychotic conditions, including loss of reality, might be significantly associated at least with certain cases of IEL-EMF.

According to the cognitive model by Freeman and colleagues (2002), delusions are maintained by searching for meaning for inexplicable (or unacceptable) experiences, and finding relief which is paired with a "meaning". The personal significance of the overvalued idea for our participants was so strong that it overwrote their general attribution tendencies (Participant #1 and #2 showed above average values in psychological and somatic attribution style). This also raises questions about the applicability of the three attribution styles to environmental

Table 2. Comparison of the three IEI-EMF cases.

Environmental analysis	<ul style="list-style-type: none"> no known extreme EMF exposure in the past (self-reported) no above average EMF level in the present (measured with personal dosimeters) no association between EMF-attributed complaints and suspected RF EMF exposure for Participant #1 and #2 a relationship of suspected EMF exposure with symptom perception and physiological changes cannot be excluded for Participant #3
Medical analysis	<ul style="list-style-type: none"> no other known medical condition which sufficiently explains the symptoms a significant amount of different medical problems and general poor health status in the past and in the present which can be associated with non-specific symptoms
Psychosocial analysis	<ul style="list-style-type: none"> previous life events causing high and long-lasting psychosocial distress social deprivation high levels of negative affectivity, emotional instability and paranoid tendencies for Participant #1 and #2 hypochondriasis and somatic symptom distress for Participant #1 and #2 normal psychological profile for Participant #3 cognitive processes which focus attention on bodily sensations for all participants

Note. Differences are marked in bold.

illnesses, as environmental attribution in the latter case refers to a temporally stable and harmful factor while originally it is the normalizing attribution style (Kóteles, 2021).

In contrast with Participant #1 and #2, however, the psychological profile of Participant #3 can be considered as largely clinically normal, only impaired subjective sleep quality and somatosensory amplification tendency being higher than the average.

To conclude, the results of our three IEI-EMF cases show considerable similarities as well as differences (Table 2). Positive or negative associations between RF EMF exposure and symptoms were found for all three participants (see Part II), however, some of the psychological characteristics, such as high levels of emotional instability, negative affectivity, somatosensory amplification tendency, paranoid tendencies and a pre-psychotic state were also observable for two of them. The psychological profile of the third individual, however, showed no clear pathology. At the same time, significant psychosocial stressors in the past as well as above average scores on the somatosensory amplification scale seemed to be present and plausibly linked to IEI-EMF also for this participant. As the association between exposure to EMF and symptom reporting was positive in this case, the effect of low intensity actual RF EMF exposure could not be excluded in the background of her EMF-related symptoms (for further details see Part II). These findings suggest that careful individual assessment of possible risk factors is required for persons with severe IEI-EMF, as very different patterns of internal and environmental factors can contribute to the condition. This holds true for the association between symptoms and actual exposure to EMF, also warranting an individual analysis instead of the typically used group-level approach (Bogers et al., 2018).

4.2. Limitations

The most important limitation of this qualitative study is that the results of three IEI-EMF cases are not generalizable, these can serve only as demonstrative examples. Moreover, assessment of medical aetiology was based on past examinations only, and the older version of MMPI was used instead of MMPI-2.

5. Conclusion

Substantial differences among participants with severe IEI-EMF with respect to theoretically important psychological characteristics were

revealed. Psychological factors may play a decisive role in the development and maintenance of the IEI-EMF condition for some individuals. If dysfunctional relation to the distress-evoking stimulus exists, a psychological intervention is definitely warranted. The existence of markedly different patterns in the background of IEI-EMF warrants the use of idiographic multimodal assessments, which could provide us with a deeper understanding of the aetiology and may facilitate person-tailored treatment.

Declarations

Author contribution statement

All authors listed have significantly contributed to the investigation, development and writing of this article.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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