

Is There a Connection Between Electrosensitivity and Electrosensibility? A Replication Study

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Published online: 17 March 2015
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Abstract

Background Among people with idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF), a better than random detection ability for a 50-Hz 0.5-mT magnetic field (MF) and a propensity to experience more symptoms than controls was reported in a previous study.

Purpose The current study aimed to replicate and clarify these results using a modified experimental design.

Method Participants of the provocation experiment were 49 individuals with self-reported IEI-EMF and 57 controls. They completed the questionnaires (symptom expectations, Somatosensory Amplification Scale—SSAS, radiation subscale of the Modern Health Worries Scale—MHWS Radiation) and attempted to detect the presence of the MF directed to their right arm in 20 subsequent 1-min sessions. Symptom reports were registered after each session.

Results Individuals with IEI-EMF as opposed to the control group showed a higher than random detection performance (d' index of signal detection theory), while no difference in their bias (β index) toward the presence of the MF was found. Predictors of reported symptoms were self-reported IEI-EMF and believed as opposed to actual presence of the MF. People with IEI-EMF reported significantly more symptoms particularly in the believed presence of the MF. IEI-EMF was closely related to MHWS Radiation and SSAS scores.

Conclusion People with IEI-EMF might be able to detect the presence of the MF to a small extent; however, their symptom reports are connected to perceived exposure.

Keywords Electrosensitivity · Signal detection · EHS · IEI-EMF · Nocebo effect

Introduction

Realization of the possibility that modern technologies might have harmful side effects evoked an increasing public concern which has recently been called modern health worries (MHWs) [1]. According to empirical findings, there are well-defined categories within MHWs in people's mind [1–5], and fears related to electric and magnetic fields or electromagnetic radiations (EMFs) represent such a distinct category beyond environmental pollution (e.g., traffic fumes), toxic interventions (e.g., toxic chemicals in household products), and tainted food (e.g., food additives). Characteristics of EMFs make them particularly menacing for laypeople who usually have insufficient information on the phenomenon: they are invisible, present almost everywhere today, and (according to the stereotypical belief) can permeate body tissues as well as buildings. From a professional point of view, of course, different ranges of electromagnetic radiation pose different threats, depending on their frequency and magnitude [6, 7].

Although the domain of extremely low frequency magnetic fields (ELF MFs, 30 to 300 Hz) is considered harmless below the reference levels ($B=0.2$ mT for public exposure and $B=1$ mT for occupational exposure) [6], there are people who experience and report unpleasant symptoms in the proximity of electric devices working at this frequency range. The phenomenon is called idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF) (formerly electromagnetic hypersensitivity, EHS, or electrosensitivity) [8], and it is not restricted to the ELF range. Symptoms are reported with respect to all frequency domains, in fact, many people experience symptoms related to devices operating at very different EMF frequencies (mobile phones, computers, power lines, Wi-Fi routers, etc.). As reported symptoms were not related to the presence of the MF/EMF in the majority of double-blind experiments [9–13], they were also experienced

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during sham exposure [14–16], and their severity was a function of the believed magnitude of the field [17], we can conclude that IEI-EMF refers to sensitivity to *believed* as opposed to *actual* presence of MFs/EMFs. Moreover, reports of symptoms attributed to MF/EMF exposure were related to certain trait-like personality characteristics and cognitive-emotional factors (e.g., somatization tendency, somatosensory amplification, elevated risk perception, MHWs, expectations) [17–20]. In summary, although there were a few studies that reported a connection between symptoms and actual MF/EMF exposure [21–23], the IEI-EMF phenomenon is recently regarded as mainly of psychogenic origin [24, 25] or, in other words, as a nocebo-related phenomenon [9, 10, 17, 19].

The individual ability to perceive electric or electromagnetic exposures (electrosensitivity, ES) is not necessarily related to symptom reports [26]: people with IEI-EMF were usually not able to detect the presence of MFs/EMFs [10, 11]. However, in a previous double-blind provocation experiment using the methodology of signal detection theory (SDT), we found a better than random detection performance (i.e., a higher than zero d' index) with respect to 50 Hz 0.5 mT MF among people with IEI-EMF while controls could not discriminate between presence and absence of the MF during 20 subsequent 1-min sessions [19]. Moreover, IEI-EMF was connected to a higher bias (i.e., a stronger tendency to assume the presence of the MF, or, in technical terms, a lower decision criterion, β), to more reported symptoms, to higher levels of somatosensory amplification, and to higher scores on the radiation subscale of the MHW scale. Unfortunately, symptom reports were obtained in a retrospective manner, following the last detection session, thus symptoms might have been of psychogenic as well as of “toxicogenic” origin (i.e., caused by the exposure). In consequence, although the IEI-EMF group showed a better detection performance and reported more symptoms than the control group, we were not able to directly investigate the link between sensibility and actual sensitivity. The current study aimed (1) to replicate previous findings and (2) to investigate the abovementioned relationship using a modified experimental design with symptom reports registered after each detection session. Concerning the second point, it was hypothesized that symptom reports would be connected to believed but not to actual EM exposure (i.e., reported symptoms would be of psychogenic origin).

Materials and Methods

Participants

Participants were recruited by advertisements in a daily advertising paper. In the advertisements, individuals with or without IEI-EMF (defined as experiencing unpleasant symptoms in the presence of electromagnetic fields, see below) willing to

participate in a MF-related experiment were recruited. Exclusion criteria were left-handedness, and the presence of major medical disorders or acute health problems or symptoms (e.g., PMS, common cold).

A priori sample size calculation was based on the detection-related results of our previous study. In that study, an effect size of 0.47 was found in the IEI-EMF group. For the present study, considering an effect size of 0.45, 0.05 for type I error, 0.9 for type II error, and one-tailed t -test, a sample size of 44 was calculated as necessary for each group. Taking into account possible data loss due to outliers and possible technical problems, this number was rounded up to 49–50. For methodological reasons, advertisements for and experiments in the IEI-EMF and the control group were running simultaneously, and while the size of the IEI-EMF group reached the planned value of 49, the control group already comprised 57 individuals.

Two applicants were excluded due to the presence of acute symptoms and one who did not met our criteria of IEI-EMF (no device working in the ELF range was mentioned). Finally, data of 49 individuals with self-reported IEI-EMF (mean age=34.8 years, IQR=18; 49.0 % male) and of 57 control people (35.4 years, IQR=25; 56.1 % male) were included in the analysis. Participants received 3000 HUF (approx. 10 EUR) for their participation. The study has been approved by the Institutional Ethical Review Board of the Eötvös Loránd University, Budapest, Hungary.

Questionnaires

Idiopathic Environmental Intolerance Attributed to Electromagnetic Fields (IEI-EMF) One single yes-or-no question about being sensitive to electromagnetic fields (“Many people experience unpleasant symptoms (e.g., headache, nausea, concentration problems, palpitation, etc.) when staying in electromagnetic fields (e.g., near electric devices, computers, electric power lines, or during mobile phone calls). This phenomenon is called electromagnetic hypersensitivity or electrosensitivity. Do you consider yourself to be electrosensitive?”).

Expectations One question rated on a 5-point Likert scale (1= *not at all* to 5=*certainly*) about the estimated probability of experiencing unpleasant symptoms attributed to the magnetic exposure during the experiment.

Radiation Subscale of the Modern Health Worries Scale (MHWS Radiation) [1] The MHWS is a 25-item scale that measures people’s concerns about the possibly harmful effects of the features of modern life on a 5-point Likert scale from 1 (“no concern”) to 5 (“extreme concern”). The scale consists of four subscales: environmental pollution, toxic interventions, tainted food, and radiation. In the present study, only the three-item radiation subscale (assessing concerns about radiation

from cell phones, radio or cell phone towers, and high tension power lines) of the Hungarian version of the MHW scale [27] was used. Its internal consistency was 0.87 and 0.88 for the IEI-EMF and the control group, respectively.

Somatosensory Amplification Scale (SSAS) [28] A 10-item scale that measures the tendency to experience somatic sensations as intense, noxious, and disturbing on a 5-point Likert scale from 1 (“not at all”) to 5 (“fully”). The Hungarian version of the SSAS proved to be valid in previous studies [17, 29]. Its internal consistency (Cronbach’s alpha coefficient) was 0.65 and 0.74 for the two groups in the present study.

Motivation to Cooperate (CoMotiv) A 6-item scale controlling for participants’ cooperativity bias. The items (e.g. “I can cooperate with the researchers of the study very well”) measure the perceived amiability and professionalism of the researcher and the overall professionalism of the whole study on a 5-point Likert scale with the anchor points of 1 (“not at all”) and 5 (“fully”). Higher scores refer to higher motivation to cooperate in the experiment. The scale was used in previous studies [17, 19], and its internal consistency was 0.91 and 0.87 for the two groups in the current study, respectively.

Experienced Symptoms A 16-item list containing 15 often mentioned somatic symptoms related to the central nervous system (CNS) (headache, dizziness, fatigue, blurred vision), to visceral functions (palpitation, nausea, sweating), or felt in the right (exposed) hand (warm or hot sensation/crawly feelings/itching or irritation on the skin; cold palm; warm feelings/pain/crawl/muscle tension in the forearm or in the hand). An ‘other’ category for symptoms that had not fit into the previously mentioned categories was also included. The questionnaire was a shortened version of the list used in our previous experiment [19]. Participants were asked to rate severity of each symptom on a 4-point scale (1=*no symptom at all*; 2=*mild*; 3=*definite*; 4=*severe*) as experienced during the previous exposure session.

Additional Questions Participants of the IEI-EMF group were asked to answer several questions to better characterize their condition. The questions concerned (1) the device(s) they are sensitive to (open question), (2) the symptoms they usually experience (open question), (3) mean severity of these symptoms (1=*low*, 2=*medium*, 3=*high*), and (4) the negative impact of these symptoms on their everyday life (0=*no impact at all*, 1=*some impact*, 2=*medium impact*, 3=*high impact*).

Magnetic Field

MF was generated by a standard Helmholtz coil apparatus. The device consisted of two coils (inner diameter 42 cm, outer diameter 55 cm) placed on a common axis spaced apart at a

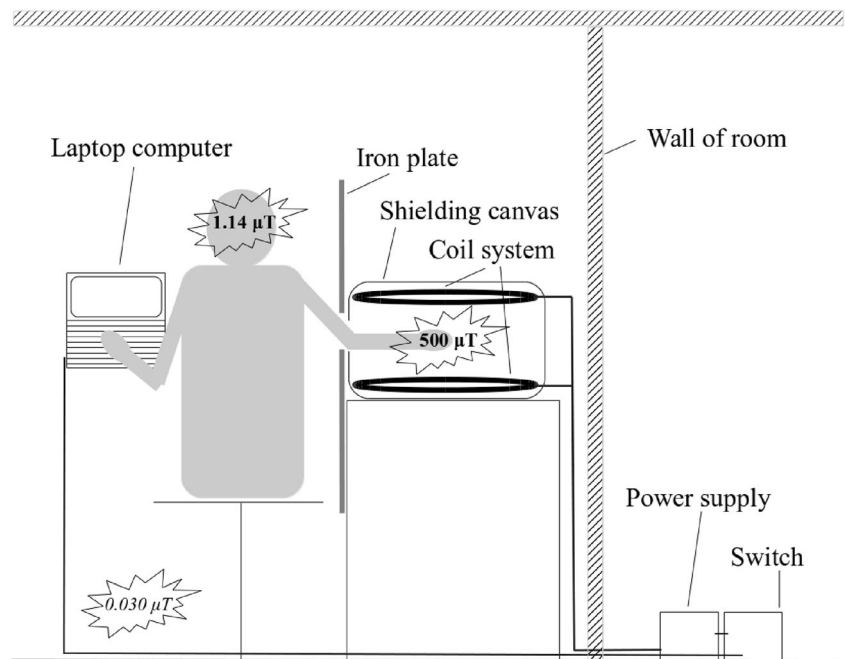
distance equal to their radii (21 cm) with equal currents flowing in the same direction. Helmholtz coil produces a homogeneous MF in the space between the coils. The coils were constructed of glaze-insulated copper wire ($d=1.4$ mm) and had 240 turns (DC resistance was $2.9\ \Omega$). A sinusoidal current with 50 Hz frequency, generated by a 230 V, 180 VA adjustable toroidal transformer, was fed into the coils, producing an oscillating magnetic field. The level of magnetic flux density was set at $500\ \mu\text{T}$ (rms). This value represents a relatively high level: magnetic flux density on 50 Hz generated by commonly used household devices at a similar distance (50 cm) ranges from $0.05\ \mu\text{T}$ (refrigerators) to $1.66\ \mu\text{T}$ (microwave ovens) [30]. Moreover, magnetic flux densities from 0.7 to $2.9\ \mu\text{T}$ were measured in the proximity (15 m) of power transmission lines [31].

Participants were requested to put their right hand between the coils (as symptoms attributed to MF in the ELF range are often reported following the use of handheld household devices, exposure was directed to the hand). MF exposure of other body parts was minimized by an iron plate (dimensions $800\times 500\times 2$ mm) positioned between the coil system and the participants’ body, and by covering the coils with a special fabric containing copper fibers (both shields had a gap through which the hand could have been put between the coils) (for details, see Fig. 1). Ambient magnetic field in the room was $0.030\ \mu\text{T}$. When the laptop computer used in the experiment was turned on, the stray magnetic flux density measured at the position of participants’ head was $0.036\ \mu\text{T}$. During the operation of the Helmholtz coil, the latter value was $1.14\ \mu\text{T}$. Magnitudes of the MF were measured by a hand-held electric and magnetic field meter (Maschek-ESM-100, Bad Wörishofen, Germany).

Procedure

Participants were tested one by one in a separate room. Upon arrival, they were asked to confirm that they consider themselves electrosensitive/not electrosensitive using the definition described above, and then they read and signed an informed consent form. They were told that the aim of the study was to investigate their ability to detect a magnetic field of low magnitude. People with IEI-EMF were asked to answer the additional questions on their complaints. Participants were asked to sit on the experimental seat and to put their right hand onto an ergonomic support placed between the two magnetic coils (in phase 2 only, see below). The experimenter left the room and the participants followed the instructions of a computer program during the whole experimental session. In phase 1 of the experiment, sociodemographic and personality variables, motivation to cooperate, and symptom expectations were recorded. In phase 2, participants were informed that they had to attempt to detect the presence/absence of a MF of low magnitude in 20 subsequent 1-min sessions. During the 20 detection

Fig. 1 Sketch of the experimental setting. Magnetic field generated by the Helmholtz coil was shielded by an iron plate and a copper-based fabric. *Values marked in bold indicate magnetic flux densities with the coil system and the laptop computer turned on. Value marked in italic refers to ambient magnetic field*



sessions, the power supply of the coils was enabled or disabled by the computer software in a quasi-random pattern (i.e., to achieve an equal frequency of the two options, only random sequences representing 10 on and 10 off trials were used). After each session, participants had to guess whether the field was enabled or disabled and they also completed the symptom list. Detection sessions were separated by 30-s relaxation periods. At the end of the experiment, participants were assured that the experienced symptoms were transient and harmless, and they received the reward for their participation. Finally, they were asked to report all complaints and problems that they attribute to the experiment via E-mail. No reports were received.

Steps Taken to Exclude Indirect Cues

As one of the aims of the experiment was to exclude possible confusing factors and indirect cues that might have contributed to previously reported findings, the whole experimental equipment was moved to another building of the university. Power supply of the coils and the control switch were located in an adjacent room equipped with a sound-proof door. Coolers of the power supply were operating during the whole experiment, not just in the active 1-min periods of the trials (therefore, noise level did not change during the experiment). As the coils were covered by an isolating plastic material, no changes in temperature were measurable (with a tolerance of 0.1 °C) even on the surface of the coils in a 5-min period (duration of the trials in the experiment was 1 min). Background noise level in the room was between 34.8 and 36.3 dB (A-weighted average), and change in noise level after

turning on the power supply of the coils was under 0.1 dB (A-weighted average) which is clearly under the human discrimination threshold. To prevent transmission of vibrations to the participants' hand, the isolating metal plate and the flexible hand support were fixed independently from the coils. In fact, even direct touching of the coils caused no feeling of vibration.

To minimize the chance of cheating in the detection task, participants were asked to put all personal properties (mobile phones, watches, backpack, rings, necklaces, etc.) in a place that was unreachable for them during the experiment. In addition, there was a mirror-like window in the wall of the experimenting room. In the introduction phase of the experiment, participants were showed this window and were told that the experimenter would watch them during the whole experiment from the adjacent room. In fact, this supervision was conducted only occasionally (2–3 times in each experiment). No cheating attempts were uncovered.

Statistical Analysis

As for signal detection-related calculations, hit rates and false alarm rates were calculated from the results of the 20 detection sessions (hit rate=corrected number of hits/10, false alarm rate=corrected number of false alarms/10). Numbers of hits and false alarms (N) were corrected according to the generally accepted method: if $N_{\text{original}}=0$, $N_{\text{corrected}}=0.5$, and $N_{\text{corrected}}=N_{\text{original}}-0.5$ for all other cases [32]. Using the corrected hit and false alarm rates, a discriminability index (d') characterizing detection ability and the classical β index that estimates participant's bias toward *yes* or *no* answers was calculated for

each participant, then individual indices were averaged within the two groups. As the requirement of normality was fulfilled (Kolmogorov-Smirnov statistics), one-sample *t*-tests were used to check whether means of *d'* indices differ from zero in the IEI-EMF and the control groups, respectively. Mean *d'* and β values of the two groups were compared by two-sample *t*-tests. Connection between *d'* and total reported symptom score was checked using Pearson correlation.

Total scores of the questionnaires were calculated after reverse-scoring of respective items. A total symptom score was also composed by summarizing the scores of the 20 sessions. Differences between the two groups in gender ratio and age were checked using χ^2 test and Mann-Whitney test, respectively. As data were appropriate for parametric statistical analysis, differences between the two groups in terms of questionnaire scores were investigated by two-sample *t*-tests. Symptom scores were summarized for each 1-min session, then average symptom scores were calculated for the four detection categories (i.e., *hits*, *false alarms*, *misses*, and *correct rejections*) for each person. Predictors of symptoms were investigated in two ways. First, multiple linear regression analysis was used to identify personality predictors of total symptom score. After checking data for multicollinearity and independence of the residuals, variables were entered in three steps: (step 1) sociodemographic control variables (age; gender: 0=male, 1=female; educational qualification), (step 2) situational variables (motivation to cooperate; symptom expectation score), (step 3) trait-like personality variables (IEI-EMF: 0=no, 1=yes; SSAS; MHWS Radiation). Second, a mixed analysis of variance with a design of $2 \times 2 \times 2$ was carried out. In this analysis, within-subject categories were the four detection categories mentioned above (i.e., *actual* presence/absence of the MF $\times$ *perceived or believed* presence/absence of the MF), and IEI-EMF was used as a between-subject variable (yes/no). In this analysis, data of 10 subjects (7 controls and 3 with IEI-EMF) were not usable as one of the four categories were missing (e.g., no correct rejections or false alarms were made).

Personality predictors of IEI-EMF were analyzed by multiple binary logistic regression analysis. Variables were entered into the regression equation in two steps: (step 1) age, gender, educational qualification and (step 2) SSAS and MHWS Radiation scores.

Results

Features of Self-reported IEI-EMF

Mean number of devices mentioned by participants was 2.30 ± 0.98 , and everyone listed at least one device working at the extremely low frequency range. Most often reported devices causing symptoms in everyday situations were mobile phones

(56.1 %), television monitors (38.3 %), PCs or laptop computers (35.3 %), and microwave ovens (29.4 %). Typical symptoms connected to the phenomenon were headache (70.6 %), dizziness (20.1 %), crawly feeling on the skin or in certain body regions (17.7 %), and nausea (11.8 %). Reported severity of the symptoms was low in 73.5 % and medium 26.5 % of the participants; mean impact of the symptoms on their daily life was 1.88 ± 0.686 referring to a medium impact.

Detection of the MF

Means and SDs of hits and false alarms for the two groups are presented in Table 1. According to the results of the *t*-tests, the mean of the *d'* indices in the control group did not differ significantly from zero ($M=0.110$, $SD=0.641$; $t(56)=1.291$; $p=0.202$; $d=0.172$), while a significant difference was found in the IEI-EMF group ($M=0.280$, $SD=0.919$; $t(48)=2.131$; $p=0.038$; $d=0.305$). It is worth mentioning that a *d'* value of zero indicates completely random guessing while a perfect detection performance would be characterized by 3.3 in this case. However, the difference between the *d'* values of the two groups was not significant ($t(104)=1.116$; $p=0.267$; $d=0.219$). Similarly, correlation between detection performance (*d'*) and total reported symptom score (as an alternative indicator of electrosensitivity) was close to zero ($r=0.04$, $p=0.687$). No significant difference between mean β values of the two groups was found (IEI-EMF group: $M=1.225$, $SD=0.705$; control group: $M=1.176$, $SD=0.622$; $t(104)=-0.380$; $p=0.705$; $d=-0.074$).

Descriptive Statistics and Comparison of the Two Groups

The two groups did not differ from each other in terms of age (Mann-Whitney $U=1350$, $p=0.768$) and gender ($\chi^2=0.340$, $p=0.560$), and no significant difference between their motivation score was found either (Table 2). On the other hand, the IEI-EMF groups showed significantly higher expectation, SSAS, MHWS Radiation, and total symptom scores than the control group. Effect sizes in these differences were in the large domain (for details, see Table 2).

Table 1 Means and standard deviations of hits and false alarms for the two groups

Group	Number of hits (mean $\pm$ SD)	Number of false alarms (mean $\pm$ SD)
IEI-EMF	5.61 $\pm$ 1.967	4.71 $\pm$ 2.273
Control	4.16 $\pm$ 2.016	3.84 $\pm$ 2.136

Table 2 Descriptive statistics (means and standard deviations) of the two groups, results of *t*-tests, and effect sizes

	IEI-EMF	Control	<i>t</i> (104)	<i>p</i> value	Cohen's <i>d</i>
Motivation	28.20±3.747	27.03±4.226	−1.496	0.138	−0.293
Expectations	2.80±0.816	2.18±0.782	−3.992	<0.001	−0.783
SSAS	35.41±5.972	27.61±7.218	−5.997	<0.001	−1.176
MHWS Radiation	8.59±3.109	5.84±2.590	−4.968	<0.001	−0.974
Total symptom score	85.29±71.966	37.00±36.145	−4.456	<0.001	−0.874

SSAS Somatosensory Amplification Scale, MHWS Radiation radiation subscale of the Modern Health Worries Scale

Reported Symptoms

As for possible psychological predictors of total symptom score, expectations proved to be significant predictors after controlling for sociodemographic variables and motivation to cooperate in step 2 of the multiple linear regression analysis. In the final equation (step 3), however, electrosensitivity (IEI-EMF) remained the only significant predictor (this equation explained 26 % of the total variance; see Table 3 for details).

In the mixed ANOVA analysing effects of the MF on reported symptoms, no *actual* MF main effect ($F(1)=0.910$; $p=0.343$) was found, and none of the interaction terms containing the *actual* presence/absence of the MF were statistically significant. On the other hand, main effect of the *believed* presence/absence of the MF was highly significant ($F(1)=180.062$; $p<0.001$) as well as the effect of the between-subject factor (IEI-EMF; $F(1)=128.608$; $p<0.001$). Moreover, a significant interaction between *believed* presence/absence of the MF and IEI-EMF was found ($F(1)=20.416$; $p<0.001$) (for details, see Table 4).

Table 3 Standardized β -coefficients of the three steps of the multiple linear regression analysis predicting total experienced symptom score

	Step 1: $\Delta R^2=0.10$; $p=0.797$	Step 2: $\Delta R^2=0.118$; $p<0.05$	Step 3: $\Delta R^2=0.260$; $p<0.001$
Gender	0.047	0.040	0.005
Education	−0.034	0.026	0.096
Age	−0.073	−0.050	−0.146
Expectations	—	0.324***	0.141
Motivation	—	−0.085	−0.154
MHWS Radiation	—	—	0.196
SSAS	—	—	0.062
IEI-EMF	—	—	0.267*

SSAS Somatosensory Amplification Scale, MHWS Radiation radiation subscale of the Modern Health Worries Scale, IEI-EMF electrosensitivity

* $p<0.05$; *** $p<0.001$

Personality Background of IEI-EMF

According to the results of the multiple binary logistic regression analysis with IEI-EMF as a criterion variable, SSAS and MHWS Radiation scores remained significant predictors after controlling for sociodemographic variables (Table 5).

Discussion

In a double-blind provocation experiment, individuals with IEI-EMF as opposed to controls were able to detect the presence of a 500- μ T 50-Hz MF to a small extent (i.e., their accuracy was not far from random guessing). However, no direct connection between IEI-EMF (electrosensitivity) and detection performance (electrosensibility) was found. As for reported symptoms, (1) *actual* presence of the MF had no impact on symptom reports, (2) more symptoms were reported in the *believed* presence of the MF (i.e., hits or false alarms) in both groups, and (3) people with IEI-EMF reported more symptoms than controls, particularly when they believed that the MF was present. Higher levels of somatosensory amplification and higher scores on the radiation subscale of the MHWS were independently related to IEI-EMF even after controlling for sociodemographic variables.

An important thing that should be kept in mind when evaluating these findings is that participants in the IEI-EMF group were not patients with serious complaints. They voluntarily participated in the experiment and reported severity of their symptoms, and impact of their condition on their everyday life lied in the low to medium range. Their most often mentioned

Table 4 Average symptom scores and standard deviations for the four detection categories in the two groups

	IEI-EMF	Control
Hits	6.18±4.215	3.12±2.295
False alarms	6.06±4.116	3.08±2.336
Correct rejections	1.99±3.165	0.98±1.416
Misses	1.94±3.042	1.10±1.563

Table 5 Parameters of the two steps of the multiple binary logistic regression analysis predicting self-reported electrosensitivity (0=no; 1=yes)

	Exp(B) (95 % C.I.)
Step 1: $p=0.249$; Cox and Snell $R^2=0.038$; Nagelkerke $R^2=0.051$	
Gender	1.476 (0.670–3.249)
Age	1.004 (0.975–1.033)
Education	0.473 (0.213–1.053)
Step 2: $p<0.001$; Cox and Snell $R^2=0.310$; Nagelkerke $R^2=0.414$	
Gender	1.045 (0.399–2.737)
Age	0.976 (0.939–1.015)
Education	0.566 (0.217–1.475)
SSAS	1.140 (1.051–1.237)**
MHWS-R	1.283 (1.051–1.566)*

SSAS Somatosensory Amplification Scale, MHWS Radiation radiation subscale of the Modern Health Worries Scale

* $p<0.05$; ** $p<0.01$

complaints (headache, dizziness, crawly feelings, nausea) clearly belong to the so-called non-specific category which means that the source of these complaints is difficult to identify [33–36].

The most surprising finding of our earlier research, namely the better than random detection performance of the IEI-EMF group, was replicated in the current study, even the magnitude of the d' indices was quite similar ($M=0.296$ vs 0.280). Similarly, d' indices of the control groups did not statistically differ from zero in both studies. It is worth mentioning, however, that detection performance of the IEI-EMF group was only slightly better than random (i.e., it was far from perfect discrimination), and there was no statistically significant differences between the detection performance of the groups. Still, better performance of the IEI-EMF group cannot easily be explained by leaking of information due to insufficient preventive measures (e.g., through changes in levels of noise or heat generated by the equipment), as this factor must have affected both groups. An alternative possibility is that electrosensitives are not specifically sensible to MFs but are generally more sensible to normal sensory information (in this case: to indirect cues) than controls, and this factor lies behind their better detection performance. As no known and accepted neural mechanism for the detection of MFs exists (although speculations and theories were proposed, for example, intracorporal electric fields generated by pulsed MFs can directly stimulate peripheral nerves) [37–39], neither of the two possibilities can be excluded. Moreover, symptom reports did not correlate with detection performance. These findings support the hypothesis that electrosensitivity and electrosensibility are not directly connected to each other.

Participants in the IEI-EMF group of our previous experiment showed a significantly higher bias toward the presence

of the MF than the controls. In the current study, however, no such difference between the two groups was found. Level of bias applied by participants always heavily depends on demand characteristics of the experiment and on other situational factors. In this respect, there was an important difference between the two experiments. After each detection session of the current study, participants had not only to make a guess at the presence or absence of the MF as in the first study, but they also had to report their complaints in detail. This latter task might have induced a more critical attitude which caused a shift in the level of bias (in fact, both groups were slightly biased toward answering “no” in the current experiment).

Sensibility and sensitivity to MFs are two distinct characteristics; the latter refers to the symptoms and complaints that are *attributed* to the MFs. While results of our previous experiment did not shed light on the exact connection between these phenomena (symptoms were reported only once, following the 20 detection sessions), the current experiment was intentionally designed to differentiate between possible factors behind sensitivity, e.g., *actual* and *believed* presence of the MF. According to the results, symptom reports were connected only to believed (*perceived*) but not to *actual* presence of the MF which clearly reflects a top-down cognitive process. Moreover, people with IEI-EMF had higher expectations of symptoms, reported more symptoms, and showed higher levels of somatosensory amplification and more EMF-related concerns. These findings are in accordance with previous results and give us some insight into the *top-down* (or *nocebo-like*) process of symptom generation. Basically, an interaction of trait-like (i.e., temporally stable) personality characteristics and situational factors (proximity of operating electric devices) leads to the *perception* of more symptoms. Similarly to the previous experiment, misattribution of symptoms of other origin (e.g., the inconvenient hand support of the experimental equipment) may have also contributed to the symptom reports. Moreover, people with higher levels of somatosensory amplification are *per definitionem* prone to experience body sensations as more disturbing and possibly harmful. In other words, the same body signals and sensations lead to the reporting of more symptoms in their case. This propensity was found to be an important factor behind modern health worries [4, 27, 40] which are closely related to the IEI-EMF phenomenon [41, 42].

Limitations

Most important limitation of the present study concerns its external validity, as the two groups were not representative of their respective populations. In fact, the IEI-EMF group represented individuals with not really severe complaints—data obtained from this group is not generalizable for patients with IEI-EMF. Second, as symptoms were registered after

each detection session, a carryover process (i.e., symptoms reported following a given session originated from previous sessions) may have occurred. Third, symptoms were assessed by a checklist which usually increases symptom reports compared to a free reporting paradigm. Fourth, only self-evaluation but no expert diagnoses was used to check electrosensitivity and the absence of major psychiatric disorders. Five, according to our current knowledge, no accepted model concerning the biophysical mechanism of the detection exists (the amplitude of the MF exposure used in the study was below the excitation threshold). Finally, although careful steps were taken to avoid the use of indirect cues during the detection sessions, this possibility can never be completely excluded.

Conclusions

Sensibility and sensitivity to a 500- μ T 50-Hz MF seem to be independent of each other. People with IEI-EMF of low severity might be able to detect the presence of the MF to a small extent; however, their symptom reports are clearly connected to the believed as opposed to the actual presence of the MF.

Acknowledgments This research was supported by the Hungarian National Scientific Research Fund (OTKA K 76880, K 109549) and by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences. The authors would like to thank Prof. Wolfgang Schwartz for his help and valuable comments on signal detection calculations and György Thuróczy for his comments on the exact description of the physical characteristics of the experimental equipment.

Conflict of Interest All authors declare that they do not have any conflict of interest.

Ethical Statement The authors state that all procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

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