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Polluted places or polluted minds? An experimental sham-exposure study on background psychological factors of symptom formation in 'Idiophatic Environmental Intolerance attributed to electromagnetic fields'

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ABSTRACT

Introduction: 'Idiophatic Environmental Intolerance attributed to electromagnetic fields' (IEI-EMF) refers to the perception of subjective symptoms during or following EMF exposure. IEI-EMF has become disproved to be a mostly biologic entity by now, and evidences accumulate to support the role of nocebo effect in the phenomenon. The two aims of this study were to demonstrate the significant role of the nocebo effect in physical symptoms reported at 50 Hz frequency of EMF exposure, as well as to explore some psychological factors which may predispose to IEI-EMF.
Methods: A total of 40 volunteer university students have completed a battery of psychological questionnaires (expectations; IEI-EMF; state anxiety – STAI-S; dispositional optimism – LOT-R; somatisation – PHQ-15; somatosensory amplification – SSAS) before, and checklists of physical symptoms during sham exposure to "weak" and "strong" EMFs, respectively. Participants were also asked about the extent to which they had perceived the presence of the presumed EMF.
Results: Participants with higher IEI-EMF scores expected and experienced more symptoms. Suggestion of stronger EMF exposure resulted in larger symptom scores and enhanced EMF-perception as compared to the presumed weaker exposure. Experienced symptom scores were predicted primarily by somatisation scores, whereas self-rating of IEI-EMF was predicted by somatosensory amplification scores.
Conclusion: The results confirm that there is considerable nocebo effect in symptom reports related to 50 Hz frequency EMFs. IEI-EMF seems to be formed through a vicious circle of psychosocial factors, such as enhanced perception of risk and expectations, self-monitoring, somatisation and somatosensory amplification, causalization and misattribution.

Introduction

As a consequence of the continuously increasing exposure to artificial electromagnetic fields (EMFs), there is a growing number of people who worry about possible harmful effects of EMFs, and report symptoms attributed to the exposure (Sivertsen and Hysing, 2008). Originally, this phenomenon was described as 'electrosensitivity' or 'electromagnetic hypersensitivity' (Bergqvist and Vogel, 1997). Recently the term 'Idiophatic Environmental Intolerance attributed to electromagnetic fields' (IEI-EMF) was recommended because of its aetiologically more neutral meaning (Hillert et al., 2006).

The aetiology of IEI-EMF is unknown, as no widely accepted bioelectromagnetic mechanism is proposed to explain the perceived symptoms to date (NRPB, 2004; Schrottner and Leitgeb, 2008). In double-blind experimental provocation studies, no connection between exposure to EMFs and reported symptoms have been found in the radio frequency range (for reviews, see Roosli, 2008; Rubin et al., 2009; Seitz et al., 2005). Much less attention has been paid to extremely low frequency (0–300 Hz), particularly to power-line (50/60 Hz) frequency EMF, though its world-wide prevalence in homes and workplaces may result in a lifetime accumulated ELF-EMF exposure. A significant effect of EMF has been found only in one experiment of nine exposure studies in this category (Mueller et al., 2000), but since the exposure was associated with higher levels of pleasure and arousal, this finding does not seem to support the hypothesis that IEI-EMF sufferers are indeed adversely affected by EMF. None of the other studies reported significant differences between IEI-EMF and control participants (David et al., 2006; Lyskov et al., 2001; Mueller et al., 2002; Reissenweber et al.,

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2000; Toomingas, 1997; Trimmel and Schweiger, 1998; Wennberg et al., 1994; Wenzel et al., 2005).

According to Staudenmayer, there is no evidence supporting the fundamental postulate that IEI has a toxic aetiology. In contrast, the results of several double-blind, placebo-controlled studies suggest a psychogenic origin (Staudenmayer, 2006). In the experiment of Rubin et al. (2006), sham exposure to EMF was sufficient to trigger severe symptoms in some participants. Generally, symptom scores in provocation studies were related to the beliefs about exposure rather than the actual presence or intensity of EMF (e.g. Lonne-Rahm et al., 2000; Regel et al., 2006; Rubin et al., 2006). In addition, Landgrebe et al. (2008) found that the anticipation of an exposure to sham mobile phone radiation resulted in increased activations in the anterior cingulate and the insular cortex as well as in fusiform gyrus in electrosensitive persons compared to controls. These brain areas are supposed to be involved in the perception of unpleasantness and also in generation of functional somatic syndromes.

In the context of medication, symptoms or adverse side effects of drugs that cannot be explained by the pharmacological action of an active substance are called non-specific or nocebo symptoms (Barsky et al., 2002). As the toxic aetiology of IEI-EMF has failed to be supported, it is reasonable to speculate that subjective symptoms attributed to EMF exposure are at least in part of nocebo origin. Nevertheless, other factors (e.g. environmental influences, pathological body processes) may also play a role, and the interaction of these factors is also possible. In contrast to the majority of provocation studies which applied uni- or bi-modal approaches, Brand et al. (2009) adopted a multi-modal interdisciplinary procedure by gathering medical, environmental, and psychological data, respectively, and assessed complaints attributed to environmental agents. They found that a multi-causal base could be detected in all patients, with different degrees of involvement of the three factors examined. The complaints of 47.5% of the participants could be linked to real environmental and/or somatic findings.

However, if symptoms reported by IEI-EMF sufferers are at least partly of nocebo origin, background mechanisms of symptom formation might be similar as well. Non-specific symptoms are usually regarded as amplified signals of normal body processes or as somatic concomitants of emotions or stress (Barsky et al., 1988; Barsky et al., 2002). If there is no clear explanation for the perceived bodily changes or symptoms, people tend to create one, which is called labelling (Mechanic, 1972) or, more generally, misattribution. Modern life is characterized by overly strong attention and concern about environmental hazards (Petrie et al., 2001), and the thereby evoked negative expectations and worries invoke many possible and partly incorrect explanations. Misattribution then focuses attention on the complaints, which generates anxiety and rumination (Brown, 2006), and may, in turn, enhance symptoms. In other words, symptom generation and misattributional processes may depend on the subjective perception of risk (Frick et al., 2002).

Moreover, it is reasonable to speculate that people with IEI-EMF may be characterized by similar personality features as people with enhanced nocebo reactivity. Important personality features suspected to be behind nocebo reactivity are somatisation tendency ("the proneness to express emotional dysphoria as somatic symptoms"; Spinhoven and van der Does, 1997), somatosensory amplification ("the tendency to experience somatic sensation as intense, noxious, and disturbing"; Barsky et al., 1988), and pessimism (Barsky et al., 2002; Geers et al., 2005; Köteles and Bárdos, 2009). Furthermore, one of the most important situational factors behind the nocebo effect is anxiety (Barsky et al., 2002; Keeley, 2002). In the study of Rubin et al. (2008), the general IEI-EMF group had significantly higher scores for depression and worries about toxic agents than the mobile phone sensitive and control groups. In a large-scale survey, Eltiti et al. (2007) found that IEI-EMF individuals reported greater severity of the same symptoms that occur naturally in the general population. All these personality characteristics are associated with the broader construct of negative affectivity, thus negative affectivity is suspected to be a significant risk factor of IEI (Bailer et al., 2007; Petrie et al., 2004). Furthermore, IEI has been associated with a tendency to experience self-altering states of consciousness (absorption as a personality trait; Witthoft et al., 2008).

The aim of the present study was twofold. First, the emergence of nocebo phenomenon associated with 50 Hz frequency EMFs was studied in an experimental unimodal approach, by means of sham exposure accompanied by suggestions about the presence of a low and a high intensity EMF, respectively. The second aim of the current work was the investigation of nocebo-related personality characteristics as psychological risk factors in IEI-EMF and in symptom reports associated with the phenomenon.

It was hypothesized that increased perception of symptoms as well as of the presence of sham EMF would be reported (1) by participants with larger self-rated IEI-EMF, and (2) in the presumed presence of higher intensity EMF. In addition, higher somatisation and somatosensory amplification scores, increased anxiety throughout the experimental session, and lower optimism scores were hypothesized to predict (3) increased reporting of symptoms and (4) self-rating of IEI-EMF.

Method

Participants

Participants ($N = 40$) were undergraduate university students (mean age = 22.80, SD = 3.20 years, 11 males and 29 females), who volunteered to take part in the study and had not received any financial or educational reward for their participation. Applicants were excluded if they reported major medical disorders, acute health problems or symptoms e.g. PMS, common cold, etc.).

Questionnaires

Life Orientation Test Revisited (LOT-R; Scheier et al., 1994): a 6-item scale that measures dispositional optimism as a generalized tendency of expecting positive outcomes. Answers are given on a 5-point rating scale with the anchor points 0 (=not at all) to 4 (=fully). In the present study, the unidimensional approach of optimism was applied: the three negative items were reversed. All six scores were summarized, and participants with higher scores were considered to be rather optimistic, while those with lower scores as rather pessimistic. The Hungarian version of LOT-R proved to be valid and internally consistent (Cronbach-$\alpha = 0.77–0.81$) in previous studies (Bérdi and Köteles, 2009; Köteles and Bárdos, 2009; Köteles et al., 2009). Its internal consistency was Cronbach-$\alpha = 0.84$ in the present study. In a comprehensive Hungarian survey (Köteles et al., 2009), average LOT-R scores of university students were 15.86 (SD = 5.05; range: 3–27; $N = 184$), while average scores of patients from GPs' waiting rooms were 14.55 (SD = 4.76; range: 0–24; $N = 554$).

Patient Health Questionnaire Somatic Symptom Severity Scale (PHQ-15; Kroenke et al., 2002): a 15-item scale designed to measure the prevalence of the most common bodily symptoms (e.g. headache, nausea, etc.) experienced in the last four weeks. Patients diagnosed with somatoform disorders usually report similar symptoms. Therefore, Kroenke (2006) proposed a new and broader diagnostic category, Physical Symptom Disorder (PSD), which can be partly diagnosed using the PHQ-15 scale. Answers are given on a 3-point rating scale with the anchor points 0 (=not at all) to 2 (=fully). Higher PHQ-15 symptom scores can reflect either to the proneness to somatisation or simply to a generally worse body condition. The internal consistency of the Hungarian version in previous studies (Köteles and Bárdos, 2009; Salavecz et al., 2006; Stauder and Konkoly Thege, 2006) was between Cronbach-α = 0.7 and 0.8, and Cronbach-α = 0.71 in the present study. In a comprehensive Hungarian survey (Köteles et al., 2009), average PHQ-15 scores of university students were 5.61 (SD = 3.83; range: 0–16; N = 184), while average scores of patients from GPs' waiting rooms were 9.39 (SD = 5.79; range: 0–28; N = 554).

Somatosensory Amplification Scale (SSAS; Barsky et al., 1988; Barsky et al., 1990): a 10-item scale that measures the tendency to experience somatic sensations as intense, noxious, and disturbing. Answers are given on a 5-point rating scale with the anchor points 0 (=not at all) to 4 (=fully). Higher SSAS scores indicate increased tendency to amplify normal body sensations as well as pathological symptoms. The Hungarian version proved to be valid in previous studies (Köteles and Bárdos, 2009; Köteles et al., 2009). Its internal consistency was Cronbach-α = 0.74 in the present study. In a comprehensive Hungarian survey (Köteles et al., 2009), average SSAS scores of university students were 15.99 (SD = 5.77; range: 0–31; N = 184), while average scores of patients from GPs' waiting rooms were 17.19 (SD = 7.30; range: 0–39; N = 554).

State Anxiety Inventory (STAI-S; Spielberger et al., 1970): a 20-item questionnaire which measures the current level of anxiety. Answers are given on a 4-point rating scale with the anchor points 0 (=not at all) to 3 (=fully). The sum of the scores on the 20 items reflects the momentarily experienced anxiety. The Hungarian version of the scale (Sipos et al., 1994) has been widely used for more than 10 years. Its internal consistency values in the present study were high, from Cronbach-α = 0.89–93 for the three measures.

Idiophatic Environmental Intolerance attributed to electromagnetic fields: a question about the self-rating of being electromagnetic hypersensitive ("Do you consider yourself to be electrosensitive?"). We considered that IEI-EMF phenomenon can be measured on a continuous scale rather than as a dichotomic state of health or illness. Therefore, to permit healthy subjects in the present study somewhat more latitude in responding, a 5-point rating scale (0=not at all to 4=fully) were used instead of a binary scale.

Motivation to cooperate: a 6-item self-constructed scale to control the cooperativity biases of participants. The items measure the perceived cooperativity, professionalism and personal likeability of the researcher and the overall professionalism of the whole study on a 5-point rating scale with the anchor points 0 (=not at all) to 4 (=fully). The higher is the sum score, the more is someone's motivation to cooperate in the experiment is pronounced. The internal reliability of the scale was Cronbach-α = 0.63

20-item symptom checklist: in a checklist, 19 often mentioned and experienced somatic symptoms related to the central nervous system (CNS) (*headache; dizziness; irritability, agitation; drowsiness; fatigue*), to visceral functions *(palpitation; shortness of breath; heartburn; nausea; abdominal pain; muscle tension, shaking*), to the sensory organs (*nasal congestion; dryness of mouth; tinnitus; blurred vision*) and to skin problems (*sweating; cold skin (e.g. palms); itching, sensations on the skin; crawly feelings*) based on data from the literature (Eltiti et al., 2007; Köteles and Bárdos, 2009; Roosli, 2008; Roosli et al., 2004; Rubin et al., 2008; Seitz et al., 2005; Szemerszky et al., 2009) and an '*other*' category for symptoms that had not fit the previously mentioned categories were used. Expectations were rated on a 5-point rating scale, a participant could expect symptoms 0 = certainly not; 1 = probably not; 2 = perhaps; 3 = probably; 4 = surely. Experienced severity of each symptom was rated on a 4-point scale (0 = no symptom at all; 1 = mild; 2 = definite; 3 = severe). Scores for each symptoms were summarized to form the total expected ('*ExpectSSc*') or experienced symtom scores ('*ExperSSc1*' and '*ExperSSc2*'). Expectancy checklist was presented once, at the beginning of the experimental session

Fig. 1. The experimental situation. The Helmholtz-coils below the chair were only virtually connected to the power supply hence no electromagnetic field had been generated at all.

Perception of the presence of EMF (*'EMFperc1'* and '*EMFperc2*'): following the exposures to the sham EMF, participants were asked to score the extent to which they had perceived the presence of the sham EMF on a 5-point rating scale (0 = not at all to 4 = fully) for the "weak" and the "strong" fields, respectively.

Procedure

The study has been approved by the Institutional Ethical Review Board of the Eötvös Loránd University, Budapest, Hungary. Participants were tested one by one in a separate room. Upon arrival, participants read and signed an informed consent form. They were told that the aim of the study was to investigate the interaction of the acute somatic effects of weak/strong EMFs with several personality traits. Participants were asked to sit on a special seat placed above two large electromagnetic coils (diameter: 45 cm; the ambient electromagnetic field was <0.04 μT at this place). Coils seemed to be connected to an impressive electric power supply with coloured lights and an operating panel, but actually there were no real electric connections between them (i.e. no EMF was generated at all; Fig. 1). After signing the form, the experimenter left the room and the participants followed the instructions of a computer program during the whole experimental session (Table 1).

In the first phase, self-rating of IEI-EMF, expectations of somatic symptoms which would be evoked by the EMF exposure, and baseline (T0) state anxiety data (STAI-S) were recorded. Subsequently, the personality questionnaires (LOT-R, PHQ-15, SSAS) and the cooperational motivation scale were completed. In the second phase,

Table 1
The three phases of the experimental session.

Phase 1
Self-rating of IEI-EMF
Symptom expectations checklist
Baseline state anxiety – T0
Personality questionnaires (optimism, somatisation, somatosensory amplification)
Motivation to cooperate questionnaire
Phase 2
State anxiety – T1
Sham exposure with suggestion of low intensity EMF (10 min)
Symptom experience checklist 1 during the exposure
Phase 3
State anxiety – T2
Sham exposure with suggestion of high intensity EMF (10 min)
Symptom experience checklist 2 during the exposure
Rating of the perception of the presumed weak/strong EMF

participants were informed that first an exposure to a weak EMF, comparable to the everyday exposure was coming. After having recorded state anxiety data (T1) again, participants were asked to switch on the power supply of the electromagnetic coils, to monitor themselves for 10 min and to check the experienced symptoms on the experience checklist. In the third phase, the same procedure as in the second phase was repeated with the information of being exposed to a very strong EMF within the reference limit. Following the self-monitoring period, participants were asked to rate the extent to which they had perceived the two EMFs. At the end of the experiment, participants were assured that the experienced symptoms were transient and harmless, and were properly debriefed. No persistent symptoms or long-term health consequences were reported.

Statistical analysis

Statistical analyses were performed by using the *SPSS Statistics 17.0* softwer package. The level of statistical significance was set at $p < 0.05$ in all analyses. Total scores of the questionnaires were calculated after reverse-scoring of items, if necessary. State anxiety change scores (*'STAI-S ch1'* and *'STAI-S ch2'*) were obtained by subtracting the baseline (T0) anxiety score from the second (T1) and third (T2) scores, respectively.

All data sets passed the Kolmogorov–Smirnov normality test with the exception of data related to EMF-perceptions. Therefore *'EMFperc1'* and *'EMFperc2'* were compared by the nonparametric Wilcoxon matched pairs test, while *'ExperSSc1'* and *'ExperSSc2'* were compared by two-sample paired Student's *t*-tests. Changes of state anxiety were analyzed by a repeated measures one-way ANOVA. Pearson's correlation coefficients were used to estimate the strength of the association among self-rated IEI-EMF, expected and experienced symptom scores, and believed perception of EMF, respectively, and to assess their correlations with cooperational motivation and with personality variables (Table 2). After checking data for multicollinearity and independence of the residuals, variables were subjected to hierarchical multiple regression analyses using the "Enter" method. In the analyses, dependent variables were *'ExperSSc1'* and *'ExperSSc2'*, respectively (Tables 3 and 4). Gender (0 = males, 1 = females) was entered in the first block, and the situational factors (motivation score and changes in state anxiety) were applied in the second block. In the third step, expectation score was entered, while LOT-R, PHQ-15, and SSAS scores were added into the analyses in the fourth step. Possible personality

Table 3
Parameters of four steps of the multiple linear regression analysis predicting experienced symptom score for the sham "weak" EMF exposure (*'ExperSSc1'*).

Step	Variable	*B*	SE *B*	β
1.	Gender	2.25	1.53	0.23
2.	Gender	3.42	1.37	0.35*
	CoMotiv	−0.99	0.34	−0.47**
	STAI-S ch1	0.16	0.22	0.12
3.	Gender	2.90	1.22	0.30*
	CoMotiv	−0.92	0.31	−0.43**
	STAI-S ch1	0.11	0.20	0.08
	ExpectSSc	0.18	0.06	0.41**
4.	Gender	1.97	0.94	0.20*
	CoMotiv	−0.56	0.25	−0.26*
	STAI-S ch1	0.13	0.17	0.09
	ExpectSSc	0.03	0.05	0.06
	IEI-EMF	0.35	0.69	0.06
	LOT-R	−0.11	0.09	−0.14
	PHQ-15	0.62	0.17	0.44**
	SSAS	0.20	0.09	0.25*

The final equation explained 75.0% of the total variance (R^2; $p < 0.001$). $R^2 = 0.05$ for Step 1 ($p = 0.15$); $\Delta R^2 = 0.27$ for Step 2 ($p = 0.002$); $\Delta R^2 = 0.16$ for Step 3 ($p = 0.002$); $\Delta R^2 = 0.26$ for Step 4 ($p < 0.001$). Abbr.: IEI-EMF = Idiophatic Environmental Intolerance attributed to electromagnetic fields questionnaire; ExpectSSc = expected symptom scores; STAI-S ch1 = State Anxiety change 1 (STAI-S; T1-T0); CoMotiv = Motivation to cooperate Scale; PHQ-15 = Patient Health Questionnaire Somatic Symptom Severity Scale; SSAS = Somatosensory Amplification Scale; LOT-R = Life Orientation Test Revisited. *: $p < 0.05$; **: $p < 0.01$.

Table 2
Descriptive statistics and correlations of measured variables ($N = 40$).

Variable	1	2	3	4	5	6	Mean	(SD)	Min–max scores (possible max score)
1. IEI-EMF	1						1.25	(0.74)	0–3 (4)
2. ExpectSSc	.41**	1					21.42	(9.82)	4–46 (80)
3. ExperSSc1	.46**	.49**	1				7.72	(4.40)	1–20 (60)
4. ExperSSc2	.48**	.42**	.93***	1			13.10	(5.94)	3–30 (60)
5. EMFperc1	.28	.27	.15	.15	1		0.75	(1.13)	0–4 (4)
6. EMFperc2	.13	.16	.07	.12	.74***	1	1.23	(1.29)	0–4 (4)
7. STAI-S ch1	.39*	.12	.31	.25	−.21	−.22	−0.10	(3.16)	−6 to 9
8. STAI-S ch2	.35*	.14	.26	.19	.28	.32*	−0.55	(3.99)	−10 to 10
9. CoMotiv	−.18	−.10	−.44**	−.39*	−.06	.08	21.40	(2.07)	15–24 (24)
10. PHQ-15	.41**	.56***	.71***	.68***	.17	.21	6.10	(3.15)	1–14 (30)
11. SSAS	.44**	.37*	.53***	.48**	.25	.04	20.82	(5.70)	0–30 (40)
12. LOT-R	−.06	−.07	−.40*	−.39*	.00	.10	16.62	(5.37)	0–23 (40)
13. Gender	−.02	.10	.23	.22	.07	.26	22.8	(3.20)	

Values are Spearman's rho correlation coefficients for *EMFperc1* and *EMFperc2*, point-biserial correlation coefficients for *Gender*, and Pearson correlation coefficients for the other variables. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. Abbr.: IEI-EMF = Idiophatic Environmental Intolerance attributed to electromagnetic fields scale; ExpectSSc = expected symptom scores; ExperSSc1 = experienced symptom scores for the "weak" EMF exposure; ExperSSc2 = experienced symptom scores for the "strong" EMF exposure; EMFperc1 = perception of the sham "weak" EMF; EMFperc2 = perception of the sham "strong" EMF; STAI-S ch1 = State Anxiety change 1 (STAI-S; T1-T0); STAI-S ch2 = State Anxiety change 2 (STAI-S; T2-T0); CoMotiv = Motivation to cooperate Scale; PHQ-15 = Patient Health Questionnaire Somatic Symptom Severity Scale; SSAS = Somatosensory Amplification Scale; LOT-R = Life Orientation Test Revisited.

Table 4
Parameters of four steps of the multiple linear regression analysis predicting experienced symptom score for the sham "strong" EMF exposure ('*ExperSSc2*').

Step	Variable	*B*	SE *B*	β
1.	Gender	2.90	2.08	0.22
2.	Gender	4.40	1.99	0.33*
	CoMotiv	−1.38	0.47	−0.48**
	STAI-S ch2	−0.06	0.24	−0.04
3.	Gender	3.87	1.86	0.30*
	CoMotiv	−1.30	0.44	−0.45**
	STAI-S ch2	−0.11	0.22	−0.07
	ExpectSSc	0.21	0.08	0.35*
4.	Gender	2.65	1.54	0.20+
	CoMotiv	−0.78	0.38	−0.27*
	STAI-S ch2	−0.07	0.20	−0.05
	ExpectSSc	−0.02	0.08	−0.03
	IEI-EMF	1.48	1.08	0.19
	LOT-R	−0.14	0.14	−0.13
	PHQ-15	0.80	0.27	0.43**
	SSAS	0.22	0.14	0.21

The final equation explained 65.8% of the total variance (R^2; $p < 0.001$). $R^2 = 0.05$ for Step 1 ($p = 0.17$); $\Delta R^2 = 0.21$ for Step 2 ($p = 0.013$); $\Delta R^2 = 0.12$ for Step 3 ($p = 0.014$); $\Delta R^2 = 0.28$ for Step 4 ($p = 0.001$). Abbr.: IEI-EMF = Idiophatic Environmental Intolerance attributed to electromagnetic fields questionnaire; ExpectSSc = expected symptom scores; STAI-S ch2 = State Anxiety change 2 (STAI-S; T2-T0); CoMotiv = Motivation to cooperate Scale; PHQ-15 = Patient Health Questionnaire Somatic Symptom Severity Scale; SSAS = Somatosensory Amplification Scale; LOT-R = Life Orientation Test Revisited. $^+p < 0.1$; $^*p < 0.05$; $^{**}p < 0.01$.

Table 5
Parameters of three steps of the multiple linear regression analysis predicting IEI-EMF scores.

Step	Variable	*B*	SE *B*	β
1.	Gender	−0.03	0.26	−0.02
2.	Gender	−0.10	0.25	−0.06
	ExpectSSc	0.03	0.01	0.42**
3.	Gender	−0.14	0.24	−0.09
	ExpectSSc	0.01	0.01	0.14
	LOT-R	0.02	0.02	0.16
	PHQ-15	0.07	0.04	0.30
	SSAS	0.05	0.02	0.36*

The final equation explained 32.6% of the total variance (R^2; $p = 0.016$). $R^2 = 0.00$ for Step 1 ($p = 0.91$); $\Delta R^2 = 0.18$ for Step 2 ($p = 0.008$); $\Delta R^2 = 0.15$ for Step 3 ($p = 0.07$). Abbr.: IEI-EMF = Idiophatic Environmental Intolerance attributed to electromagnetic fields questionnaire; ExpectSSc = expected symptom scores; PHQ-15 = Patient Health Questionnaire Somatic Symptom Severity Scale; SSAS = Somatosensory Amplification Scale; LOT-R = Life Orientation Test Revisited. *: $p < 0.05$; **: $p < 0.01$.

predictors of self-reported IEI-EMF were looked for by hierarchical regression analysis entering gender in the first block, expectations in the second block, and adding LOT-R, PHQ-15, and SSAS scores in the third step (Table 5).

Results

Descriptive statistics of the used variables are summarized in Table 2. Participants expected an average 12.7 (SD = 4.6; range: 3–20) different symptoms, whereas they reported 7.1 (SD = 3.6; range: 1–15) symptoms during the "weak", and 10.4 (SD = 3.7; range: 3–19) during the "strong" EMF, respectively. The average scores for each symptom are presented in Fig. 2. A significant difference was found between '*ExperSSc1*' and '*ExperSSc2*' (paired Student's *t*-test; $t(39) = 13.61$, $p < 0.001$): participants reported more symptoms in the presumed stronger EMF than in the weaker EMF (Table 2). However, no significant change in the current levels of anxiety from T0 to T2 was found (repeated measures ANOVA; $F(2,78) = 0.53$, $p = 0.59$). Significant difference was found between '*EMFperc1*' and '*EMFperc2*' (Wilcoxon matched pairs test; $W(12,-124) = -112$, $p = 0.003$): perception of the EMF was more frequent in the presumed stronger field ($M = 1.23$; SD = 1.29) than in the weaker field ($M = 0.75$; SD = 1.13).

Regarding associations among the variables (Table 2), moderate correlations were found between '*ExpectSSc*' with '*ExperSSc1*' and with '*ExperSSc2*'. '*ExperSSc1*' and '*ExperSSc2*' showed a high intercorrelation. Moderate negative correlations among experienced symptom scores ('*ExperSSc1*', '*ExperSSc2*') and cooperational motivation scores as well as dispositional optimism scores (PHQ-15) were found (i.e. lower experienced symptom scores were associated with higher motivation and optimism scores). Moreover, '*ExperSSc1*' and '*ExperSSc2*' showed moderate positive correlations with somatosensory amplification and strong correlations with somatisation scores. IEI-EMF scores correlated significantly with the expected and experienced symptom scores, with the changes in the anxiety level, and with somatisation and somatosensory amplification scores. '*EMFperc1*' and '*EMFperc2*' showed a high intercorrelation.

Results of the multiple linear regression analyses showed that significant predictors of '*ExperSSc1*' in the final step were gender, motivation, somatisation (PHQ-15), and somatosensory amplification scores (SSAS) (Table 3). These results indicate that women as well as participants with lower motivation reported more symptoms and/or higher severity of symptoms, and similarly did subjects with higher somatisation and SSA scores. Motivation and somatisation scores were significant predictors of '*ExperSSc2*' (Table 4). However, only somatosensory amplification score (SSAS) proved to be a significant predictor of IEI-EMF (Table 5).

Discussion

The major findings of this study are: (1) participants with higher IEI-EMF scores expected and experienced more symptoms, but did not report to perceive the EMF more often; (2) suggestion of a higher intensity of EMF resulted in significantly increased symptom reporting as well as in enhanced perception of EMF as compared to the suggestion of a weak exposure; (3) the main predictor of experienced symptom scores among the inquired personality characteristics was the somatisation score, while (4) self-rating of IEI-EMF was predicted only by somatosensory amplification score.

Hypothesis 1. Association between self-reported IEI-EMF and non-specific symptoms.

In accordance with the hypothesis, larger self-rating of IEI-EMF was related to higher expectations and perception of symptoms during the sham-EMF exposures. According to these results, healthy participants with different degree of IEI-EMF showed similar responses to IEI-EMF patients examined in other studies. These patients have usually experienced more symptoms in everyday exposure situations than the general population (Eltiti et al., 2007; Roosli et al., 2004; Rubin et al., 2008; Stenberg et al., 2002). In contrast to the current findings, double-blind experimental provocation studies did not reveal differences between the number, severity or type of symptoms perceived by IEI-EMF patients during active or sham-EMF exposure (Rubin et al., 2006). This contradiction demonstrates that a significant portion of symptoms reported by IEI-EMF patients is not related to the EMF exposure directly. Similarly to the healthy individuals with different levels of IEI-EMF in the present study, electrosensitive patients also might generate or misattribute at least a part of their symptoms to EMF, which obviously could be interpreted as a nocebo effect.

Hypothesis 2. Effects of enhanced risk perception.

Suggestion of a higher intensity EMF resulted in enhanced symptom- and EMF-perception, which supports the assumption of Bergqvist and Vogel (1997): the subjective perception of risk

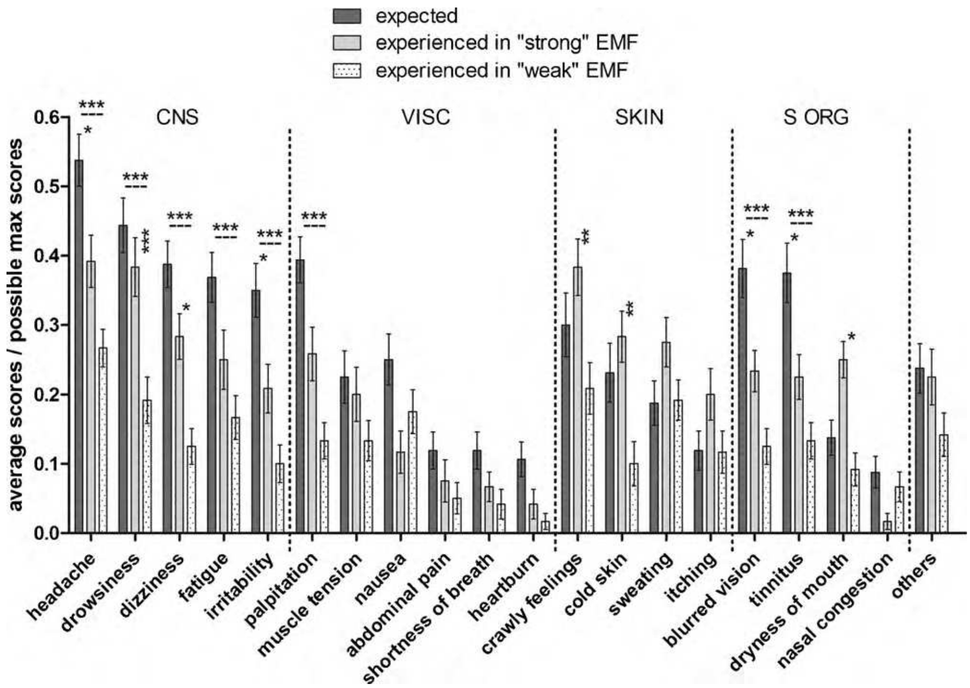

Fig. 2. Average scores of each symptom as a ratio of the possible maximum scores. Values are means ± SEM of 40 participants. Repeated measures two-way ANOVA; *ExpectSSc–ExperSSc1–ExperSSc2* dimension: $F(1.1, 43.5) = 70.21$, $p < 0.001$; symptoms: $F(10.9, 424.6) = 25.23$, $p < 0.001$; interaction: $F(15.0, 584.2) = 6.81$, $p < 0.001$. Bonferroni post hoc tests: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. Abbr.: CNS = symptoms related to central nervous system; VISC = symptoms related to visceral functions; SKIN = skin-related symptoms; S ORG = symptoms related to the sensory organs.

plays a fundamental role in the maintenance or aggravation of certain symptoms. Nowadays, the perception of health hazards of EMF pollution might be strongly influenced by the abundant and often exaggerated stories in the media. Further, repeated warnings about the health hazards of the EMF by several governmental agencies render the public insecure and anxious (Rubin et al., 2009). Unfortunately, both media stories and precautionary advice have been largely driven by the experiences of IEI-EMF sufferers (Rubin et al., 2009), which obviously generates a vicious circle.

In the present study, both enhanced risk perception and higher expectations resulted in increased symptom perception. Furthermore, the significant role of the nocebo effect in EMF-related symptom reports was also supported by the finding that type and distribution of symptoms reported by healthy participants in the current study proved to be very similar to complaints of IEI-EMF patients in previous reports. In the survey of Hillert and Kolmodin-Hedman (1997), more than 90% of the IEI-EMF patients reported that symptoms had started as temporary skin problems with neurovegetative symptoms appearing years later. In the present study, although participants expected mainly symptoms related to CNS *(headache, drowsiness, dizziness, fatigue, irritability*) and to sensory organs *(blurred vision, tinnitus*) before the exposure, skin-related complaints *(crawly feelings, cold skin and sweating*) emerged to a great extent and surpassed the original expectations during the sham-EMF exposures, in addition to the CNS- and sensory organ-related symptoms (Fig. 2).

Hypothesis 3. Personality characteristics associated with symptom reporting.

Although scores of expected and actually experienced symptoms have correlated significantly, the size of the correlations were only moderate, which indicates that the process of symptom generation cannot be explained by the expectations alone. This fact is supported by the results of regression analyses for both exposure conditions (sham "weak" and "strong" fields). While expectation scores have predicted the experienced symptom scores in the third step of the analyses, the significance of these connections was lost after entering personality characteristics in the fourth step (Tables 3 and 4). From among personality characteristics assessed in the study, somatisation (PHQ-15) scores proved to be significant predictors of experienced symptoms in both sessions. Somatisation was a predictor of retrospectively or actually experienced symptoms in previous studies, too (Frick et al., 2002; Hillert and Kolmodin-Hedman, 1997; Szemerszky et al., 2009). Higher scores on PHQ-15 scale may refer either to the proneness to somatisation or simply to a generally worse body condition. In both cases, the former result may be interpreted as a specific attributional error: people with symptoms of uncertain origin frequently seek reasonable causes for their problems, and may find an obvious explanation by the presumed adverse effects of the EMF exposure. An other personality-related predictor in the final step of the analysis was somatosensory amplification for symptom perception in the sham "weak" EMF exposure. Similarly, SSAS was predictor of symptom perception in the study of Köteles and Bárdos (2009) on non-specific drug adverse effects. Taken together, certain personality characteristics seem to predict the symptom perception due EMF exposure better than expectations or the self-evaluation of being IEI-EMF.

Previous findings about the role of optimism-pessimism and anxiety in the nocebo phenomenon have not been replicated in this study. Lower scores of dispositional optimism (LOT-R) were in relation with the nocebo reaction in the study of Geers et al. (2005), while it was not a predictor of symptom generation in the present study. Similarly, in the study of Nevelsteen et al. (2007) state anxiety (STAI-S) appeared to be a significant predictor of symptom reports, contrary to the result of the present study. A possible reason may be that the anxiety of participants did not change significantly throughout the experimental session. While it is highly speculative, but one may explain it with the *ab ovo* high anxiety level of participants (ceiling effect) due to the advance information about risks of the experiment. The same was the case in the experimental nocebo study of Köteles and Bárdos (2009). Control variables, i.e.

gender and cooperative motivation proved to be significant predictors. According to these results, women as well as participants with lower motivation reported more symptoms and/or higher severity of symptoms. Other studies have also found that environmental annoyance and EMF-related symptoms are more frequent among women (Frick et al., 2002; Rubin et al., 2008).

As more factors have been investigated simultaneously in the current study, the relative importance or predictive power of these variables could also be compared by using the β coefficients of the regression equations. In the final regression equations, the highest standardized regression weights belonged to somatisation scores (Tables 3 and 4), which means that the contribution of somatisation tendency (PHQ-15) to the symptom generation process was the largest. In conclusion, by increasing the perceived number and severity of subjective somatic symptoms, somatisation tendency together with somatosensory amplification could provide IEI-EMF sufferers with a necessary somatic background for the misattributional process. These processes may account for the impaired subjective physical well-being and perceived general health, the higher level of subjective and medically unexplained symptoms, and the higher somatic anxiety of IEI-EMF patients (Bergdahl, 1995; Carlsson et al., 2005; Rubin et al., 2008; Stenberg et al., 2002).

Hypothesis 4. Personality characteristics behind IEI-EMF.

To the best knowledge of the authors, the relationship between somatosensory amplification and IEI-EMF phenomenon has not been investigated up to date. However, SSA proved to be the only significant predictor of self-evaluation about being IEI-EMF, while expectations lost their significant effect in the final step of regression analysis. According to recent results (Barsky et al., 1994; Brown et al., 2007), SSA is not associated with enhanced sensation of sensory inputs but may be the product of a higher level cognitive bias in interpreting sensory input that reach consciousness (Mailloux and Brener, 2002; Nakao and Barsky, 2007). People with higher SSAS scores have a marked cognitive predisposition to monitor themselves for symptoms, and actually experience symptoms as more intensive and more disturbing (Mailloux and Brener, 2002).

Limitations

First, the most important shortcoming of this study is its lower ecological validity: results from the rather small sample of healthy, young and intellectual adults cannot be generalized. Our results may be reliable and specific to healthy individuals with different levels of self-reported IEI-EMF. However, patients with serious EMF-related symptoms may respond differently. Second, the order in which exposures were received was not counter-balanced. In the present study, one of the conditions represented a significantly stronger stimulus than the other one, therefore the weak stimulus was given first and the strong one second in order to prevent a residual effect. Third, the present study as a consequence of its unimodal approach leaves the interaction of possible biophysical effects with psychosocial influences out of consideration, and demonstrate the psychological aspects of IEI-EMF alone.

The strength of the nocebo effect might be underestimated for two reasons in our study: first, people with considerable worries and anxiety about health hazards of EMF exposure were less inclined to participate in such an experiment, and second, participants with greater cooperativity motivation have reported less symptoms, i.e. individuals with larger motivation experienced smaller nocebo effect.

Conclusions

While direct biophysical effects of EMF and interactions of biophysical and psychosocial influences cannot be excluded, our results confirm the important role of the nocebo phenomenon in the genesis of symptoms attributed to EMFs. This is particularly true for individuals with increased proneness to somatisation and somatosensory amplification.

A considerable part of complaints of healthy people with different degrees of IEI-EMF seems to stem from a vicious circle of psychosocial factors to a great extent. Information from the media and policy makers about health hazards of EMF pollution generate negative expectations and enhance the perception of risk. Increased expectancies and perceived risk lead people to monitor themselves and search for symptoms during EMF exposures. People with stronger somatisation tendency already have more symptoms in advance, whereas people who are more prone to somatosensory amplification experience the emerging body feelings as more disturbing. Both dispositions reinforce the presumed causal relationship between symptoms and EMF exposure (misattribution), and finally these people label themselves as IEI-EMF sufferers which, in turn, feeds the media for stories and precautionary advice of governmental organisations.

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