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Psychological factors associated with self-reported sensitivity to mobile phones

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Abstract

Objective: Some people report symptoms associated with mobile phone use. A minority also report "electrosensitivity," experiencing symptoms following exposure to other electrical devices. Research suggests that electromagnetic fields do not trigger these symptoms. In this study, we examined the differences between these two "sensitive" groups and healthy controls. **Methods:** Fifty-two people who reported sensitivity to mobile phones, 19 people who reported sensitivity to mobile phones and "electrosensitivity," and 60 nonsensitive controls completed a questionnaire assessing the following: primary reason for using a mobile phone, psychological health, symptoms of depression, modern health worries (MHW), general health status, symptom severity, and the presence of other medically unexplained syndromes. **Results:** Perceived sensitivity was associated with an increased likelihood of using a mobile phone predominantly for work (3% of controls, 13% of those sensitive to mobile phones, and 21% of those reporting "electrosensitivity") and greater MHW concerning radiation [mean (S.D.) on a scale of 1–5: 2.0 (1.0), 2.7 (0.9), and 4.0 (0.8), respectively]. Participants who reported "electrosensitivity" also experienced greater depression, greater worries about tainted food and toxic interventions, worse general health on almost every measure, and a greater number of other medically unexplained syndromes compared to participants from the other two groups. No group differences were observed with regards to psychiatric caseness. **Conclusions:** The data illustrate that patients reporting "electrosensitivity" experience substantially worse health than either healthy individuals or people who report sensitivity to mobile phones but who do not adopt the label "electrosensitivity." Clinicians and researchers would be wise to pay greater attention to this subdivision.

Keywords: Electrosensitivity; Idiopathic environmental intolerance; Mobile phones; Modern health worries

Introduction

Mobile phone use in the United Kingdom has grown exponentially since the mid-1990s, with almost all households now owning at least one handset [1]. This rapid uptake has been accompanied by a persistent low level of concern [2,3], with the perceived association between mobile phone use and the onset of nonspecific symptoms such as headaches, fatigue, and concentration problems being of particular concern to the public [4]. There exist no generally accepted bioelectromagnetic mechanisms that might explain this correlation [2], and experiments that have exposed healthy adults to mobile phone signals under blind placebo-controlled conditions suggest that exposure to this form of electromagnetic radiation is not causally linked to symptom onset [5]. Nonetheless, a small percentage of the population report being "sensitive" to mobile phone signals, experiencing subjective symptoms almost every time they use one or, in some cases, even approach one.

This apparent sensitivity represents a subcategory within a broader illness referred to as "electrosensitivity," "electrical sensitivity," or "electromagnetic hypersensitivity." As no consistent objective signs of disease have been observed in

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patients reporting electrosensitivity and as the symptoms they describe do not form any coherent syndrome, it has not been possible to set any formal diagnostic criteria for the condition. Instead, a working definition, which simply emphasizes a person's attribution of symptoms to the presence of weak electromagnetic fields (EMFs), has been proposed [6]. Within this definition, one subdivision has also been suggested between people with discrete problems relating to a specific electrical device and those who report a more complex illness involving multiple symptoms associated with several electrical stimuli [7]. People in this second group are more likely to adopt a label for their condition (such as "electrosensitivity"), to have more severe symptoms, to have a worse prognosis, and to exhibit a psychological profile different from those of people in the first group [7–9].

Whether the symptoms experienced by electrosensitivity suffers are caused by the presence of weak EMF has been tested in >30 blind or double-blind experiments [5,10]. These have consistently demonstrated that people who report electrosensitivity cannot differentiate between conditions involving genuine EMF and conditions involving sham EMF, and are just as likely to experience symptoms during sham exposure as during genuine exposure. Several authors have therefore suggested that psychological factors may be particularly relevant to the etiology of the condition [11]. As electrosensitivity often initially manifests itself as an apparent intolerance to work-related electrical devices [12], one hypothesis is that the stress associated with having to deal with a new piece of equipment in an occupational setting may initially cause someone to experience symptoms while using it [13]. Attributing these stress-related symptoms to the device's electrical fields might be more likely if the individual has preexisting concerns about the health effects of EMF and modern life [14] and if the individual tends to experience negative affect [15]. Once the attribution has been made, every new use of the technology is then likely to be accompanied by expectations of further symptoms and heightened anxiety—factors that, in turn, can lead to increased symptom perception [16,17].

We have previously published the results of a double-blind provocation study in which the effects of mobile phone signal exposure were assessed in volunteers who reported being sensitive to mobile phones and in non-sensitive control volunteers; no specific effects of exposure to active signals were found for any outcome measure [5]. In this study, we have tested differences between our participants in terms of reason for using a mobile phone, general physical and psychological health, modern health worries (MHW), the presence of other medically unexplained syndromes, and utilization of different health care providers. Sensitive participants were subdivided according to whether they used a label such as electrosensitivity to describe themselves. We hypothesized that those who used such a label would report worse physical and psychological health, greater MHW, and greater treatment-seeking behavior compared to other participants, and would be more likely to use mobile phones for work-related reasons.

Methods

Ethics

Ethical approval for the study was given by the South London and Maudsley and Institute of Psychiatry NHS Research Ethics Committee. All participants gave informed written consent prior to completing the questionnaires.

Design

Three groups of participants were compared: those who reported mobile-phone-related symptoms and who also described themselves as suffering from electrosensitivity (ES group), those who reported mobile-phone-related symptoms but did not explicitly describe themselves as having electrosensitivity (MP group), and control group subjects who did not report any mobile-phone-related symptoms.

Participants

Participants were recruited between September 2003 and March 2005 using notices placed in general practitioners' surgeries, mailshots organized by an electrosensitivity support group and by interested clinicians, advertisements in local press and specialist health publications, e-mail circulars, and referrals from our funding body and relevant governmental agencies. Our advertisements requested volunteers for an experiment examining the effects of exposure to mobile phone signals on self-reported symptoms. Individuals who often experienced symptoms as a result of mobile phone use or who never experienced such symptoms were asked to contact us for further information.

People who contacted us were screened for eligibility and asked for their consent to take part in our experiment. Eligible participants were invited to attend our laboratory for three testing sessions. Those who attended the first session constituted the sample for this paper.

Participants were eligible for inclusion if they were aged between 18 and 75 years, were not suffering from a psychotic illness or were not taking antidepressants, and were not pregnant. To be eligible for inclusion in the MP group or the ES group, participants had to report often experiencing negative symptoms within 20 min of using a mobile phone and to attribute those symptoms to exposure to the phone's signal. In addition, ES participants had to answer yes to a single item in our questionnaire: "Do you currently suffer from electrosensitivity/sensitivity to electromagnetic fields?" Only people who did not report any symptoms relating to mobile phone signals were eligible for inclusion in the control group.

Questionnaire measures

All participants completed a questionnaire booklet assessing the following: demographics; frequency of mobile phone use (≤3, 4–12, or ≥13 times a week); typical duration of mobile phone calls (<5, 5–15, or ≥16 min); reason for using a mobile phone (only for work, mainly for work, for both work and social reasons, mainly for social reasons, or only for social reasons); perceived usefulness of mobile phones (I find having access to a mobile phone "not at all useful," "slightly useful," "moderately useful," or "extremely useful"); nonpsychotic psychiatric caseness [defined using a cutoff score of ≥4 on the 12-item General Health Questionnaire (GHQ-12)] [18]; total depression score [9-item Patient Health Questionnaire (PHQ-9)] [19]; concern about the health effects of various aspects of modern life categorized under the headings "toxic interventions," "radiation," "tainted food," and "environmental pollution" (MHW) [20]; general health status [Medical Outcomes Survey 36-item Short Form (SF-36)] [21]; symptom severity in the past month for a list of 49 common symptoms clustered into groups representing 10 body systems [22]; and self-reported "chronic fatigue syndrome/myalgic encephalomyelitis," "fibromyalgia," or "multiple chemical sensitivity or environmental illness." The ES and MP groups were also asked whether they had ever sought treatment for their sensitivity to mobile phones and what techniques they had tried in order to alleviate their mobile-phone-related symptoms. Finally, all participants were asked to report whether exposure to 10 common electrical stimuli and 11 common chemical stimuli would cause them to experience negative symptoms [23]. These stimuli were as follows: mobile phones, mobile phone masts, cordless telephones, landline telephones, visual display units, televisions, fluorescent lighting, household electrical appliances (e.g., fridge, electrical oven), overhead powerlines, household electrical wiring, smog or air pollution, cigarette smoke, vehicle exhaust fumes, photocopiers or printers, newsprint, pesticides, new office buildings, carpeting or curtains, solvents, cosmetics, and dental amalgam.

Procedure

All questionnaires were completed during the participants' first visit to our laboratory, before any experimental exposure had taken place.

Analyses

Differences between the three groups in terms of total depression score, MHW, SF-36 subscales, symptom severity in the past month, and the number of chemical or electrical stimuli that the participant reported being sensitive to were assessed using one-way analyses of variance and post-hoc Tukey tests. Differences in terms of frequency of mobile phone use, typical duration of mobile phone calls, reason for using a mobile phone, perceived usefulness of mobile phones, psychiatric caseness, presence of other medically unexplained syndromes, and health care use were assessed using chi-square tests.

Results

Demographics

One hundred and fifty-two eligible individuals answered our advertisements and provided verbal consent for the study (69 controls and 83 people reporting mobile-phone-related symptoms). Of these, 60 control participants

Table 1
Demographics for the control, MP, and ES groups

Demographic variable	Control group (n=60)	MP group (n=52)	ES group (n=19)	Test for group differences
Age [mean (S.D.)]	33.5 (10.2)	33.4 (10.9)	47.3 (14.0)*	$F(2,128)=12.6$, $P<.001$
Gender: female [n (%)]	33 (55)	29 (56)	11 (58)	$\chi^2=0.05$, $P=.98$
Ethnicity: non-White participants [n (%)]	15 (25)	11 (21)	4 (21)	$\chi^2=0.3$, $P=.87$
Marital status [n (%)]				
Single	39 (65)	26 (50)	12 (63)	$\chi^2=3.0$, $P=.55$
Married/cohabiting	19 (32)	24 (46)	6 (32)	
Divorced/separated	2 (3)	2 (4)	1 (5)	
Employment status [n (%)]				
Working	30 (50)	33 (63)	9 (47)	$\chi^2=9.1$, $P=.17$
Unemployed	10 (17)	3 (6)	6 (32)	
Housewife or househusband	2 (3)	2 (4)	1 (5)	
Student	18 (30)	14 (27)	3 (16)	
Socioeconomic status: professional, managerial, or intermediate participants [n (%)]	31 (52)	37 (71)	14 (74)	$\chi^2=5.7$, $P=.06$
Educational level: university-educated participants [n (%)]	42 (70)	32 (62)	13 (68)	$\chi^2=0.9$, $P=.63$

MP: participant reported sensitivity to mobile phones but did not use the label "electrosensitivity"; ES: participant reported sensitivity to mobile phones and did use the label "electrosensitivity."

* Significantly different from the control group or the MP group (post-hoc Tukey tests, $P<.001$).

Table 2
Mobile phone usage for the control, MP, and ES groups

Mobile phone variable	Control group (n=60)	MP group (n=52)	ES group (n=19)	Test for group differences
Weekly frequency of mobile phone use[a] [n (%)]				
<4 times	8 (13)	11 (21)	6 (32)	χ^2=4.1, P=.39
4–12 times	25 (42)	16 (31)	6 (32)	
≥13 times	27 (45)	25 (48)	7 (37)	
Typical length of call[a] [n (%)]				
<5 min	32 (53)	29 (56)	15 (79)	χ^2=7.1, P=.13
5–15 min	22 (37)	14 (27)	4 (21)	
≥16 min	6 (10)	9 (17)	0 (0)	
Perceived usefulness of mobile phones[a] [n (%)]				
Not at all	3 (5)	2 (4)	4 (21)	χ^2=7.2, P=.13
Moderately	14 (23)	11 (21)	3 (16)	
Extremely	43 (72)	39 (75)	12 (63)	
Reason for using a mobile phone[a] [n (%)]				
Mainly work	2 (3)	7 (13)	4 (21)	χ^2=12.3, P=.02
Both, equally	21 (35)	27 (52)	8 (42)	
Mainly social	37 (62)	18 (35)	7 (37)	

MP: participant reported sensitivity to mobile phones but did not use the label "electrosensitivity"; ES: participant reported sensitivity to mobile phones and did use the label "electrosensitivity."

[a] Former mobile users (n=10) based their answers on the last time they regularly used one.

(72%) and 71 symptomatic participants (86%) completed the questionnaires. Of the 71 symptomatic participants, 19 reported having electrosensitivity: the other 52 constituted the MP group. The demographic characteristics of the three groups are shown in Table 1. The ES group was significantly older [F(2,128)=12.6, P<.001] than either the control group (P<.001) or the MP group (P<.001), but there were no other significant demographic differences between them (P>.05). In terms of illness duration, ES participants reported having been sensitive to mobile phones for a median of 54 months (interquartile range: 30–84 months), compared to 41 months (interquartile range: 24–60 months) for MP participants. Mann–Whitney U test showed that this difference was significant (U=263, P=.02).

Mobile phone usage

Five MP participants and five ES participants reported that they no longer used mobile phones. For these individuals, mobile phone usage questions were asked in relation to the last time they had regularly used one. No significant group differences were seen with regards to typical call duration (χ^2=7.1, P=.13) or weekly frequency of use (χ^2=4.1, P=.39) (see Table 2 for data). Neither were any significant differences observed with regards to the perceived usefulness of mobile phones (χ^2=7.2, P=.13). However, a significant difference was observed in terms of the reasons for using a mobile phone (χ^2=12.3, P=.02), with MP and ES participants having been more likely to use them predominantly for work (Table 2).

Psychological health, negative affect, and MHW

Group scores on the GHQ-12, PHQ-9, and MHW scales are shown in Table 3. There were no significant group differences in the percentages of participants classified as psychiatric cases using the GHQ-12 (χ^2=2.9, P=.24). However, there was a significant group difference in PHQ-9 depression scores [F(2,126)=7.5, P=.001], with ES participants having a significantly higher level of depressive symptoms than control (P=.002) or MP partic-

Table 3
Psychiatric caseness, depression scores, and MHW scores for the control, MP, and ES groups

Variable (range of scores; meaning of higher score)	Control group (n=60)	MP group (n=52)	ES group (n=19)	Test for group differences
Frequency of GHQ-12 cases [n (%)]	10 (17)	4 (8)	4 (21)	χ^2=2.9, P=.24
PHQ total depression score (0–27; more depression) [mean (S.D.)]	2.2 (2.8)	1.9 (2.4)[a]	4.8 (3.8)*,**	F(2,126)=7.5, P=.001
MHW toxic interventions (1–5; greater concern) [mean (S.D.)]	2.2 (1.0)	2.3 (0.8)	3.2 (1.1)*,**	F(2,128)=7.4, P<.001
MHW environmental pollution (1–5; greater concern) [mean (S.D.)]	3.0 (1.0)	2.9 (0.9)	3.3 (1.0)	F(2,128)=1.4, P=.26
MHW tainted food (1–5; greater concern) [mean (S.D.)]	2.8 (1.1)	2.9 (1.2)	3.6 (1.2)*	F(2,128)=3.5, P=.03
MHW radiation (1–5; greater concern) [mean (S.D.)]	2.0 (1.0)	2.7 (0.9)*	4.0 (0.8)*,**	F(2,128)=33.1, P<.001

MP: participant reported sensitivity to mobile phones but did not use the label "electrosensitivity"; ES: participant reported sensitivity to mobile phones and did use the label "electrosensitivity."

[a] n=50.

* Significantly different from the control group (post-hoc Tukey test, P<.05).

** Significantly different from the MP group (post-hoc Tukey test, P<.05).

Table 4
General health status of participants in the control, MP, and ES groups

Variable (range of scores; meaning of higher score)	Control group (n=60)	MP group (n=52)	ES group (n=19)	Test for group differences
SF-36 physical functioning (0–100; better health)	95.3 (8.6)	93.4 (16.0)	78.7 (28.9)*,**	$F(2,128)=8.1$, $P<.001$
SF-36 social functioning (0–100; better health)	93.3 (10.6)	93.1 (11.5)	69.3 (31.3)*,**	$F(2,128)=19.2$, $P<.001$
SF-36 role limitations—physical (0–100; better health)	93.3 (20.5)	95.7 (13.8)	48.7 (43.7)*,**	$F(2,128)=31.7$, $P<.001$
SF-36 role limitations—emotional (0–100; better health)	85.0 (27.0)	86.5 (25.8)	61.4 (42.0)*,**	$F(2,128)=5.7$, $P=.004$
SF-36 mental health (0–100; better health)	76.8 (13.3)	78.7 (12.9)	68.2 (19.8)**	$F(2,128)=3.8$, $P=.02$
SF-36 energy/fatigue (0–100; better health)	69.7 (16.1)	67.5 (16.4)	52.9 (27.4)*,**	$F(2,128)=6.3$, $P=.003$
SF-36 pain (0–100; better health)	86.1 (16.3)	85.5 (14.3)	68.7 (27.6)*,**	$F(2,128)=7.7$, $P=.001$
SF-36 general health perceptions (0–100; better health)	75.6 (18.4)	78.0 (17.6)	56.3 (24.3)*,**	$F(2,128)=9.5$, $P<.001$
SF-36 change in health (0–100; better health)	57.5 (18.0)	57.7 (18.9)	56.6 (28.7)	$F(2,128)=0.02$, $P=.98$

MP: participant reported sensitivity to mobile phones but did not use the label "electrosensitivity"; ES: participant reported sensitivity to mobile phones and did use the label "electrosensitivity."
All values are presented as mean (S.D.).
* Significantly different from the control group (post-hoc Tukey test, $P<.05$).
** Significantly different from the MP group (post-hoc Tukey test, $P<.05$).

ipants (P=.001). There were also significant group differences in terms of the MHW toxic intervention [$F(2,128)$= 7.4, $P<.001$], tainted food [$F(2,128)=3.5$, $P=.03$], and radiation [$F(2,128)=33.1$, $P<.001$] subscales, although not for the environmental pollution subscale [$F(2,128)=1.4$, $P=.26$] (see Table 3 for details).

General health status

In terms of general health status, there were significant differences between groups for every SF-36 scale [$F(2,128)>3.8$, $P<.05$], except for changes in health [$F(2,128)=0.02$, $P=.98$]. These differences were all due to worse health status in the ES group compared to either the MP group or the control group (Table 4; $P<.05$). The only exception was for the mental health scale, for which no significant difference was observed between the ES group and the control group ($P=.06$). Similarly, there were significant group differences with regards to 9 of 10 categories of somatic symptoms experienced in the past month [$F(2,128)>4.5$, $P<.05$], the sole exception being for gastrointestinal symptoms [$F(2,128)=2.6$, $P=.08$]. Again, these differences were almost entirely due to the greater symptom severity reported by the ES group than either the control group or the MP group (see Table 5 for details; $P<.05$). There was also a significant difference in terms of the number of comorbid medically unexplained syndromes that were reported, with seven ES participants (37%) reporting one or more of fibromyalgia, multiple chemical sensitivity, or chronic fatigue syndrome/myalgic encephalomyelitis, compared to none from the MP group and one (2%) from the control group ($\chi^2=36.7$, $P<.001$).

Significant differences were found in the number of electrical [$F(2,128)=45.1$, $P<.001$] and chemical [$F(2,128)=6.8$, $P<.001$] stimuli reported as triggering symptoms. For electrical stimuli, differences were apparent between all three groups ($P<.001$), with ES participants reporting more stimuli [number of triggers: mean (S.D.)=5.1 (2.8)] than MP participants [mean (S.D.)=2.8 (1.6)], who in turn reported more triggers than controls [mean (S.D.)=1.1 (1.2)]. For chemical stimuli, there were no significant differences between the MP group [mean (S.D.)=3.4 (2.1)] and the control group [mean (S.D.)=3.1 (2.5), $P=.73$], although participants in both groups reported significantly

Table 5
Reported symptoms severity in the past month for participants in the control, MP, and ES groups

Variable (range of scores; meaning of higher score)	Control group (n=60)	MP group (n=52)	ES group (n=19)	Test for group differences
Neurophysiological symptoms (0–3; worse symptoms)	0.4 (0.4)	0.4 (0.4)	1.0 (0.7)*,**	$F(2,128)=15.0$, $P<.001$
Respiratory symptoms (0–3; worse symptoms)	0.1 (0.2)	0.2 (0.2)	0.4 (0.7)*,**	$F(2,128)=5.0$, $P=.008$
Cardiovascular symptoms (0–3; worse symptoms)	0.1 (0.2)	0.2 (0.4)	0.4 (0.7)*,**	$F(2,128)=6.1$, $P=.003$
Ophthalmologic symptoms (0–3; worse symptoms)	0.1 (0.2)	0.1 (0.4)	0.5 (0.6)*,**	$F(2,128)=12.8$, $P<.001$
Global symptoms (0–3: worse symptoms)	0.1 (0.1)	0.1 (0.2)	0.3 (0.3)*,**	$F(2,128)=8.2$, $P<.001$
Peripheral–neurological symptoms (0–3; worse symptoms)	0.1 (0.3)	0.3 (0.5)	0.5 (1.0)*	$F(2,128)=4.5$, $P=.01$
Gastrointestinal symptoms (0–3; worse symptoms)	0.2 (0.2)	0.2 (0.3)	0.3 (0.6)	$F(2,128)=2.6$, $P=.08$
Urogenital symptoms (0–3; worse symptoms)	0.1 (0.2)	0.1 (0.2)	0.3 (0.6)*,**	$F(2,128)=7.0$, $P=.001$
Auditory symptoms (0–3; worse symptoms)	0.1 (0.3)	0.2 (0.5)	0.8 (0.9)*,**	$F(2,128)=13.7$, $P<.001$
Musculoskeletal symptoms (0–3; worse symptoms)	0.2 (0.5)	0.2 (0.4)	0.7 (0.9)*,**	$F(2,128)=6.6$, $P=.002$

MP: participant reported sensitivity to mobile phones but did not use the label "electrosensitivity"; ES: participant reported sensitivity to mobile phones and did use the label "electrosensitivity."
All values are presented as mean (S.D.).
* Significantly different from the control group (post-hoc Tukey test, $P<.05$).
** Significantly different from the MP group (post-hoc Tukey test, ($P<.05$).

fewer chemical triggers than ES participants [mean (S.D.)=5.4 (3.1), $P<.01$].

Significantly more participants from the ES group (11 participants, 58%) than from the MP group (10 participants, 19%) reported having sought treatment for their mobile-phone-related symptoms ($\chi^2=10.0$, $P=.002$). The most commonly consulted clinicians were general practitioners (MP=17%, ES=42%, $\chi^2=4.7$, $P=.03$), complementary and alternative health care practitioners (MP=2%, ES=32%, $\chi^2=13.8$, $P<.001$), and neurologists (MP=8%, ES=11%, $\chi^2=0.1$, $P=.7$). When asked about techniques used to alleviate mobile-phone-related symptoms, most participants had tried altering call duration (MP=92%, ES=89%, $\chi^2=0.1$, $P=.7$), changing the phone's position (MP=85%, ES=79%, $\chi^2=0.3$, $P=.6$), or mechanical solutions such as commercially available "radiation shields" or hands-free kits (MP=62%, ES=79%, $\chi^2=1.9$, $P=.2$). Some, predominantly from the ES group, had also tried complementary and alternative techniques, such as crystal jewelry, flower essences, and "energy therapy" (MP=6%, ES=32%, $\chi^2=8.4$, $P=.004$).

Discussion

A psychological etiology of electrosensitivity

The results of experimental provocation studies have repeatedly shown that people who report electrosensitivity are unaffected by acute exposure to EMF [5,10]. How then do some people come to believe that they are sensitive to EMF? For a minority, the answer may be that they are experiencing symptoms as a result of some other illness—symptoms that they mistakenly attribute to the presence of EMF. For instance, in three clinical trials of treatments for electrosensitivity, between 14% and 33% of potential volunteers had to be excluded after careful examination revealed the presence of a well-defined organic or psychiatric illness that might have explained their symptoms [24–26]. This is not the case for most sufferers, however, and our GHQ-12 results suggest that there is no substantially greater prevalence of conventionally defined psychiatric disorder in people who believe themselves to be sensitive to mobile phone signals compared to healthy controls. Similar GHQ-12 results have previously been reported for two samples of office workers reporting mild electrosensitivity [12] or symptoms attributed to visual display units [27] and in a large Swedish survey of people who reported "much," "a little", or "no" annoyance from electrical devices [28].

At the same time, although not implying the presence of psychiatric disorder, we did observe significantly worse mean mental health scores in our ES participants on the PHQ-9 depression scale when compared to controls or MP participants, and on the SF-36 mental health scale when compared to MP participants only. Similar findings have been reported before in the electrosensitivity literature [9,29]. Previous research into processes that cause people to attribute symptoms to innocuous exposures has suggested that the presence of negative affect is a risk factor for developing this association [15], and it is possible that our results reflect this. Alternatively, given that these effects were only seen for the ES group, they may reflect a role for negative affect in the progression, generalization, and/or maintenance of this attribution. Given the cross-sectional nature of our study, however, it might equally be the case that these differences were due to the presence of perceived electrosensitivity affecting a participant's mood or the actions of some unknown third factor. Either way, the presence of negative affect is unlikely to improve a sufferer's chances of recovery, and clinical trials of cognitive–behavioral therapy that have aimed to address negative mood as part of a treatment package for electrosensitivity have shown some degree of efficacy [11].

Whether stress plays a role in the etiology of electrosensitivity has been the focus of a larger number of previous studies. In particular, it has been observed that people who attribute symptoms to the effects of EMF coming from their computer monitors tend to display levels of "technostress" higher than those of their healthy colleagues. Technostress can be defined as the stress associated with having to use a new technology that should allow for increased productivity but which is difficult to master—a situation that can be particularly frustrating for individuals who are well-motivated at work and who perceive their job as stimulating [13]. Thus, people who report sensitivity to visual display units have been found to be unsatisfied with the information they have about their computer systems, to be skeptical about their computers, to feel unable to substitute other work for computer work, to be unable to control or assess the amount and type of work that they are expected to do, and to have personality traits that make them predisposed to see "frustration and fatigue as a personal challenge" [30–32]. It has been argued that this technostress might contribute to the etiology of perceived sensitivity to visual display units by being one reason why symptoms initially tend to occur when a visual display unit is being used [13]. Our finding that people who report being sensitive to mobile phones are more likely to use their mobile for work suggests that a similar mechanism may also be important in this newer form of electrosensitivity, particularly as we found no other differences between the groups with regards to any other mobile phone use variable. Although using a mobile phone for work can allow for increased flexibility and productivity, surveys have shown that it can also result in increased stress, making some users more contactable than they might wish and decreasing their perceived autonomy over their work [3].

Although technostress might partly explain why symptoms are initially experienced in conjunction with mobile phone use, it does not explain how these symptoms come to be attributed to the effects of the phone's signal. One risk factor for making this attribution may be preexisting concerns about the health effects of EMF [20]. Our results

are consistent with this idea: Participants who believed themselves to be sensitive to mobile phones reported greater concern on the MHW questionnaire about radiation issues than healthy controls, while participants who described themselves as having "electrosensitivity" reported greater concern still. These findings are not unique. Previous studies have shown that the prevalence of symptoms related to overhead powerlines or mobile phone base stations also correlates with worry about these issues [33,34]. Given the cross-sectional nature of our data, we cannot say for sure whether radiation concerns were a cause or an effect of perceived mobile phone sensitivity. However, that such concerns can precede and predict the development of symptoms following exposure to a worrying environmental stimulus has been demonstrated before for symptoms relating to environmental pesticide spraying [14].

A subdivision within electrosensitivity

From the 1980s onwards, research into electrosensitivity focused on two subgroups: individuals who reported symptoms attributed to visual display units and individuals who reported symptoms attributed to a wider range of electrical devices. Typically, studies included participants from both groups and did not make comparisons between them. Those that did suggested that people who report sensitivity to multiple electrical devices tend to experience more symptoms, take more time off work, are more likely to seek medical care, have a worse prognosis, experience more stress in their daily life, have had more negative experiences in childhood, are more prone to anxiousness, and are more socially isolated and functionally impaired than those whose problems are specific to visual display units [7,9,28]. The two groups should not be seen as entirely separate populations, however. Instead, it appears that individuals who are sensitive to visual display units and who do not recover may eventually develop generalized electrosensitivity [7].

As mobile phone networks have expanded, the prevalence of reported sensitivity to mobile phones and their base stations has come to surpass that for visual display units [35]. Nevertheless, our results suggest that a subdivision between people who report problems relating to a specific electrical device and people who report more full-blown electrosensitivity remains useful. In our study, individuals who adopted the label "electrosensitivity" reported more electrical triggers for their symptoms, experienced greater depression, were more likely to seek treatment for their sensitivity, and had worse general health in almost every respect than people who reported sensitivity to mobile phones but not "electrosensitivity." Participants within our ES group also tended to have been sensitive to mobile phones for longer periods than those in the MP group—a finding consistent with the concept of generalized electrosensitivity as a possible consequence of failing to recover from an initial item-specific sensitivity [7].

ES participants also differed from MP participants with regards to non-EMF-related concerns. In particular, they reported more worries about toxic interventions and tainted food, they reported more chemical triggers for their symptoms, and they were more likely to report other medically unexplained illnesses such as chronic fatigue syndrome, fibromyalgia, and multiple chemical sensitivity. An overlap between electrosensitivity and perceived sensitivity to other environmental stimuli has been noted before. For instance, up to 60% of Californians who report being "allergic or very sensitive to getting near electrical appliances, computers, or power lines" also report being "allergic or unusually sensitive to everyday chemicals" [36]. This overlap supports suggestions that electrosensitivity can be considered a variant of idiopathic environmental intolerance, possibly sharing pathogenic factors and being amenable to the same treatments as other forms of idiopathic environmental intolerance such as multiple chemical sensitivity [6].

Also of interest was the increased tendency of ES participants compared to MP participants to seek out complementary and alternative therapies for their symptoms. In part, this may be due to greater distrust in or disappointment with modern medicine—a sentiment that would tally with the higher MHW score of this group. Equally, this finding might also fit well with previous research, which has found that patients with electrosensitivity have a greater propensity to use spiritual or philosophical coping strategies than healthy controls [37].

Limitations of this study

Two important caveats should be borne in mind when considering these results. Firstly, the cross-sectional nature of our data makes it difficult to draw firm conclusions about the direction of causality implied in the associations observed. Does using a mobile phone for work predict the development of perceived sensitivity, or do people with perceived sensitivity to their mobile phones limit nonessential non-work-related calls? Are MHW a cause or a consequence of electrosensitivity? Is negative affect a risk factor for, or a result of, this condition? This study suggests that these associations exist, yet our understanding of why they exist is largely limited to drawing parallels from previous research. While cross-sectional studies can circumvent this problem to some degree by measuring personality traits that are relatively stable over time, measurements of attitudes, psychological states, and behaviors may change as illnesses develop.

The second caveat concerns the representativeness of our samples. Are people who are willing to take part in a laboratory experiment on the health effects of mobile phone signals representative of the general population of people who consider themselves sensitive to mobile phones? It seems unlikely. Using a self-selecting sample may have resulted in us underestimating the extent of MHW in this

population, given that MHW are linked to skepticism about the validity of modern science [20]. The need to exclude people taking antidepressants from our experiment also means that we probably underestimated the extent of negative affect in this group. Certainly, the percentages of participants scoring ≥4 on our GHQ-12 measure in each of our groups were lower than the 38% reported in one large population-based survey conducted in the United Kingdom [38]. In contrast, the SF-36 subscale scores for our control and MP groups were similar to published normative data for a healthy United Kingdom sample, while scores for the ES group largely mirrored those for people with long-standing illnesses [39]. The ES group did appear to have worse scores for social functioning, emotional role limitations, and, in particular, physical role limitations, however, possibly as a result of their attempts to avoid electromagnetic devices, which are now ubiquitous in modern society.

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