



Mobile Telecommunications and
Health Research Programme

Hypersensitivity Symptoms Associated with Electromagnetic Field Exposure

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Hypersensitivity Symptom Associated with Electromagnetic Field

RUM 20/RUM 24

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1 Executive Summary

Electromagnetic hypersensitive individuals believe they suffer negative health effects when exposed to electromagnetic fields from everyday objects such as mobile phone base stations. The objective of this research project was to attempt to clarify the nature of the Electromagnetic Hypersensitivity Syndrome (EHS) in more detail and to test whether short-term exposure from typical GSM and UMTS base station signals affects health and well-being in self-reported electrically sensitive and control individuals.

In the first phase of the project a questionnaire was developed which enabled us to identify the key symptoms associated with EHS and to determine how often these symptoms occurred in the general population in the United Kingdom. A pilot study was conducted in which the "Electromagnetic Hypersensitivity Questionnaire" was developed and tested. Using this questionnaire a large-scale survey was conducted with a randomly selected sample of 20,000 adults from the Colchester area. The response rate was 18.2%. The main finding of this survey was that electromagnetic hypersensitive individuals showed a higher severity of symptoms on all subscales compared to the control group.

In the second phase of the project an open and double-blind randomised, mixed design provocation study was conducted. Participants attended four sessions in total, at least one week apart. 56 self-reported sensitive and 120 control participants were tested in an open provocation test. Of these 12 sensitive and 6 controls withdrew after the first session and the remainder completed a series of

double-blind tests. Subjective measures of well-being and symptoms were made. In addition physiological measures of blood volume pulse, heart rate and skin conductance were obtained. Three cognitive tests, one to measure immediate memory, one to measure working memory and another to measure concentration were also conducted during each of the double-blind sessions. The main findings were that during the open provocation sensitive individuals reported lower levels of well-being in both GSM and UMTS compared to sham exposure, while controls reported more symptoms during the UMTS exposure. During the double-blind tests the GSM signal did not have any effect on either group. Sensitive participants reported elevated levels of arousal during the UMTS condition, while number and severity of symptoms experienced did not increase. Overall, cognitive functioning was not affected by exposure to either the GSM or UMTS signal. Physiological measures did not differ across the three exposure conditions for either group.

2 Aims and Objectives

This study was designed in response to wide-spread public concern regarding mobile phone base station signals. There are over 40,000 base stations currently in use in the United Kingdom and a small sub-group in the population has emerged reporting symptoms such as headaches, dizziness, palpitations and short-term memory impairment as a consequence to being exposed to electromagnetic fields emitted from everyday objects including base stations. The objective of this research project was to ascertain

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whether short-term exposure to electromagnetic fields emitted from mobile phone base stations affect health and well being in adults. The specific aims of this research were to (i) clarify the nature of the Electromagnetic Hypersensitivity (EHS) syndrome in more detail, (ii) to determine whether EHS symptoms are related to exposure to radio frequency electromagnetic fields (RF-EMF) as produced by a typical GSM and UMTS signal at 10mW/m², (iii) to determine whether RF-EMF affect people who do not report sensitivity to electromagnetic fields.

3 Participants

The project's team members are from the University of Essex unless otherwise stated. Professor Elaine Fox, Dr. Stacy Eltiti, Professor Riccardo Russo, Professor Dariush Mirshekar, Dr. Francisco Sepulveda, Mrs. Denise Wallace, Ms. Konstantina Zougkou, Ms. Anna Ridgewell, Mr Roger Deeble, Dr. Stephen Joseph from the University of Nottingham and Dr. Paul Rasor from the University of Essex health centre.

4 Achievements

4.1 Electromagnetic Hypersensitivity Questionnaire

The first aim of our project was to clarify the nature of the Electromagnetic Hypersensitivity (EHS) syndrome in more detail. To this end we developed a questionnaire which was able to reliably identify the key symptoms associated with EHS and determine how often these symptoms occurred in the general population of the United Kingdom. In the pilot study an EHS questionnaire was developed and tested. It was then revised and sent to a randomly selected sample of 20,000 people. The response rate was 18.2%. Principal component analysis of the symptoms resulted in eight subscales: neurovegetative, skin, auditory, headache, cardiorespiratory, cold related, locomotor, and allergy related symptoms. EHS individuals showed a higher severity of symptoms on all subscales compared to the control group. In

addition they reported experiencing poorer levels of general health and well being and attributed the cause of their symptoms to exposure to objects that emit electromagnetic fields. A higher percentage of EHS respondents reported having a chronic illness compared to the general public. Our report on the development and evaluation of the EHS Questionnaire was published in *Bioelectromagnetics* (2007). This questionnaire is the only formal index of EHS currently available.

4.2 Open provocation and double-blind tests

This study utilized both open provocation and double-blind tests to determine if sensitive and control individuals experience more negative health effects when exposed to GSM and UMTS base station signals compared to sham. This phase of the project addressed the second and third aims of our research.

4.2.1 Subjective report

Subjective well-being was measured using visual analogue scales (VAS) and symptom scales. The VAS measured anxiety, tension, arousal, relaxation, discomfort, and fatigue. The symptom scales consisted of a list of 57 symptoms extracted from the Electromagnetic Hypersensitivity Questionnaire. A 3 (condition: sham, GSM, UMTS) X 2 (group: sensitive, control) mixed ANOVA was performed on the transformed data for each VAS separately for the open provocation and double-blind tests. On the symptom scales, the majority of control individuals reported experiencing no symptoms in any condition. Therefore, Wilcoxon Signed Ranks tests were performed on the total number of symptoms reported and total symptom scores (see Table 1 for medians and Z scores)

In the open provocation test (Session 1) 56 self-reported sensitive and 120 control participants were tested. All VAS resulted in a main effect for group with sensitive participants reporting higher levels of anxiety, tension, arousal, discomfort, and fatigue than controls, while controls reported higher levels of relaxation than sensitive participants. The main effect for condition ($F_s(2,346) > 10.04$, $ps < 0.001$) and the

interaction between condition and group was significant for all VAS except fatigue. Paired sample t-tests showed a significant difference between the sham and GSM and between the sham and UMTS conditions for sensitive participants, but not for controls. Sensitive individuals reported higher levels of anxiety, tension, arousal, and discomfort and lower levels of relaxation during the GSM and UMTS conditions compared to the sham condition. The sensitive group reported more symptoms and a higher total symptom score during the GSM and UMTS conditions compared to sham. The control group reported more symptoms during the UMTS compared to sham, but not for GSM compared to sham.

In the three double-blind tests (Sessions 2, 3 and 4) 44 self-reported sensitive and 114 control participants were tested. Analysis showed a significant main effect of group for all VAS and of condition for anxiety, tension, and arousal ($F_{s(2,312)} > 3.00$, $p \leq 0.05$). There was a significant condition by group interaction for anxiety, tension, arousal, and relaxation. Paired samples t-tests revealed higher levels of arousal during the UMTS compared to sham condition for the sensitive group only, as shown in Table 2. Regarding symptoms, there was no difference between active and sham exposures in either the total number of symptoms or the total symptom score for either group. Sensitive participants reported more symptoms than controls, but this was not related to the exposure condition.

4.2.2 Cognitive tests

Cognitive functioning was measured using the following tests: digit symbol substitution task (DSST), forward digit span (DS), and mental arithmetic (MA). Baseline measures of cognitive functioning were taken during Session 1; participants completed the Wechsler Adult Intelligence Scale-Revised (WAIS-R) Digit Span forward and backwards test, the DSST, and DS task. During sessions 2, 3, and 4 participant performed 20 minutes of relaxation (low mental load condition), 20 minutes of mental arithmetic (high mental load condition) and then completed the DSST and DS. Order of low versus high load and DSST versus DS were counterbalanced across participants.

The baseline measures of cognitive functioning taken during Session 1 yielded no difference between the groups in their performance on the baseline measurements.

4.2.2.1 Double-blind tests: Practice effects

Session X Group mixed ANOVAs were performed on the percentage correct scores for the DS (4 X 2) and MA (3X 2) tasks and the number correct scores for the DSST (4 X 2).

All three ANOVAs resulted in significant main effects for session while DSST and MA also revealed a significant session by group interaction. For DS paired samples t-tests showed a significant improvement in performance between sessions 1 and 2 ($t(152) = -5.80$, $p < .001$) and between sessions 3 and 4 ($t(152) = -2.58$, $p < .01$). For the DSST, performance for control participants improved between session 1 and 2 ($t(113) = -4.24$, $p < .001$) and between sessions 2 and 3 ($t(113) = -3.13$, $p < .001$), but not between session 3 and 4 ($t(113) = -1.50$, $p > .05$). There was no significant difference in the level of performance for sensitive participants. In the MA, the sensitive group showed improved performance between sessions 2 and 3 ($t(43) = -4.88$, $p < .001$), but not between sessions 3 and 4 ($t(43) = -0.11$, $p > .05$), while the control group resulted in improved performance between sessions 2 and 3 and between sessions 3 and 4 ($t(113) = -2.96$, $p < .005$; $t(113) = -3.96$, $p < .001$: respectively).

4.2.2.2 Double-blind tests: Exposure effects

A 2 (group: sensitive, control) X 3 (condition: sham, GSM, UMTS) mixed ANOVA was performed on the percentage correct scores for the DS and MA tasks and the number correct scores for the DSST to determine if type of exposure affected cognitive performance.

The results for the MA and DSST revealed that no within or between group differences were significant. For the DS task there was a significant group by condition interaction ($F(2,302) = 3.87$, $MSe = 2.017$, $p = 0.022$). There are two possible approaches to this statistical outcome. If a stringent approach is taken and a Bonferroni correction is applied to the ANOVA

results for the three cognitive tasks, the interaction above is not significant ($p > 0.0167$). However, a more lenient interpretation would make allowance for further analysis. On this assumption, paired sample t-tests revealed a significant difference for the sensitive group, with poorer performance during the GSM compared to sham and UMTS compared to sham condition ($t(38) = 2.46, p = 0.019$; $t(38) = 2.25, p = 0.03$, respectively). However, after correcting for multiple comparisons ($p < 0.0125$), these differences are not statistically significant.

4.2.3 Physiological response: Open provocation and Double-blind tests

The physiological measurements of blood volume pulse (BVP), heart rate (HR), and skin conductance were recorded using a ProComp Infiniti 8 channel encoder with Biograph Infiniti software run on a Dell Latitude notebook. The data was analyzed using a 3 (condition: sham, GSM, UMTS) X 2 (group: sensitive, control) mixed ANOVA for both the open provocation and double-blind test.

The results were identical. There were no statistical differences between active and sham conditions, regardless of type or even knowledge of exposure for either group. There was, however, a significant between group difference in skin conductance, with sensitive participants having higher skin conductance responses during the open provocation and double-blind tests. The HR variance was also significantly higher in the sensitive compared to control group during the open provocation test. No other comparisons were significant.

4.2.4 On/Off Judgements

Participant performance for each group did not differ from chance. Only 2 sensitive and 4 control participants were able to correctly identify all 6 on/off judgements, while no one correctly distinguished between the GSM and UMTS signal 100% of the time.

5 Analysis of Objectives Met

Our overall objective was to assess whether electromagnetic field emissions produced by mobile phone base stations pose a risk to the health and well being of adults in the short term. Our findings suggest that there is no observable risk to adult health and well being in the short term from acute exposure to typical mobile phone base station signals.

6 Interpretation

The open provocation test verified that when sensitive individuals knew the base station was emitting either a GSM or UMTS signal they self-reported lower levels of well-being and more symptoms than during the sham condition. This response demonstrated that the GSM and UMTS signals were perceived to be similar to those experienced in everyday life and elicited the typical symptoms experienced by electrically sensitive individuals. However, when these same exposures were presented under double-blind conditions, no differences were observed except for the increased subjective feeling of arousal within the sensitive group during UMTS exposure. A problem in interpreting this significant effect is that a larger proportion of sensitive individuals received the UMTS compared to GSM or sham exposure in session 2 (the first of the 50 minute double-blind conditions). Although not statistically significant, the counterbalancing of exposure order was not perfect because we did not achieve our target of 132 participants in each group. Examination of the data showed that, regardless of exposure condition, sensitive participants had a significantly higher degree of arousal during session 2 ($M = 3.03$) compared to session 3 ($M = 2.34$; $t(1,43) = 2.64, p < 0.025$), while there was no difference between sessions 3 and 4 ($M = 2.32$; $t(1,43) = 0.47, p > 0.05$). To test if there was a significant effect of the UMTS exposure on arousal when order of exposure was held constant, separate 2 (condition: UMTS, sham) X 2 (group: sensitive, control) between-subjects ANOVAs were performed for each session. See Table 3 for mean, standard error, and F values. The main effect for condition and group by condition interaction was not significant for all three sessions. These results

indicate that the apparent increase in arousal with UMTS exposure was attributable to the higher proportion of sensitive individuals who received UMTS in session 2 (45.5%). It is important to note that regardless of type of exposure or session, all of the VAS scores fell within the lower 'not at all' end of the scale.

Consistent with previous research, sensitive individuals reported more symptoms and greater severity of symptoms and also displayed higher levels of skin conductance than control individuals regardless of type of exposure.^{1 2 4} However, sensitive individuals were no better than chance at detecting when the base station was 'on' or 'off'.³ Importantly, the number or severity of symptoms that the sensitive group attributed to electromagnetic fields did not increase in either the GSM or UMTS exposure, relative to a sham exposure. With respect to the cognitive tests the results showed that under double-blind conditions, when controlling for multiple comparisons, memory and attentional abilities of both sensitive and control individuals are unaffected by electromagnetic field exposure to GSM or UMTS base station signals.

7 Future Priorities

Although our findings indicate that electromagnetic fields emitted from mobile phone base stations are not the cause of the symptoms experienced by EHS sufferers it is still necessary to establish the real cause(s) of these symptoms given the detrimental effect they have on the quality of life of EHS sufferers. To this end it would be useful to pursue further development of the EHS Questionnaire to allow for the inclusion of information concerning aspects of illness behaviour, coping strategies and duration and progress of the illness. These additions to the questionnaire would further refine our understanding of EHS and provide directives for future projects if necessary.

8 Publications

Eltiti S, Wallace D, Zougkou K, Russo R, Joseph S, Rasor P, et al. Development and Evaluation of the Electromagnetic Hypersensitivity Questionnaire. *Bioelectromagnetics* 2007;28:137-151.

9 Financial summary

Total of expenditure	£345,387.50
Total of grant awarded	£345,458.00
Underspend remaining (if any)	£70.50

10 References

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Table 1: Medians and Z scores for Total Number of Symptoms and Total Symptom Score from the Open Provocation and Double-blind Tests for Sensitive and Control Participants by Type of Exposure

	Sham			GSM			UMTS			Sham v GSM		Sham v UMTS	
	Sensitive	Control	Sensitive v Control	Sensitive	Control	Sensitive v Control	Sensitive	Control	Sensitive v Control	Sensitive	Control	Sensitive	Control
Open Provocation	Median	Median	Z	Median	Median	Z	Median	Median	Z	Z	Z	Z	Z
Total Number of Symptoms	2	0	-4.88*	5	1	-7.65*	5	1	-7.84*	-3.67*	-1.54	-4.57*	-2.91*
Total Symptom Score	2	0	-5.21*	5.5	0	-7.88*	6	1	-8.09*	-3.45*	-1.80	-4.64*	-2.55
Double-blind													
Total Number of Symptoms	3.00	0.33	-6.86*	3.00	0.33	-6.72*	3.33	0.33	-7.06*	-0.70	-0.05	-1.65	-0.83
Total Symptom Score	3.33	0.33	-6.33*	4.00	0.33	-6.32*	4.00	0.17	-7.05*	-0.24	-0.69	-1.56	-0.17

Bonferroni corrections: Sensitive v Control p = .008; Sham v GSM, Sham v UMTS p = .006

* p ≤ .005

Table 2: Mean, Standard Error and F values on Cognitive Tasks during Double Blind Sessions for Sensitive versus Control and Sensitive versus Matched Control Participants

Cognitive Task	Sham		GSM		UMTS		Condition		Group		Condition by Group	
	Sensitive	Control	Sensitive	Control	Sensitive	Control	df	F	df	F	df	F
Digit Span	82.6 (0.03)	81.5 (0.02)	77.6 (0.03)	82.4 (0.02)	79.0 (0.03)	81.4 (0.02)	2,302	2.2 0	1,15 1	0.45	2,302	3.87*
Digit Symbol	46.2 (1.92)	46.4 (1.19)	45.9 (1.99)	47.3 (1.24)	46.3 (1.90)	47.2 (1.18)	2,312	0.3 5	1,15 6	0.15	2,312	0.55
Mental Arithmetic	69.5 (2.92)	73.8 (1.81)	69.9 (3.00)	74.1 (1.87)	67.8 (3.02)	73.5 (1.88)	2,312	1.3 4	1,15 6	1.94	2,312	0.47
Matched Controls							df	F	df	F	df	F
Digit Span	82.6 (0.03)	87.4 (0.03)	77.6 (0.03)	87.0 (0.03)	79.0 (0.03)	87.1 (0.03)	2,152	2.86	1,76	4.03*	2,152	2.09
Digit Symbol	46.2 (2.07)	51.9 (2.07)	45.9 (2.11)	51.8 (2.11)	46.3 (2.00)	52.2 (2.00)	2,172	0.18	1.86	4.39*	2,172	0.01
Mental Arithmetic	69.5 (3.05)	76.2 (3.05)	69.9 (3.16)	77.4 (3.16)	67.8 (3.06)	78.1 (3.06)	2,172	0.37	1.86	3.74	2,172	1.64

a) Means and Standard Errors)

* p< .05

Table 3: Mean, Standard Error, and F values for Level of Arousal by Session by Group

	Sham	UMTS	Condition	Group	Condition X Group
Session 2	M (SE) ^a	M (SE)	F (1,101)	F(1,101)	F(1,101)
Sensitive	2.33 (0.44)	3.52 (0.45)	1.74	8.86*	3.39
Control	1.96 (0.22)	1.69 (0.22)			
Session 3	M (SE)	M (SE)	F (1,104)	F(1,104)	F(1,104)
Sensitive	2.48 (0.52)	2.66 (0.67)	0.09	3.73	0.26
Control	1.82 (0.23)	1.65 (0.17)			
Session 4	M (SE)	M (SE)	F (1,99)	F(1,99)	F(1,99)
Sensitive	1.74 (0.37)	2.25 (0.53)	0.73	1.85	0.30
Control	1.39 (0.15)	1.62 (0.19)			

a) Means and standard errors for original untransformed data

* p < .05

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