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Abbreviations:

GSM – Global System for Mobile Communications operates at 900MHz and 1800MHz.

IEI-EMF – idiopathic environmental intolerance with attribution to electromagnetic fields is a condition in which an individual is experiencing non-specific symptoms and attributes the cause of these symptoms to exposure to electromagnetic fields.

rf-emf – electromagnetic fields are electric and magnetic energy fields that surround any electrical devise that are closely interrelated; therefore, they are usually referred to as electromagnetic fields. Electromagnetic fields within the radio frequency range are referred to as radio frequency electromagnetic fields.

UMTS – Universal Mobile Telecommunications System operates at 2100MHz.

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Abstract

Background: Individuals with Idiopathic Environmental Illness with attribution to electromagnetic fields (IEI-EMF) believe they suffer negative health effects when exposed to electromagnetic fields from everyday objects, such as mobile phone base stations.

Objectives: 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 base station-like signals compared to sham.

Methods: 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. The remainder completed a series of double-blind tests. Subjective measures of well-being and symptoms, as well as physiological measures of blood volume pulse, heart rate and skin conductance were obtained.

Results: During the open provocation, sensitive individuals reported lower levels of well-being in both the Global System for Mobile Communication (GSM) and Universal Mobile Telecommunications System (UMTS) compared to sham exposure, while controls reported more symptoms during the UMTS exposure. During double-blind tests the GSM signal did not have any effect on either group. Sensitive participants did report elevated levels of arousal during the UMTS condition, while number or severity of symptoms experienced did not increase. Physiological measures did not differ across the three exposure conditions for either group.

Conclusions: Short-term exposure to a typical GSM base station-like signal did not affect well-being or physiological functions in sensitive or control individuals. Sensitive individuals reported elevated levels of arousal when exposed to a UMTS

signal. Further analysis, however, indicated that this difference was likely to be due to the effect of order of exposure rather than the exposure itself.

Introduction

Radio frequency electromagnetic fields (rf-emf) do not fall within the ionizing spectrum. Nevertheless, high intensity rf-emf can cause thermal effects with serious implications for human health (Conway 2001). In everyday life, however, most humans are not exposed to such high intensity rf-emf and do not possess sensory organs that can detect electric or magnetic fields. The question remains as to whether exposure to low intensity rf-emf, even if undetected, can negatively affect human health. A subgroup of the population has claimed that they are sensitive to rf-emf and this condition, formerly known as Electromagnetic Hypersensitivity, has recently been relabelled in a World Health Organization workshop (Hansson Mild et al. 2006) as Idiopathic Environmental Intolerance with attribution to electromagnetic fields (IEI-EMF). In a recent UK survey, it has been reported that around 4% of people claim that they are sensitive to rf-emf to some degree (Eltiti et al. 2007). A variety of negative health effects (e.g., cold and flu-like symptoms) are attributed to exposure to rf-emf from objects such as computers and mobile phones. Previous research has indicated that IEI-EMF individuals report lower levels of well-being compared to healthy individuals (e.g. Eltiti et al. 2007; Regel et al. 2006; Rubin et al. 2005; Zwamborn et al. 2003) and that the symptoms they experience may greatly impact upon their quality of life (e.g. Bergqvist and Vogel 1997; Irvine 2005). However, evidence that IEI-EMF symptoms are indeed caused by rf-emf exposure is yet to be established. A systematic review of 31 blind and double-blind provocation studies yielded no evidence that IEI-EMF individuals could detect the presence of rf-emf, and only seven studies indicated that exposure to rf-emf did affect health indices (Rubin et al. 2005). In two of these, however, the authors failed to replicate their own the findings. Another four studies involved inappropriate use of statistics, while one

reported improved mood in the active exposure condition. One unpublished double-blind study specifically examining base station signals did find that exposure to a universal mobile telecommunications system (UMTS) signal resulted in reduced subjective well-being for both sensitive and non-sensitive individuals, while a global system for mobile communication (GSM) base station signal had no effect (Zwamborn et al. 2003). However, a recent study conducted in Switzerland was unable to replicate this effect (Regel et al. 2006). Another double-blind study has recently reported no negative health effects from exposure to a standard 900MHz GSM handset signal for either sensitive or control participants (Rubin et al. 2006).

The existing evidence therefore indicates that exposure to rf-emf signals from mobile phone base stations and handsets has little effect on health, even in those with a perceived sensitivity to rf-emf. Nevertheless, only two double-blind studies have been conducted with base station signals, with contrary results. Given the increase in mobile phone base stations around the world and the level of public concern regarding possible negative health implications, further research is necessary to investigate the short and long-term impact of exposure to rf-emf in both healthy and IEI-EMF groups.

The aim of the current study was to test whether short-term exposure to typical GSM and UMTS base station signals affected a variety of measures of well-being in sensitive and control individuals, using both open provocation and double-blind tests. It was hypothesized that sensitive participants would report more symptoms and lower levels of well-being during GSM and UMTS exposure compared to sham. In addition, sensitive participants should be able to identify above chance level whether the base station was turned ‘on’ or ‘off’. For control participants no difference was expected in the number or severity of symptoms reported during exposure. Previous research has

reported higher levels of heart rate, heart rate spectrum ratio, and electrodermal activity in sensitive compared to controls individuals (e.g. Lyskov et al. 2001a; Lyskov et al. 2001b). Thus, physiological measurements were also conducted to determine whether exposure to GSM and UMTS base station signals affected objective measures of well-being in both sensitive and control individuals.

Methods

Participants

58 self-reported sensitive and 121 control individuals came in for testing. Of these, 56 sensitive and 120 controls completed the open provocation test, while 44 sensitive and 115 controls also completed the double-blind tests. See Figure 1 for flow diagram of participation. Before testing, all participants completed the Electromagnetic Hypersensitivity Questionnaire (Eltiti et al. 2007), which allowed the researchers to assess their current state of health and whether or not the individual attributed their symptoms to exposure to rf-emf. Participants in the sensitive group self-reported experiencing negative health effects from electromagnetic field exposure; in particular exposure from mobile phones and/or mobile phone base stations, while those in the control group did not report experiencing any negative health effects from rf-emf exposure. Individuals who had suffered a brain injury, currently suffered from epilepsy or claustrophobia, were fitted with pacemakers, had undergone treatment for a mental disease, or taken psycho-active medication in the four months prior to testing, were excluded from participation. Participants were recruited through local advertising, action groups and word of mouth. In addition, some participants had previously participated in a questionnaire study conducted by the research group (Eltiti et al. 2007).

All testing was conducted at the Electromagnetics and Health Laboratory at the University of Essex, UK. Participants were reimbursed for their travel expenses and received a small payment for participation. The study was approved by the University of Essex ethics committee. All participants signed an informed consent before proceeding with testing.

Design

The study was a mixed design in which participants were exposed to three conditions: GSM, UMTS, and sham. Each participant took part in four testing sessions which occurred at least one week apart, at approximately the same time of day (±3 hours). Session 1 consisted of an open provocation and a quick double-blind test. During the open provocation both the participants and experimenters knew when the base station was 'on' and 'off' and, if it was 'on', whether it was emitting a GSM or UMTS signal. During the double-blind tests neither the participants nor experimenters knew which exposure was being generated. Sessions 2, 3, and 4 each consisted of a single exposure condition (GSM, UMTS or sham) and these were double-blind. Counterbalancing of all the exposures was pre-programmed into the exposure system control computer, for a target of 264 participants (132 sensitive and 132 controls). Assuming there is a small effect of rf-emf on human health (d=0.40), and that sometimes this effect is positive and sometimes negative (two–tailed), it was calculated that 66 participants per group were needed to have a power level of .90 to detect a within-subjects effect (i.e. difference between real and sham exposure conditions) and 132 participants per group were need to detect a between-subjects effect (i.e. group by exposure condition interaction) for a total of 264 participants (Howell, 1997). For each test the researcher simply entered the participant and session number into the computer, and the pre-programmed exposure condition was

generated. Thus, the study consisted of 3 types of exposure (GSM, UMTS, sham) and 2 groups (sensitive and control). The dependent variables were various measures of subjective well-being and physiological functioning.

Materials and Equipment

Screened Room

All testing took place in the Electromagnetics and Health Laboratory, which comprised a testing room, reception area, and experimenter's room. The testing room was 7m X 4m X 2.4m and had a shielding effectiveness greater than 60dB at the tested frequency range. Participants were seated exactly 5m from the base station antenna, which was blocked from view by a screen (2.8 m from the participant), upon which instructions were projected. The projector was located outside the testing room, with projection made through a screened window located on the wall behind the antenna. A screened window (47cm x 47cm) on the near wall enabled constant visual contact between the participant and experimenter.

Exposure System

There were three exposure conditions: GSM, UMTS, and sham. Both the GSM and UMTS exposures were designed to propagate a signal that replicated as closely as possible those generated by actual base stations in the environment. The GSM signal was a combined signal of both 900MHz and 1800MHz frequency bands, each with a power flux density of 5mW/m^2 resulting in a combined power flux density of 10mW/m^2 over the area in which the participant was seated. The GSM signal contained both broadcast channels (886.8MHz and 1877MHz) and traffic channels (888.8MHz and 1879MHz). The 8 time slots on the broadcast channels were always occupied, while changes in the power level of the traffic channels were simulated using two first order, two state Markov processes, assuming a blockage rate

of 1% and call activity of 40%. This provided a realistic approach for traffic channel modelling, similar to that carried by live base stations during peak hours, resulting in the traffic channels having a blockage rate of 1% and a call activity of 40%. The time slot occupancy of the GSM signal consisted of 8 timeslots, each with a duration of 576.875μs resulting in a total frame duration of 4.615ms. Interslot guard intervals of 32μs duration were implemented into each GSM frame, with a drop in power level of around 50dB between the active state (the burst) and the inactive state (the guard).

The UMTS signal had a frequency of 2020MHz with a power flux density of $10mW/m^2$ over the area where the participant was seated. Traffic modelling for the UMTS signal was achieved using Test Model 1, as defined by the 3GPP standard. This model represented a realistic traffic scenario, with high peak to average ratio power changes, and also ensured both repeatability and parameter control over the UMTS exposure.

During the sham condition the power level was nil and no signal was transmitted. The stability of the exposure system was checked and calibrated every 6 months and was found not to exceed ±3dB of tolerance at any of the three frequency bands. All base station signals and field uniformity were independently tested and verified by the National Physical Laboratory.

Signals were generated using a Rohde and Schwarz SMU200, which was connected to a diplexer, an interslot trigger module, a power amplifier, a through line power meter, a controller PC, and an antenna. The diplexer enabled the mixing of the 900MHz and 1800MHz signals to create the GSM exposure, while the power amplifier enabled the signal to be set at the correct power level. The through line power meter was used to perform continuous checks of the power into the antenna during the tests. The operator was informed if the power level exceeded the tolerance

value. The controller PC regulated all the exposures, giving the system both repeatability and full control over the parameters for each exposure. A copy of the technical reference manual is available upon request.

Subjective well-being

Subjective well-being was measured using visual analogue scales (VAS) and symptom scales. The VAS consisted of 10cm lines anchored at one end with the phrase 'not at all', at the other with 'extremely' and measured anxiety, tension, arousal, relaxation, discomfort, and fatigue. The corresponding words used to anchor the lines were 'anxious', 'tense', 'agitated', 'relaxed', 'discomfort', and 'tired'. The symptom scales consisted of a list of 57 symptoms extracted from the Electromagnetic Hypersensitivity Questionnaire (Eltiti et al. 2007) in which participants indicated how much they were suffering from each symptom, from 'not at all' to 'a great deal'.

Physiological Measures

The dependent variables for BVP, SC, and HR were the mean (M) and standard deviation (SD) values calculated for the 15 minute open provocation and 50 minute double-blind tests. The physiological measurements of blood volume pulse (BVP), heart rate (HR), and skin conductance (SC) were recorded using a ProComp Infiniti 8 channel encoder with Biograph Infiniti software run on a Dell Latitude notebook. Signals were sampled at a rate of 2048samples/s for BVP and 256samples/s for SC. The BVP was submitted to a 4^{th} order Butterworth low-pass filter with a 10Hz cut-off frequency. The HR was calculated from the filtered BVP by calculating the time locations for the BVP peaks and valleys based on the locations on which the derivative of the BVP reached zero (dicrotic notches were discarded). HR was then estimated based on the time between peaks: HR = 1/(interpeak interval). All signals

were re-sampled at 8 samples/s in order to have a uniform rate. BVP signals were detrended as the important information in this signal was on the peak-to-peak values.

On/Off Judgements

For the three quick double-blind tests (in session 1) and the three 50-minute double-blind tests (sessions 2 to 4) participants judged whether the base station was on or off and indicated how confident they were of this judgement using a scale from 0 ‘not at all sure’ to 100 ‘completely sure’. The ROC curve method was chosen to analyze the responses as this takes into account not only accurate (hits) and inaccurate responses (false alarms), but also how confident participants are of their judgments.

Procedure

Testing took place on four separate occasions at least one week apart, with one participant tested at a time. During session 1 informed consent and background information including a medical history was taken and the cognitive tests (to be reported elsewhere), open provocation, and quick double-blind tests were performed. During the open provocation and quick double-blind tests participants received all three exposures. Sessions 2, 3, and 4 each consisted of a single exposure (GSM, UMTS, or sham) and were all double-blind, with the three exposures being randomly spread across the three sessions. Session 1 took approximately 3 hours to complete while sessions 2, 3, and 4 each took approximately 1½ hours. For full details of the sessions see Table 1.

Results

Exposure

As we were unable to reach our target of 264 participants, we could not guarantee complete counterbalancing of order of exposures across sessions for the double-blind tests. Chi-square analysis revealed that there were no significant

differences between the groups and order of exposure for the double-blind tests; however, almost half of the sensitive group received the UMTS exposure first (45.5%) compared to the GSM first (27.3%) or sham first (27.3%). The order of exposure was more evenly distributed for the control group with 35.1% receiving sham first, 36.0% receiving GSM first, and 28.9% receiving UMTS first.

Biographical Information

The sensitive group (M=46.1, SD=13.5) was significantly younger than the control group (M=54.5, SD=15.23; t(174)=-3.51, p<.01) with equal numbers of males and females in each group (sensitive: male 57.1%; control: male 57.5%; $\chi^2(1)=0.002$, P>.05). Significantly more controls (38.3%) reported having a chronic illness compared to sensitive participants (21.4% ; χ^2 (1)=4.94, P<.05) although there were no differences between the groups among the 5 most commonly reported chronic illnesses: high blood pressure, underactive thyroid, high cholesterol, asthma, and arthritis (χ^2s (1)< 4.5, Ps>.01). Bonferroni corrections were applied to all multiple comparisons to reduce the likelihood of familywise alpha errors.

Visual Analog Scales

The data for the VAS were skewed, due mainly to individuals reporting close to the end points. The data was therefore transformed into normal distributions using the square root transformation. The relaxation VAS was reversed from the others so was transformed using the reflect and square root transformation (SQRT(10-*X*)). 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. See Table 2 for means, standard errors, F, and t values. For the open provocation, 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 (Fs (2,346)>10.04, ps<.001) and the interaction between condition and group was significant for all VAS except fatigue. Paired sample t-tests showed a significant difference between sham and GSM and between sham and UMTS conditions for sensitive participants, but not 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 results for the double-blind data were similar, with a significant main effect of group for all VAS and of condition for anxiety, tension, and arousal (Fs(2,312)>3.00, ps≤.05). Of more interest, there were significant condition by group interactions 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. 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). 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(43)=2.64, p< .025), while there was no difference between sessions 3 and 4 (M=2.32; t(43)=0.47, p>.05). To further 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.

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 4 for medians and Z scores). During the open provocation 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. During the double-blind tests 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 exposure condition.

Physiological Measures

Inspection of the physiological data revealed that it was skewed for all measurements except the HR (M). Square root transformations were applied to the BVP (SD), SC (M), and SC (SD). A logarithmic transformation was applied to the HR (SD) to form normal distributions (see Table 5 means, standard errors, and F values). The BVP (M) did not lend itself to transformation or analysis due to low kurtosis values. The data was analyzed using a 3 (condition: sham, GSM, UMTS) X 2 (group: sensitive, control) mixed ANOVA for the open provocation and double-blind tests. There was no difference 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 SC, with sensitive participants having higher SC (M and SD) responses during the open provocation and double-blind tests. The HR (SD) was also significantly higher in the sensitive compared to control group during the open provocation test. No other comparisons were significant.

On/Off Judgements

Participants made on/off judgements during both the 5 minute and 50 minute double-blind exposures. Sensitive participants had an accuracy rate of 55.2% during the 5 minute tests (d'=-0.08, sensitivity=66.4%, specificity=32.7%) and 59.8% during the 50 minute tests (d'=0.20, sensitivity=69.3%, specificity=40.9%). The control group had an accuracy rate of 51·4% during the 5 minute tests (d'=0.10, sensitivity=51.7%, specificity=50.8%) and 50.1% during the 50 minute tests (d'=0.06, sensitivity=48.0%, specificity=54.3%). See Figure 2 for ROC curves and 95% confidence intervals. For each group the 95% confidence interval on the ROC curves include the diagonal axis, implying that participant performance for each group did not differ from chance. Only 2 sensitive and 5 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.

Discussion

Elevated levels of arousal were found under double-blind conditions for the sensitive participants during the UMTS compared to sham exposure, similar to the findings of Zwamborn et al. (2003). Further analysis revealed that this increased arousal was most likely due to a higher proportion of sensitive individuals receiving the UMTS signal first. It is not surprising that sensitive individuals would be more anxious in the first of the double-blind sessions, given the degree of uncertainty they

may have felt in not knowing how the signal would affect them. This was reflected in the significant condition by group interaction for the anxiety-related measures of anxiety, tension, arousal and relaxation. However, during sessions 3 and 4 the sensitive individuals knew what to expect and were overall less anxious. In addition, the elevated level of arousal was not reflected in either the number or severity of symptoms reported, or the intensity of physiological measurements. Control individuals did not report any difference in levels of well-being for the UMTS signal, consistent with the findings of Regel et al. (2006) and the GSM signal did not affect levels of well-being for either group.

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 demonstrated that the laboratory conditions did not prevent sensitive individuals from reacting to either the GSM or UMS signals. In addition, the questionnaires and statistical analysis used to measure well-being and symptom severity were sensitive enough to detect these differences. Importantly, when these same exposures were presented under double-blind conditions taking order of exposure into account, no differences were observed.

Consistent with previous research, sensitive individuals reported more symptoms and greater severity of symptoms, and also displayed higher levels of SC than control individuals, regardless of type of exposure (e.g. Regel et al. 2006; Rubin et al. 2006; Lyskov et al. 2001b). This elevated level of SC in IEI-EMF compared to control individuals may reflect either a psychophysiological stress response to participating in the study, or a more general imbalance in autonomic nervous system regulation as suggested by Lyskov and colleagues (2001a). Further research in this

area is needed to specify what physiological parameters in sensitive individuals are significantly elevated compared to control individuals and if regulation of these parameters can help alleviate IEI-EMF symptoms.

The present data, along with current scientific evidence, leads to the conclusion that short-term rf-emf exposure from mobile phone technology is not related to levels of well-being or physical symptoms in IEI-EMF individuals. Furthermore, IEI-EMF individuals are unable to detect the presence of rf-emf under double-blind conditions. It remains the case however, that IEI-EMF individuals present with a range of distressing and serious symptoms and often have a very poor quality of life. Given the current findings, together with findings of related research (Rubin et al. 2005), it is imperative to determine what factors other than low-level rf-emf exposure could be possible causes of the symptoms suffered by IEI-EMF individuals, so that appropriate treatment strategies can be developed.

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Table 1: Procedures for Open Provocation and Double-blind Tests

Session 1	Task	Duration	Wash-out period
Open Provocation (e.g. sham, GSM, UMTS)	VAS completed every 5 minutes, symptoms reported, physiological measurements taken continuously	15 minutes for each exposure	2 minutes between each exposure
Cognitive Tests[a]	Participants completed Digit Symbol Substitution Task and Digit Span Task	8 minutes	
Quick Double-blind Test (e.g. GSM, UMTS, sham)	Participants made a judgement as to whether base station was 'on' or 'off' and how confident of this judgement they were using a scale from 0 'not at all sure' to 100 'completely sure'. If participants thought base station was 'on' they also indicated whether they believed it was the GSM or UMTS signal and how confident they were of this judgement from 0 to 100.	5 minutes for each exposure	2 minutes between exposures
Session 2, 3, 4 Double-blind (e.g. session 2: UMTS, session 3: GSM, session 4: sham)			
Low Load	Participants watched 'Blue Planet' video, completed VAS every 5 minutes, and recorded any symptoms. Physiological measurements were taken continuously during the session.	20 minutes	
High Load	Participants performed mental arithmetic (e.g. adding and subtracting 2 digit numbers). Task interrupted every 5 minutes for them to complete VAS and record any symptoms.	20 minutes	
Cognitive Tests	Participants completed Digit Symbol Substitution Task and Digit Span Task	8 minutes	
On/off Judgement	Same as in session 1, participants made a judgement as to whether the base station was 'on' or 'off.'		

a) The results of cognitive tests will be reported elsewhere.

Table 2: Descriptives and Statistical Tests for the VAS from the Open Provocation and Double-blind Tests for Sensitive and Control Participants by Exposure

	Sham		GSM		UMTS				Sham v GSM		Sham v UMTS	
	Sensitive	Control	Sensitive	Control	Sensitive	Control	Sensitive v Control	Group by Condition	Sensitive	Control	Sensitive	Control
Open Provocation	M (SE)[a]	M (SE)	M (SE)	M (SE)	M (SE)	M (SE)	F[b]	F	t	t	t	t
Anxiety	1.99 (0.26)	1.27 (0.10)	2.47 (0.28)	1.31 (0.11)	2.82 (0.32)	1.33 (0.11)	14.85**	14.30**	4.01**	0.52	5.23**	0.68
Tension	2.05 (0.27)	1.34 (0.11)	2.65 (0.30)	1.35 (0.11)	2.81 (0.31)	1.41 (0.12)	14.59**	15.65**	4.97**	0.52	5.18**	0.60
Arousal	1.96 (0.26)	1.18 (0.10)	2.61 (0.29)	1.19 (0.10)	2.72 (0.30)	1.22 (0.11)	17.26**	20.51**	4.72**	-0.16	6.14**	-0.22
Relaxation[c]	6.69 (0.34)	8.06 (0.15)	6.06 (0.35)	7.98 (0.16)	6.06 (0.36)	8.01 (0.16)	26.16**	7.39**	3.49**	0.97	3.39**	0.14
Discomfort	2.44 (0.29)	1.37 (0.13)	3.21 (0.30)	1.41 (0.12)	3.30 (0.32)	1.39 (0.13)	28.58**	15.38**	4.02**	0.46	4.47**	-0.14
Fatigue	3.26 (0.33)	1.97 (0.16)	3.21 (0.32)	1.91 (0.16)	3.40 (0.33)	2.00 (0.16)	14.52**	0.33				
Double-blind												
Anxiety	2.14 (0.26)	1.82 (0.12)	2.50 (0.27)	1.77 (0.13)	2.82 (0.31)	1.67 (0.11)	7.72*	8.15**	1.90	-0.63	2.89	-2.06
Tension	2.28 (0.27)	1.92 (0.12)	2.59 (0.27)	1.87 (0.13)	3.02 (0.33)	1.81 (0.12)	7.41*	8.36**	1.70	-0.72	2.94	-1.59
Arousal	2.17 (0.26)	1.74 (0.12)	2.59 (0.28)	1.71 (0.12)	2.92 (0.31)	1.65 (0.11)	9.6**	8.52**	2.20	-0.22	3.37**	-0.74
Relaxation	6.58 (0.34)	7.38 (0.15)	6.51 (0.32)	7.50 (0.15)	5.97 (0.40)	7.53 (0.16)	10.78**	6.47**	0.74	-1.14	2.15	-2.10
Discomfort	2.39 (0.31)	1.32 (0.11)	2.41 (0.25)	1.30 (0.11)	2.53 (0.30)	1.25 (0.11)	18.27**	0.94				
Fatigue	3.04 (0.37)	1.94 (0.15)	3.00 (0.33)	1.65 (0.13)	2.88 (0.33)	1.67 (0.13)	16.62**	0.82				

a) Means and SE are original untransformed data

b) With regards to the open provocation test, one sensitive participant failed to complete any of the VAS, while another did not complete any of the fatigue VAS.

c) The relaxation VAS was reversed so that a high score indicates extremely relaxed.

* $p \leq .01$, ** $p \leq .0025$

Bonferroni correction for multiple comparisons: open provocation $p<.0025$; double-blind $p<.003$

Non-parametric statistics was also performed on the untransformed data with virtually the same results (copies of this analysis is available upon request)

Table 3: Descriptives and Statistical Tests for Level of Arousal by Session by Group

	Sham	UMTS	Condition	Group	Condition X Group
Session 2	M (SE)[a]	M (SE)	F[b]	F	F
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					
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					
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
b) Session 2 df = (1,101), Session 3 df = (1,104) Session 4 df = (1,99)
* $p \leq .05$

Table 4: Medians and Z-scores for Total Number of Symptoms and Total Symptom Score from Open Provocation and Double-blind Tests for Sensitive and Controls by 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	2.00	0.00	-4.88*	5.00	1.00	-7.65*	5.00	1.00	-7.84*	-3.67*	-1.54	-4.57*	-2.91*
Total Symptom Score	2.00	0.00	-5.21*	5.50	0.00	-7.88*	6.00	1.00	-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
* $p \leq .005$

Table 5: Descriptives and Statistical Tests for Physiological Measures for Sensitive and Control Participants by Exposure during Open Provocation and Double-blind Tests

	Sham		GSM		UMTS				
	Sensitive	Control	Sensitive	Control	Sensitive	Control	Condition	Sensitive v Control	Group by Condition
Open Provocation	M (SE)[a]	M (SE)	M (SE)	M (SE)	M (SE)	M (SE)	F	F	F
BVP M[bc]	34.34 (0.06)	34.39 (0.04)	34.30 (0.07)	34.38 (0.04)	34.32 (0.06)	34.38 (0·04)			
BVP SD	2.23 (0.23)	2.51 (0.17)	2.07 (0.22)	2.50 (0.16)	2.17 (0.23)	2.50 (0.17)	1.38	2.89	1.70
SC M	5.36 (0.52)	3.47 (0.21)	5.50 (0.50)	3.46 (0.20)	5.53 (0.51)	3.43 (0.21)	0.32	21.82****	1.22
SC SD	0.62 (0.08)	0.45 (0.03)	0.62 (0.07)	0.45 (0.03)	0.64 (0.07)	0.46 (0.03)	0.70	6.78**	0.51
HR M	67.73 (1.21)	66.27 (0.88)	68.35 (1.27)	66.06 (0.89)	68.82 (1.46)	66.22 (0.89)	1.74	1.44	2.24
HR SD	6.60 (0.56)	5.77 (0.32)	6.18 (0.46)	5.80 (0.33)	6.73 (0.54)	5.76 (0.34)	0.43	5.35*	1.05
Double-blind									
BVP M[b]	34.29 (0.05)	34.34 (0.03)	34.29 (0.10)	34.36 (0.04)	34.40 (0.06)	34.37 (0.04)			
BVP SD	2.52 (0.26)	2.73 (0.15)	2.45 (0.23)	2.67 (0.16)	2.48 (0.24)	2.92 (0.15)	0.78	.·59	0.59
SC M	5.52 (0.54)	3.96 (0.22)	5.39 (0.45)	3.86 (0.23)	6.12 (0.57)	4.34 (0.27)	2.81	15.14****	0.08
SC SD	1.07 (0.13)	0.83 (0.07)	1.14 (0.13)	0.79 (0.06)	1.17 (0.12)	0.88 (0.07)	1.36	8.55***	0.38
HR M	72.80 (1.41)	71.95 (1.03)	73.80 (1.53)	71.55 (0.97)	73.21 (1.46)	71.41 (0.99)	0.23	0.89	0.79
HR SD	7.77 (0.85)	7.18 (0.34)	7.27 (0.62)	7.65 (0.39)	7.75 (0.68)	7.24 (0.35)	0.05	0.01	1.63

a) Means and standard errors for original untransformed data

b) BVP: blood volume pulse; SC: skin conductance; HR: heart rate; M: mean; SD: standard deviation

c) BVP M data did not lend themselves to transformation as participants' scores were tightly grouped around the mean; therefore, ANOVAs were not conducted on this data.

d) Non-parametric statistics was also performed on the untransformed data with virtually the same results (copies of this analysis is available upon request)

* $p \leq .05$, ** $p \leq .01$, *** $p \leq .005$, **** $p \leq .001$

Figure legends

Figure 1: Flow chart of Sensitive and Control Participation in Open Provocation and Double-blind Tests

Figure 2: ROC Curve and 95% Confidence Intervals for 'On/Off' Judgements for Sensitive and Control Participants

Figure 1: Flow chart of Sensitive and Control Participation in Open Provocation and Double-blind Tests

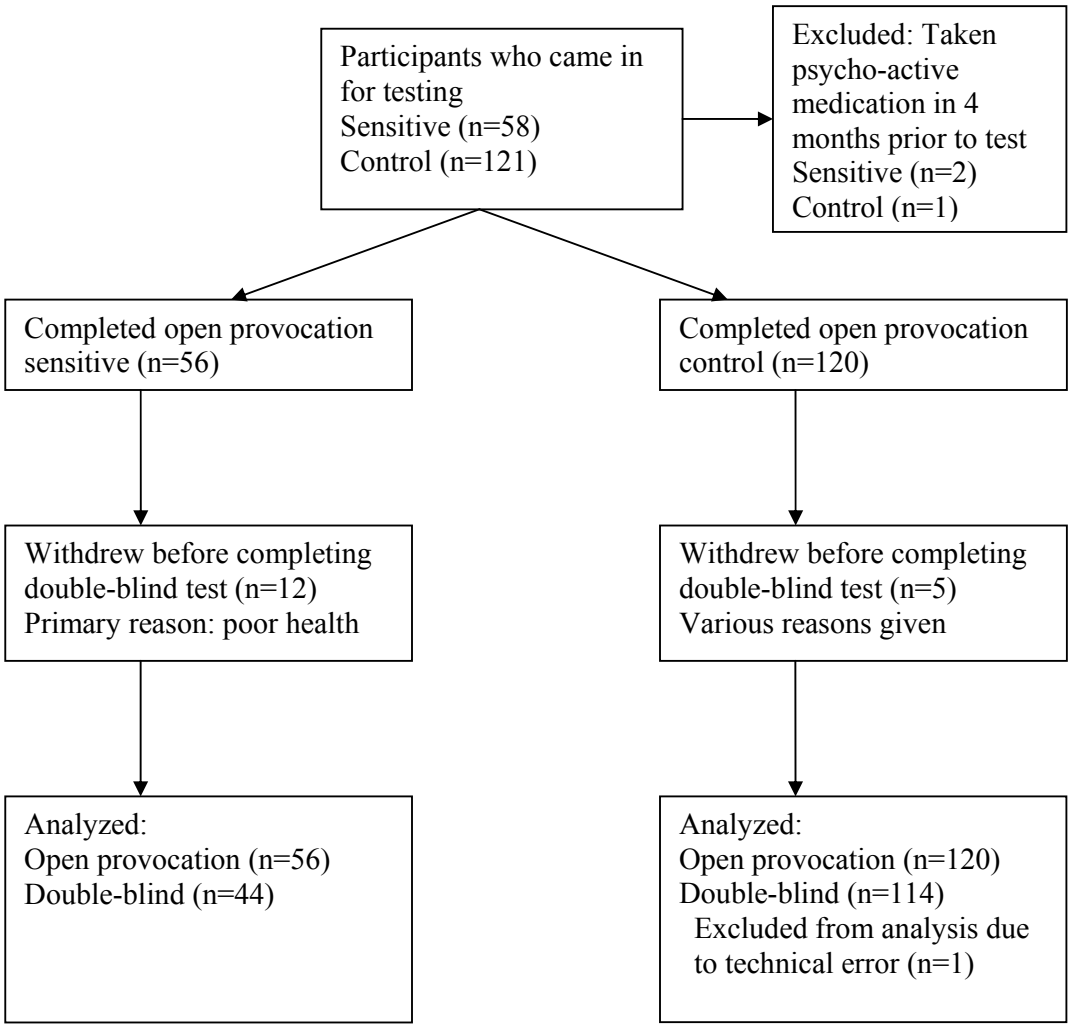
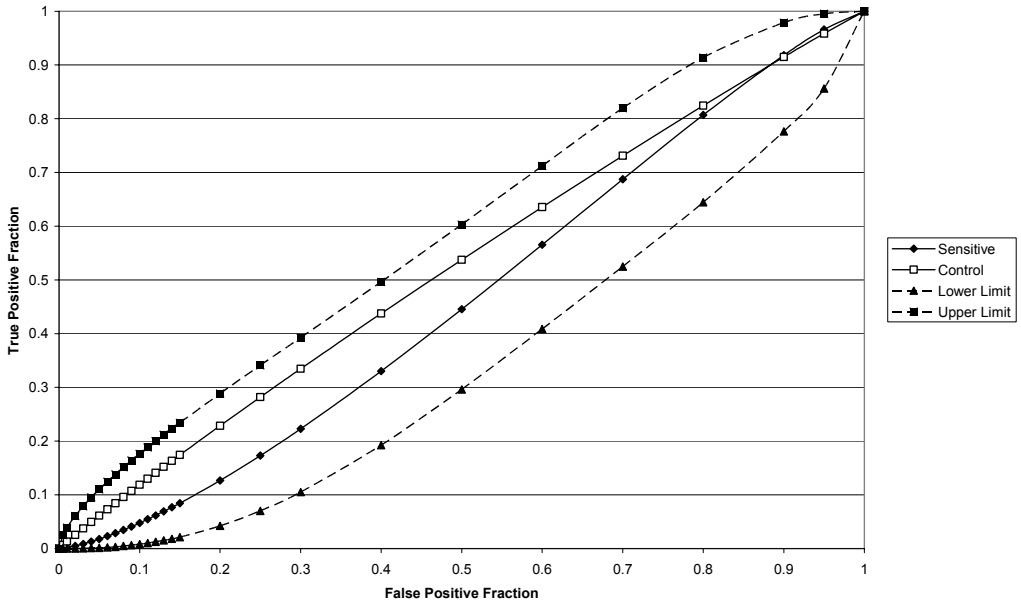
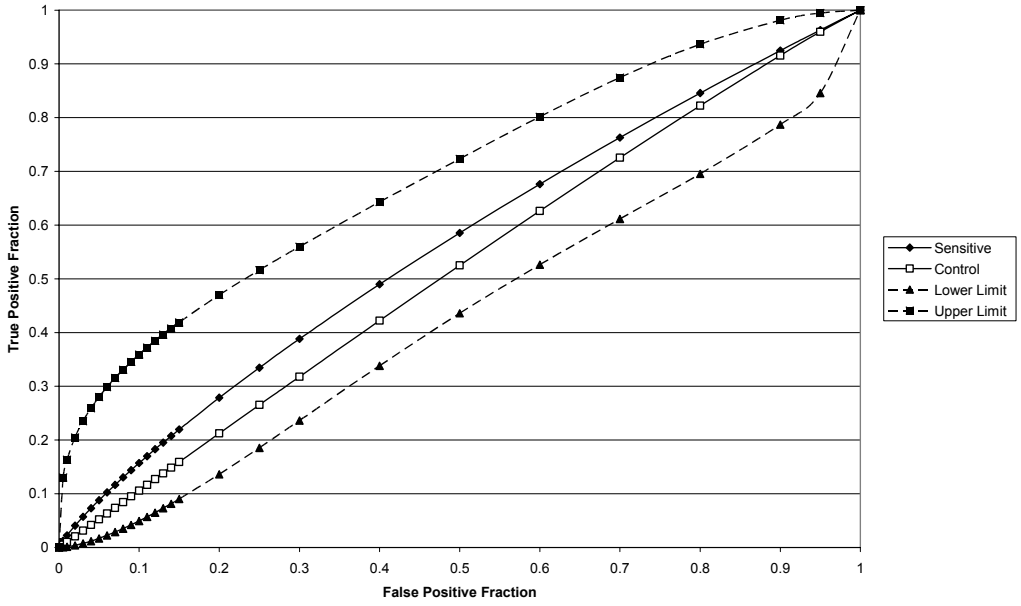


Figure 2: ROC Curve and 95% Confidence Intervals for 'On/Off' Judgements for Sensitive and Control Participants

a)



b)



a) ROC curve for the 5 minute double-blind sessions
b) ROC curve for the 50 minute double-blind sessions