Mobile Telecommunications and Health Research Programme

The Effect of TETRA Radiofrequency Fields on Symptoms in Police Officers

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RUM 23

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The Effect of TETRA Radiofrequency Fields on Symptoms in Police Officers

Dr G James Rubin[1,2], Dr Anthony J Cleare[2], Professor Simon Wessely[1]

1 Executive Summary

Concerns about possible adverse health effects have been raised with respect to a new radio system that has been introduced for the UK's emergency services. 'Terrestrial Trunked Radio' (TETRA) is a digital mobile radio system in which some of the signal emitted by a user's handset pulses at a frequency of 17.6 Hz. This is close to a frequency that the UK's Independent Expert Group on Mobiles Phones recommended should be avoided if possible as a precautionary measure. Some police officers from the first area to trial the equipment reported suffering symptoms such as nausea and headaches which they attributed to their use of the radio.

In this study we tested whether exposure to a TETRA signal could trigger short term symptoms. 120 police officers took part in our experiment, including 60 'sensitive' officers who reported previously experiencing adverse symptoms as a result of TETRA exposure and 60 'non-sensitive' officers who did not report these experiences. Each volunteer was asked to take part in three testing sessions, involving exposure to 50 minutes of a pulsing TETRA signal, exposure to 50 minutes of a non-pulsing signal and exposure to 50 minutes with no signal present. The order that these conditions occurred in was determined at random for each volunteer and the study was 'double-blind' with neither the volunteers nor researchers being told which sessions were which. During each session, volunteers were asked to complete questionnaires about any adverse symptoms that they experienced.

We found no robust evidence that the TETRA exposure had an adverse effect. Unexpectedly, however, our results suggested that the non-pulsing signal reduced the occurrence of skin symptoms in the sensitive participants when compared to our sham (no signal) exposure.

Questionnaire measures revealed several psychological differences between the sensitive and non-sensitive volunteers. Sensitive volunteers tended to be more concerned about the health effects of a wide range of environmental issues, had higher levels of depression, anxiety and occupational stress, and were more likely to associate TETRA use with stressful changes in their work. We also found that participants who expected to develop symptoms during our experiment were significantly more likely to actually develop symptoms.

Overall, our results suggested that TETRA use does not cause symptoms. Further research on this, and on our unexpected finding relating to the non-pulsing signal, would be of interest. Psychological mechanisms may partly explain the symptoms reported by some officers.

2 Aims and Objectives

Our research assessed whether exposure to TETRA radiofrequency fields (RF) affects symptom reporting in police officers who believe themselves to be particularly sensitive to TETRA and in police officers who do not report any sensitivity to it. We also tested whether certain psychological factors might contribute to this sensitivity.

Our specific hypotheses were that:

1) Exposure to TETRA RF will be associated with higher symptom severity than exposure to continuous wave RF or sham RF.

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2) Increases in symptom severity in response to TETRA exposure will be significantly greater amongst sensitive officers than amongst non-sensitive officers.

3) Symptom severity during the experiment will be associated with psychological factors such as emotional distress and expectation of symptom occurrence.

4) In comparison to non-sensitive officers, sensitive officers will report greater concern about the health risks of modern life, higher levels of occupational stress and greater negative affect. They will also be more likely to associate TETRA use with stressful situations.

5) Sensitive officers will have higher resting heart rates and critical flicker fusion thresholds than non-sensitive officers.

3 Participants

Dr GJ Rubin (Senior Research Fellow)[1,2]
Ms R Nieto Hernandez (Research Worker)[1,2]
Dr J Williams (Consultant Psychiatrist)[3 *]
Dr S Landau (Reader in Biostatistics)[4 *]
Dr AJ Cleare (Reader in Affective Disorders)[1,2]
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* Dr Williams and Dr Landau assisted with the analysis of the provocation study data.

4 Achievements

'Terrestrial Trunked Radio' (TETRA) is a digital mobile radio system in which some of the signal emitted by a user's handset pulses at a frequency of 17.6 Hz. This is close to a frequency that the UK's Independent Expert Group on Mobiles Phones (IEGMP) recommended should be avoided if possible. Their recommendation related to "amplitude modulation around 16Hz" and was based on earlier equivocal evidence of biological effects caused by signals operating at this frequency (Independent Expert Group on Mobile Phones 2000).

The TETRA system was introduced to the UK police in 2000 as a replacement to their existing analogue radios. Some police officers from the first area to trial the equipment reported suffering symptoms such as nausea and headaches which they attributed to their use of the radio. The subjective nature of the symptoms and the fact that they are attributed to weak electromagnetic fields (EMF) suggests that this phenomenon may be a subset of a broader condition called Idiopathic Environmental Intolerance with attribution to EMF (IEI-EMF; formerly called 'electrosenstivity'). This occurs when individuals experience any of a wide array of subjective symptoms which they attribute to the EMF emitted by electrical devices such as mobile phones, visual display units, microwave ovens and fluorescents lights. To date, 46 experiments have found no robust evidence linking exposure to EMF with the symptoms reported by people who have IEI-EMF (Rubin et al. 2005;Rubin et al. 2010).

Speculation exists that IEI-EMF may be related to psychological factors (Rubin et al. 2007). Stress may be one factor which plays a role in causing an individual to initially develop negative symptoms while using an electrical device, particularly stress associated with use of the device itself (Rubin and Wessely 2006;Rubin et al. 2007). Other factors, such as having a high degree of concern about the health effects of modern life or a tendency to experience negative mood may also help to determine whether or not someone comes to believe that an electrical device is responsible for triggering their symptoms (Petrie et al. 2005;Petrie et al. 2001;Rubin et al. 2007). Other psychological factors including negative mood or expectations have also been implicated as

potential causes of short term symptoms as part of the 'nocebo' effect (Rubin et al. 2006).

Physiological mechanisms may also be relevant in the aetiology of IEI-EMF. For instance, it has been reported that individuals who suffer from IEI-EMF tend to exhibit higher basal heart rates and decreased heart rate variability than healthy individuals (Lyskov et al. 2001) suggesting an abnormality in the autonomic nervous system. There has also been some suggestion that patients with IEI-EMF may show generalised hyperresponsiveness to external stimuli, as demonstrated by a heightened ability to discriminate flicker from constant light (the Critical Flicker Fusion (CFF) test) (Lyskov et al. 2001).

As yet, no experimental study has examined the effects of short-term exposure to TETRA on subjective symptoms. In this study, we used a double-blind experiment to test whether exposure to a TETRA-like signal causes acute symptoms among regular TETRA users. In order to assess if the pulsing nature of the TETRA signal is important, the effects of exposure to a continuous wave (CW) signal of the same mean power were also tested. Finally, we also tested whether any effects of exposure were more noticeable in individuals who had previously attributed symptoms to TETRA than in individuals who have not previously reported such symptoms.

The same study was also used to test whether participants who reported sensitivity to TETRA were significantly different to non-sensitive participants with regards to psychological variables such as emotional distress, concern about the health effects of modern life, occupational stress and the association of TETRA radio use with stress. We also tested whether differences in baseline CFF threshold or pulse rate could be observed between the groups. Finally, in order to assess factors that might be relevant in triggering the nocebo effect, we tested whether expectations and negative affect predicted symptom onset during our provocation study.

5. Methods

Design

In order to assess the impact of TETRA on symptom reporting, we exposed two groups of participants ('sensitive' and 'non-sensitive') to three different conditions (TETRA, CW and sham exposure) in a double-blind within-participants randomised controlled study. The handset used to generate the three exposures allowed for 256 different settings. Ten settings were pre-allocated to each of the three conditions and were only known by the manufacturer of the handset and by staff at the Institute of Psychiatry Clinical Trials Unit (CTU). CTU staff randomised the order of the exposure sessions for each participant upon their entry into the study using a computerised random numbers generator, with condition order being counter-balanced within blocks of six consecutive participants. The randomising procedure generated a setting code for each condition which was entered onto the handset by CTU staff on the day of testing. As an additional layer of blinding, the setting entered was then obscured using opaque tape.

A sub-set of the data obtained in the provocation study was used to test the importance of expectations and negative affect in driving the nocebo effect.

For the comparison of sensitive and non-sensitive participants with respect to psychological and physiological variables, we used a cross-sectional design in which we compared baseline measures between the two groups.

Participants

Volunteers had to be 18 years or over and use a TETRA radio at least once a week. Participants were eligible for the sensitive group if they reported experiencing subjective symptoms which they attributed to TETRA and if they reported being at least 70% sure that their radio's signal was to blame. Participants were only included in the sensitive group if these sensations occurred within an hour of radio use and if they occurred when the radio was used near their head. Participants were included in the non-sensitive group if they did not experience any symptoms which they attributed to the radio. Participants were excluded from the provocation study if they reported being pregnant or trying to conceive or if

they reported suffering from any medical or psychological condition which could cause similar symptoms to those examined here. We advertised the study within UK Police Forces by sending circular emails and by putting notices in police newsletters and intranet sites. We also placed adverts in several police related magazines and websites.

Exposure equipment

The exposures were delivered by the UK Mobile Telecommunications and Health Research (MTHR) programme's TETRA exposure system (for details see www.mcluk.org/ MTHR_exposure_systems). This system produced a mean radiated power of 250mW for the CW and TETRA exposures, resulting in a maximum specific energy absorption rate (SAR) close to the antenna with a value of 1.3 W kg $^{-1}$ averaged over 10 g (± 30%). The SAR value from the handset body was 0.3 W kg $^{-1}$ in TETRA and CW mode. For the sham mode, the power was diverted to an internal load in order to provide the same heating and low-frequency magnetic fields as produced in the active signals. Minor leakage of the signal occurred through the antenna in the sham condition, producing a mean SAR of approximately 0.002 W kg $^{-1}$. The TETRA signal had a pulsing frequency of approximately 16 Hz. Because of this pulsing, the TETRA condition produced a peak radiated power of 1W, approximately four times higher than its mean radiated power. The carrier frequency for all modes was 400MHz.

Measures

We collected the following background data for both groups: demographic data; the presence of 50 symptoms over the previous month and whether these symptoms were attributed to TETRA; the presence and severity of medically unexplained sensitivities (assessed using a list of possible chemical and electrical symptom triggers including five triggers related to TETRA equipment (Rubin et al. 2006)); whether participants described themselves as suffering from "electrosensitivity / sensitivity to electromagnetic fields"; and whether participants had ever experienced symptoms which they attributed to their previous analogue radio system. We also asked participants in the sensitive group: how long they had been sensitive to their TETRA radio for; how quickly they usually developed symptoms when using their radio; how long their symptoms usually lasted for; how near a handset had to be to affect them; and how much their sensitivity to TETRA affected their ability to work.

Several psychological scales were administered to participants at baseline. These consisted of: the Modern Health Worries questionnaire (containing four subscales designed to assess concern about the health effects of modern life) (Petrie et al. 2001); the SF-36 (a widely used set of eight subscales designed to assess quality of life and functional impairment) (Ware and Sherbourne 1992); the Hospital Anxiety and Depression Scales (HADS) (Zigmond and Snaith 1983); the Police Stress Questionnaire (containing two subscales designed to assess operational stress (PSQ-op; with items relating to e.g. shift work or over-time demands) and organisation stress (PSQ-org; with items relating to e.g. red tape or staff shortages)) (McCreary and Thompson 2004); and thirteen items relating to perceptions about airwave and whether its use might be associated with increased stress (see results section for items).

Immediately before and at the end of each experimental session participants completed the Positive and Negative Affect Schedule (PANAS) (Watson et al. 1988). This mood rating scale produces two scores (positive mood and negative mood), each from 10 (least emotion) to 50 (most emotion). Immediately prior to each testing session, participants were asked "how do you expect to feel at the end of this session" and were asked to record their answers using eight 11-point numerical scales from 0 (no sensation) to 10 (worst possible sensation). These scales related to: 'headache;' 'fatigue;' 'dizziness;' 'nausea;' 'sensations of warmth or burning on skin;' 'skin itching, tingling, stinging or numbness;' 'feeling irritable, anxious, or depressed;' and 'difficulty concentrating or thinking.' During the testing sessions, participants assessed whether they were experiencing any of these eight symptoms using the same 11-point numerical scales. Following each exposure session, participants stated whether they thought the handset was emitting a signal or not and how confident they were about this on an 11-point scale from 0 (complete guess) to 100 (100% certain). At the end of the third session, they also stated which session they thought was most likely to have involved a TETRA signal, which one was most likely to have been the sham session and how confident they were about both answers.

CFF threshold and pulse rate

CFF threshold was assessed at baseline using a Flicker Fusion instrument (*Model 12021; Lafayette Instrument Company, Indiana USA*) and calculated as the mean of six trials, which alternated between ascending trials starting at a flicker rate of 1Hz and descending trials starting at 60Hz. All trials used a luminance setting of 91% and flicker increments or decrements of 1Hz per second. Resting pulse rate was measured before each of the three exposure sessions in the non-dominant wrist.

Procedure

We provided written information to those individuals who approached us about the study and conducted a telephone interview in order to assess their suitability. Individuals who met the inclusion criteria were invited to visit our research unit on three occasions. Participants who decided not to participate in the provocation study, who could not find time to attend for testing or who did not meet the strict inclusion criteria for the provocation study, but who wished to assist with the research nonetheless, were sent our background and psychological questionnaires to complete at home and return by post.

We asked participants who attended for the provocation study to refrain from taking recreational drugs for at least one week before each visit and to avoid drinking alcohol for at least 24 hours. We also asked them to avoid taking painkillers or other non-essential medication on the day of each visit and to avoid stressful situations or strenuous exercise.

Participants who attended for the provocation study were exposed to one of the three signals (TETRA, CW or sham) in each session. Sessions were booked with at least 24 hours between them, or longer if a participant reported that they usually took more than 24 hours to recover from exposure to TETRA. Sessions took place inside an unshielded room lit by two table lamps. Each session started with a resting period of 30 minutes. During this time in the first session, informed written consent was obtained, the background data and psychological questionnaires were completed, pulse was recorded and the CFF threshold was measured. After 30 minutes, the handset was attached using a headband and positioned so that the antenna was within a few millimetres of the head, above and slightly behind the participant's left ear. Immediately prior to exposure, the participant completed the PANAS, a baseline symptom severity questionnaire assessing the eight symptoms and questions about their expected symptom level for the end of the exposure session. The handset was then turned on. Symptom severity scales were completed again after 5, 15, 30, and 50 minutes during the exposure, at which point the PANAS was completed again and the handset then turned off and removed. After another resting period of 30 min, the participant was asked whether he or she thought the radio had emitted a signal and how confident he or she was about this. When not completing our questionnaires, most participants chose to read magazines during the testing sessions. At least 24 hours later, the participant completed the symptom scales again over the phone in relation to how they were feeling at that moment. The second and third sessions used the same procedure except for the type of signal emitted. At the end of the third session, participants were asked which of the three sessions they thought was emitting TETRA, which one was sham, and how confident they were about this.

Ethics

This study was approved by the South London and Maudsley NHS Trust research ethics committee (reference 04/Q0706/65).

Sample size calculation

The sample size calculation for this study was the same as that performed for a previous study using the same experimental design (Rubin et al. 2006). This suggested that 60 participants would be required in order to detect a moderate effect size of exposure to TETRA in the sensitive group. However, the nature of our data required us to change our planned analytic strategy. A subsequent power calculation (details available on request) showed that our new strategy gave us 90% power to detect an absolute increase of 25% or more of participants reporting headache in the CW condition compared with the sham condition, using the 5% significance level.

Analysis of provocation study symptom data

Although the symptom severity scales offered 11 ordered response categories, participants' responses were highly skewed and over-dispersed and attempts to use analyses based on ordered category models were found to be unstable. We therefore dichotomised each 11 point

symptom severity score into a value of symptom absent (score of 0) or present (score of 1 to 10).

We analysed the dichotomised ratings individually using univariate generalized linear mixed-effects models (GLMMs) to account for the correlation between the repeated binary measures per subject. These GLMMs used the adaptive Gaussian Hermite approximation with seven quadrature points (Pinheiro & Bates 1995) to analyse symptom severity over time in the three different conditions. This analysis used version 2.9.2 of R (R Core Development Team 2008) and the lme4 package (Bates et al. 2008). For each symptom, we first fitted an initial multi-level mixed-effects model which included the following design-related fixed effects: session (first, second or third testing session), baseline symptom rating, within-session time (5, 15, 30 or 50min), group (sensitive vs. non-sensitive) and the interactions between baseline and time, and between group and time. The models also included subject-varying random intercepts and random slopes for session and time and their two-way interaction. This model was then compared with a model that also included eight terms that were related to the experimental exposures, namely two exposure variables (CW or 'pulsing'), their two-way interactions with time and with group, and their three-way interactions with both group and time. For these second models, dummy variables were set up for exposure, with one dummy variable labelled 'CW' being coded as 1 for CW and 1 for TETRA, and the other dummy variable labelled 'pulsing' being coded as 0 for CW and 1 for TETRA. Coding the dummy variables in this way allowed us to examine the specific effects of the pulsing within our TETRA exposure by controlling for any non-pulsing effects of the signal which will also have been present in our CW condition. We first assessed whether adding the eight exposure-related terms significantly improved our ability to predict whether or not a participant had experienced a given symptom using likelihood ratio x^2 tests. For those symptoms in which adding all eight exposure-related terms significantly improved the model, we used a step-down procedure, based on the likelihood ratio x^2 test to identify which of the eight terms produced the best fitting yet most parsimonious model.

For two symptoms ('fatigue' and 'skin itching, tingling, stinging or numbness') our original models produced false convergence warnings. For these symptoms, we used analyses with a simplified random-effects structure (random intercepts and random slopes only over session) and a more robust optimisation algorithm (Laplacian approximation).

Positive and negative PANAS scores were analysed separately using a similar procedure, with positive scores dichotomised as less than or equal to 30, or more than or equal to 31, and negative scores dichotomised as scores of 10 versus scores of 11 or more. These cut-offs were selected as round numbers close to the median scores. Initial analyses included baseline score, group and session as the explanatory variables. Subsequent analyses then also included the effects of exposure and the interaction between exposure and group.

Scores for the eight symptoms which were recorded at 24 hour follow-up were also analysed in this way. We first allocated each participant an overall score of 0 or 1 for each exposure condition to indicate whether they had experienced any of the eight symptoms at follow-up (defined as reporting a score of 1 or more for any of the symptom severity scales). The initial analysis for this outcome included only the group and session terms. The subsequent analysis added in terms for exposure and the exposure by group interactions.
Finally, we tested the ability of participants to discriminate between the sessions during the experiment, and their ability to judge which session was most likely to have been sham and which TETRA, using generalised linear models with a 1/3 logit link, based on the three alternate forced choice procedure (three AFC in the sensR package of Christensen and Brockhoff (Christensen and Brockhoff 2008)).

Analysis of expectations and negative affect as predictors of symptom onset
A path diagram was produced to represent the hypothesised relationship between negative affect, symptom expectation and symptom report (see Figure 1). This path diagram was tested using data relating to headache occurrence (dichotomised in the same way as for the main provocation study analysis) during the sham exposure condition. For 'expectation of symptoms' we used data relating to the expectation of headaches prior to the sham exposure. This was dichotomised based on a

score of 0 (no headache expected) or 1 to 10 (headache expected). 'Negative affect' was measured before the sham exposure with the negative affect subscale of the PANAS. 'Modern health worries' was measured with the radiation subscale of the modern health worries questionnaire. Mediational analysis was used to test the significance of the proposed causal sequences (Baron and Kenny 2006). Due to the inclusion of dichotomous outcome and mediator variables, logistic regressions were chosen to perform the analysis. The coefficients derived from the regressions were transformed to make them comparable across the equations using software available from http://nrherr.bol.ucla.edu/Mediation/logmed.html. The Sobel test was used to determine whether the effect between independent variables and outcome through a mediator was significant.

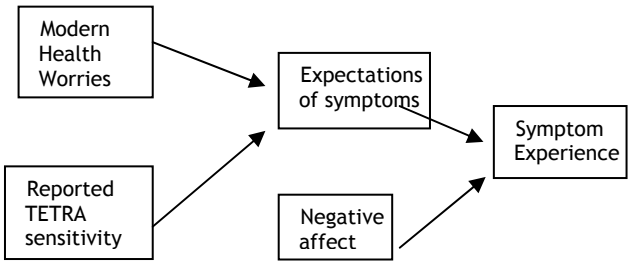

Figure 1. Path diagram illustrating hypothesised role of modern health worries, perceived sensitivity, expectations and negative affect on symptom occurrence.

Analysis of psychological, physiological and background differences between sensitive and non-sensitive groups

x^2 tests and t-tests were performed to compare background, psychological, CFF and pulse data between the groups, using SPSS version 15.0.

Results

Background variables

We were contacted by 134 individuals between December 2005 and December 2007 who appeared to be eligible for the provocation study and who gave verbal consent for it during our screening process. Of these, 133 came from 37 UK police forces and one from a different government agency. 121 participants attended their first testing session and 120 completed the study (see figure 2 for flow chart). All provocation-related and CFF analyses were based on the 120 who finished the study. Demographic data are presented in table 1. We found no significant differences between groups in terms of most demographic variables ($p>0.05$), although more sensitive participants were married or cohabiting than non-sensitive participants ($p=0.01$). The sensitive group reported being sensitive to a significantly higher number of electromagnetic ($p<0.001$) and chemical stimuli ($p=0.009$) than non-sensitives (table 2). They also reported a significantly higher number of neurophysiological, respiratory, cardiovascular, peripheral-neurological and global symptoms in the previous month ($p<0.005$). No non-sensitive participants attributed any symptoms in the previous month to their TETRA radio, while the sensitive group attributed a median of 2 (interquartile range: 1 to 4.75) symptoms. The most commonly attributed symptoms were headaches (reported by 86%), fatigue (31%), forgetfulness (23%), loss of concentration (23%) and irritability (22%).

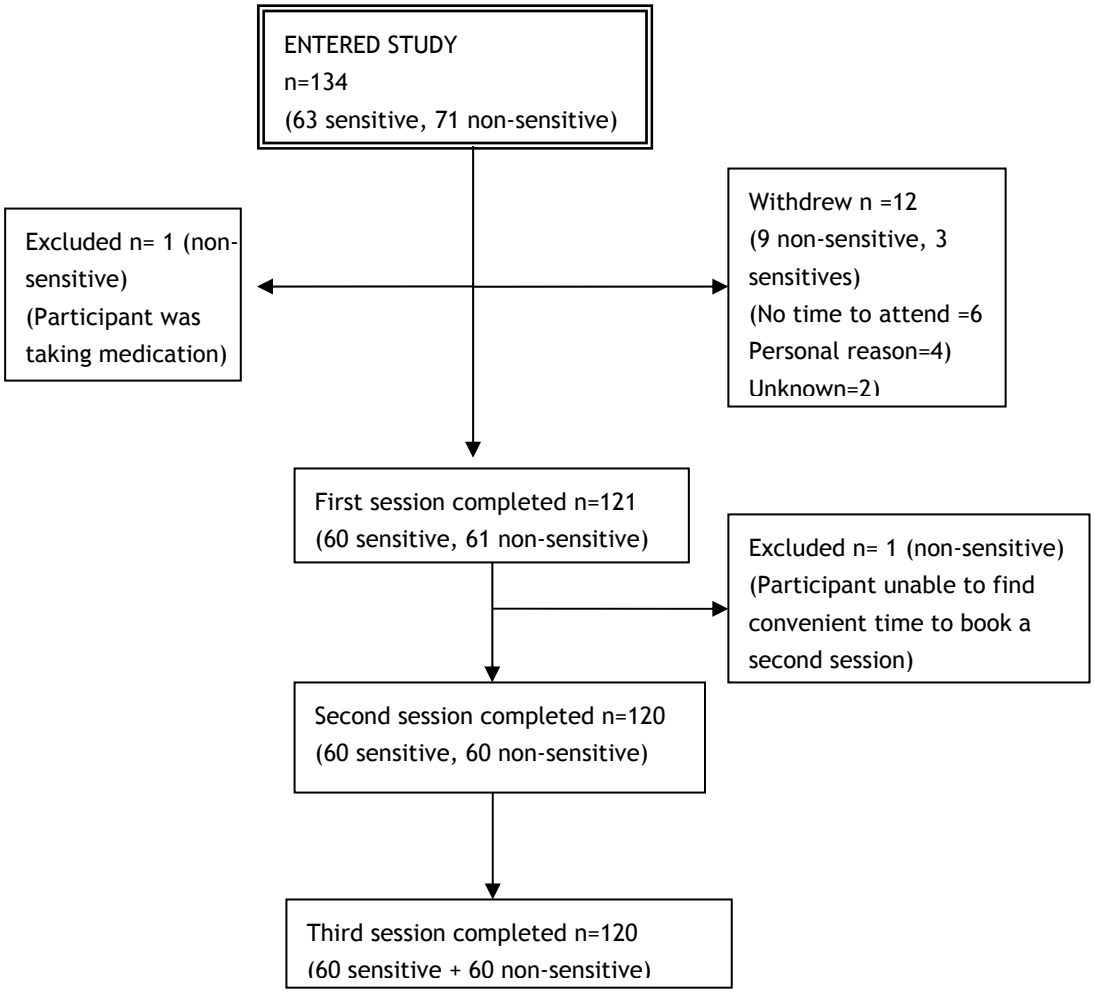

Figure 2. Study flow diagram for participants who were enrolled for the provocation study

	Sensitive n=60	Non-sensitive n=60	Difference between the groups
Age: Mean (SD)	35.6 (7.4)	38.2 (8.0)	t= 1.9, 118df, p=0.06
Sex: Male/Female (n)	53 / 7	50 / 10	x^2=0.6, 1df, p=0.43
Marital status: Single/Married or Cohabiting Separated or Divorced (n)	13 / 47 / 0	17 / 36 / 7	x^2=9.0, 2df, p=0.01
Ethnicity: White/Other (n)	55 / 5	58 / 2	x^2=1.4, 1df, p=0.24
Educational level: No qualification/ Secondary / Higher education (n)	2 / 44 / 14	1/ 45 / 14	x^2=0.3, 2df, p=0.84
Employment status: Full time/ Part-time/ Sick leave (n)	56 / 3 / 15	55 / 5 / 0	x^2=1.5, 2df, p=0.47
Police rank: Civilian / Trained police/ Higher rank (n)	7 / 44 / 9	8 / 33 / 19	x^2=5.2, 2df, p=0.07

Table 1. Demographic information for sensitive and non-sensitive participants and comparison between groups with x2 and t-tests (n=120).

Symptom subscale (number of symptoms or triggers included in scale)	Sensitive n=60 Mean score (SD)	Non-sensitive n=60 Mean score (SD)	Difference between the groups
Neurophysiological symptoms (11)	5.73 (2.67)	3.27 (2.65)	t=5.1, 118df, p<0.001
Respiratory symptoms (7)	1.05 (1.35)	0.55 (0.96)	t=2.3, 118df, p=0.02
Cardiovascular symptoms (2)	0.43 (0.62)	0.13 (0.39)	t=3.2, 118df, p=0.002
Ophthalmologic symptoms (3)	0.60 (0.74)	0.40 (0.56)	t=1.7, 118df, p=0.10
Peripherical-neurological symptoms (3)	0.58 (0.94)	0.25 (0.70)	t=2.2, 118df, p=0.03
Global symptoms (10)	1.55 (1.65)	0.52 (1.02)	t=4.1, 118df, p<0.001
Urogenital symptoms (4)	0.35 (0.61)	0.18 (0.50)	t=1.6, 118df, p=0.10
Gastrointestinal symptoms (6)	1.05 (1.13)	0.80 (1.07)	t=1.3, 118df, p=0.22
Auditory symptoms (2)	0.47 (0.65)	0.27 (0.48)	t=1.9, 118df, p=0.06
Musculoskeletal symptoms (2)	0.45 (0.79)	0.42 (0.70)	t=0.2, 118df, p=0.81
Number of EMF triggers reported (14)	3.12 (1.34)	0.78 (0.99)	t=10.8, 118df, p=0.001
Number of chemical triggers reported (11)	3.72 (2.19)	2.75 (1.79)	t=2.7, 118df, p<0.001

Table 2. Mean (SD) number of symptoms experienced in the previous month on ten symptom subscales and mean (SD) number of reported EMF and chemical triggers for symptoms

None of the participants reported having experienced symptoms with their previous analogue radios. Between 57 and 59 of the sensitive participants responded to each question about their sensitivity to TETRA radios. These participants reported having been sensitive to TETRA for a median of 18 months (interquartile range: 12 to 24 months), that their symptoms appeared within a median of 10 minutes of using the equipment (2.5 to 45 minutes) and lasted for a median of 1.5 hours (16min to 3.5 hours). Eight participants initially reported that their symptoms usually took longer than one hour to develop. However, during our interview with them each reported that they would still expect to experience some effects during a 50min exposure; they were therefore included in the study. Individuals reported that the furthest distance a radio could be and yet still trigger negative effects was a median of 17.5 centimetres from their body (interquartile range: 6cm to 30cm). The median work impairment reported by participants as a result of their TETRA sensitivity was 2 (interquartile range: 2 to 3) on a scale of 0 ('not at all') to 8 ('very severely impaired') (Mundt et al. 2002); thirteen sensitive participants (22%) reported a score of 4 ('definitely impaired') or worse.

Symptoms reported during the provocation study

CW exposure increased the likelihood of headache, but pulsing reversed this effect (figure 3). Collectively, the eight terms that involved CW and pulsing exposure improved the basic model for headache ratings (LR x^2=15.6, 8df, p=0.048). Backward stepwise elimination showed that none of the interaction terms were significant, but only the main effects of CW and pulsing (figure 3: LR x^2=9.4, 2df, p=0.009; main effect of CW: z=2.92, p=0.004; main effect of pulsing: z=-2.46, p=0.013). Compared with the sham condition, CW exposure reduced initial ratings of fatigue in non-sensitive participants, but their ratings rose more steeply over time (figure 4). Pulsing reversed these effects. Neither exposure had any effect on sensitive participants. Collectively, the exposure effects significantly improved the basic model for fatigue (LR x^2=17.9, 8df, p=0.02). Backward stepwise elimination showed that the 3-way interactions were significant (LR x^2=6.29, 2df, p=0.043). In detail, non-sensitive participants undergoing CW exposure showed lower early fatigue ratings (intercept: z=-3.31, p<0.0001) and a faster increase in these ratings over time (CW x time interaction: z=2.46, p=0.014), but

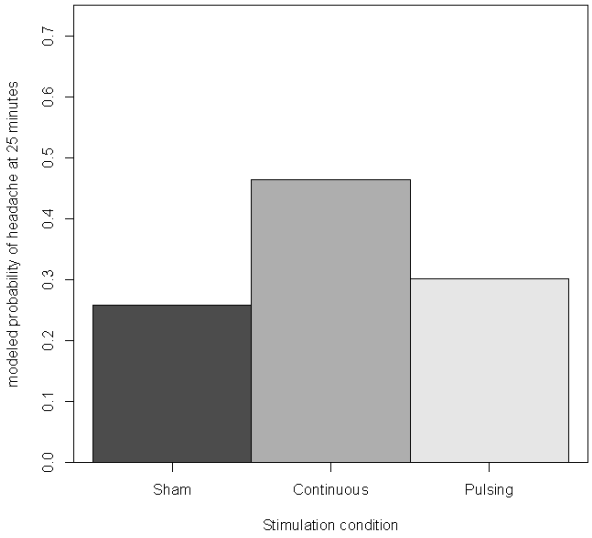

Figure 3: Modelled probability of a headache occurring during the Sham, CW and TETRA exposure conditions. In contrast to the results text, in this figure 'pulsing' results have been calculated as the sum of sham, CW and pulsing conditions, and so reflect the actual values obtained in the TETRA exposure.

pulsing reversed these effects (intercept: z=2.56, p=0.01. time x pulsing interaction: z=-2.96, p=0.003). Sensitive participants showed higher initial ratings of fatigue (z=3.72, p=0.0002), but neither CW exposure nor pulsing affected their rates of increase over time (z=1.07, p=0.29). Thus CW and pulsing had opposite effects on fatigue ratings in non-sensitives (figure 4) but neither form of exposure altered fatigue ratings in sensitive participants. CW exposure increased the likelihood of 'difficulty concentrating or thinking' in sensitive participants (figure 5). Collectively, the eight exposure-related terms improved the basic model (LR x^2=16.0, 8df, p=0.04). Backward stepwise elimination showed that the 2-way interaction of exposure with sensitivity was significant (LR x^2=8.5, 2df, p=0.014; CW x group: z=2.08, p=0.037). Pulsing exposure did not alter this rating in the sensitive group (z=0.07, ns; figure 5).

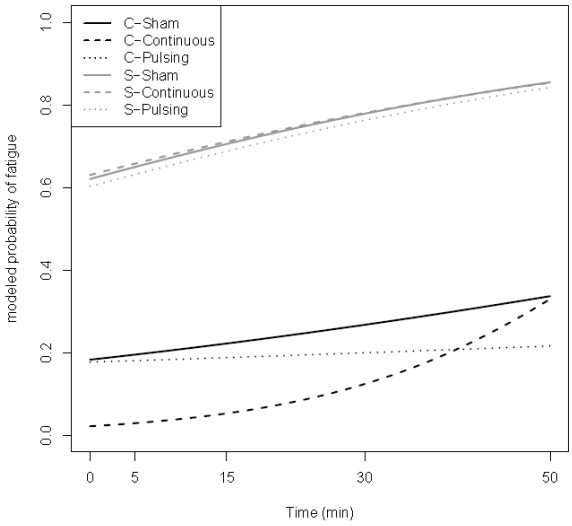

Figure 4: Modelled probability of fatigue occurring during the Sham, CW and TETRA exposure conditions In contrast to the results text, in this figure 'pulsing' results have been calculated as the sum of sham, CW and pulsing conditions, and so reflect the actual values obtained in the TETRA exposure.

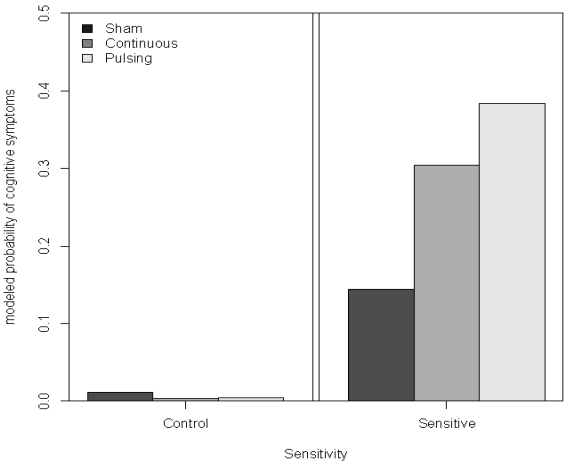

Figure 5: Modelled probability of difficulty concentrating or thinking occurring during the Sham, CW and TETRA exposure conditions. In contrast to the results text, in this figure 'pulsing' results have been calculated as the sum of sham, CW and pulsing conditions, and so reflect the actual values obtained in the TETRA exposure.

CW exposure tended to reduce ratings of itching in sensitive participants, but pulsing reversed this effect (figure 6). Collectively, the eight terms that involved CW or pulsing exposure improved the basic model for itch ratings (LR x^2=23.7, 8df, p=0.003). Backward stepwise

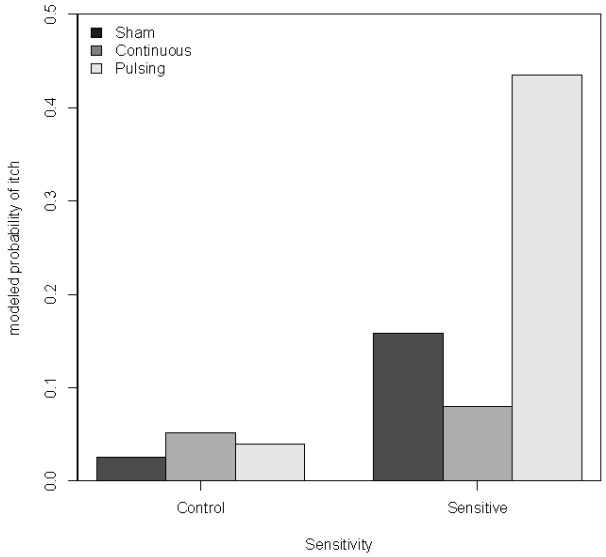

Figure 6: Modelled probability of 'skin itching, tingling, stinging or numbness' occurring during the Sham, CW and Tetra exposure conditions. In contrast to the results text, in this figure 'pulsing' results have been calculated as the sum of sham, CW and pulsing conditions, and so reflect the actual values obtained in the TETRA exposure.

elimination showed that the 2-way interaction of exposure with group was significant (LR x^2=7.94, 2df, p=0.02). The contrasting effects of exposure on itch ratings in the sensitive group (figure 6; continuous: z=-1.82, p=0.069; pulsing: z=2.61) were absent in the non-sensitives (continuous: z=1.10, ns; pulsing: z=-0.37, ns). Adding in all eight exposure related terms did not improve the basic models for the ratings of feeling irritable, anxious, or depressed (LR x^2=5.9, 8df, p=0.66), nausea (LR x^2=7.3, 8df, p=0.51), dizziness (LR x^2=4.0, 8df, p=0.86) or sensations of warmth or burning on skin (LR x^2=14.6, 8df, p=0.07).

For symptoms reported at 24 hour follow-up, CW exposure increased the likelihood of reporting any symptom, while pulsing reversed this effect. Statistically, the four exposure-related terms were significant overall (LR x^2 =10.6, 4df, p=0.03) with significant main effects of CW (z=2.3, p=0.02) and pulsing (z=-3.1, p=0.002) conditions.

In order to correct for the use of multiple statistical tests, we adjusted the p-values for the nine overall LR x^2 statistics which related to symptom reporting during the experiment of at 24 hour follow-up. This was done using

the Simes adjustment (Simes 1986). With p-values adjusted in this way, adding in exposure related terms did not significantly improve the models for any of the outcome variables (all p≥0.09), except for itch, which still showed a significant overall effect of adding in the exposure-related terms (adjusted p=0.03).

Mood reported during the provocation study

Inclusion of exposure related terms did not affect the model for the negative subscale of the PANAS (LR x^2 =2.8, 4df, p=0.6). Scores for the positive subscale showed a nearly significant effect (LR x^2 =9.1, 4df, p=0.06), with pulsing exposure tending to increase the likelihood of a high positive mood score, but only in the non-sensitive group (group x pulsing: z=-2.4, p=0.02).

Discrimination between presence and absence of signals during the provocation study

We found no evidence that participants could detect the presence of a signal during each session or that they could tell which sessions were most likely to have been sham and which were most likely to have been TETRA (see table 3). Neither non-sensitive nor sensitive participants could discriminate between the exposures during the experiment (non-sensitive: z=-0.2, p=0.84. sensitive: z=1.05, p=0.30), nor could they tell which session was most likely to have been sham (non-sensitive: z=-0.83, p=0.4. sensitive: z=-0.38, p=0.7) or which was most likely to have been TETRA (non-sensitive: z=0.39, p=0.7. sensitive: z=-0.6, p=0.55).

The role of expectations and negative affect as predictors of symptom onset

Four logistic regressions were performed to test the path diagram specified in figure 1. The first was performed to assess the impact of expectations and negative affect on the likelihood of reporting headaches at the end of a sham provocation session. The model was able to distinguish between those who developed symptoms and those who did not (x^2 =54.43, p<0.001). The model as a whole explained between 36% (Cox and Snell R^2) and 49% (Nagelkerke R^2) of the variance in symptom reporting and correctly classified 82% of cases. As shown in table 4, only expectation of symptoms made a significant contribution to the model.

	Was a signal present in this condition? (Number saying yes [mean confidence (SD)]		Which session was TETRA and which was sham? (Number correctly identifying each session [mean confidence (SD)]	
	Non-sensitive	Sensitive	Non-sensitive	Sensitive
Sham	36/60 [64.72 (26.67)]	34/60 [21.76 (29.39)]	18/60[80.00 (20.29)]	19/60 [21.05 (30.89)]
TETRA	34/60 [60.88 (22.21)]	37/60 [17.57 (23.74)]	20/60[76.50 (10.40)]	22/60 [28.64 (28.16)]
CW	34/60 [61.18 (31.21)]	37/60[24.05 (29.48)]		

Table 3. Number of participants who reported that a signal was present in each exposure session (mean and standard deviation of confidence in these decisions) and number of participants who correctly identified the TETRA and sham exposures at the end of the experiment (mean and standard deviation of confidence in these decisions).

	Dependent variable	Independent variable	B (SE)	Comp (SE)	Wald df=1 (p-value)	Odd ratio (95%CI)	Sobel z (p-value)
Total Effects	Symptom Report	Perceived Sensitivity TETRA	2.00 (0.42)	0.48 (0.10)	22.10 (<0.001)	7.36 (3.20-16.91)	na
	Symptom Report	Modern Health Worries	0.17 (0.27)	0.06 (0.12)	0.22 (0.64)	1.13 (0.67-1.91)	na
Direct Effects	Symptom Report	Expectation Symptoms	3.20 (0.51)	0.66 (0.10)	38.66 (<0.001)	24.51 (2.94-67.19)	na
	Symptom Report	Negative Affect	-0.17 (0.24)	-0.09 (0.13)	0.51 (0.48)	0.84 (0.54-1.34)	na
	Symptoms expectation	Perceived Sensitivity TETRA	3.65 (0.56)	0.71 (0.05)	45.29 (<0.001)	38.40 (12.79-115.3)	na
	Symptoms expectation	Modern Health Worries	-0.27 (0.34)	-0.12 (0.15)	0.64 (0.42)	0.76 (0.39-1.48)	na
Indirect Effects	Symptoms Report	Modern Health Worries	0.13 (0.27)	0.04 (0.008)	0.22 (0.64)	1.13 (0.67-1.91)	-0.79 (0.43)
	Symptoms Report	Perceived Sensitivity TETRA	1.99 (0.42)	0.48 (0.10)	22.10 (<0.001)	0.14 (0.06-0.31)	4.52 (<0.001)

Table 4. Direct and indirect effect results of the path analysis

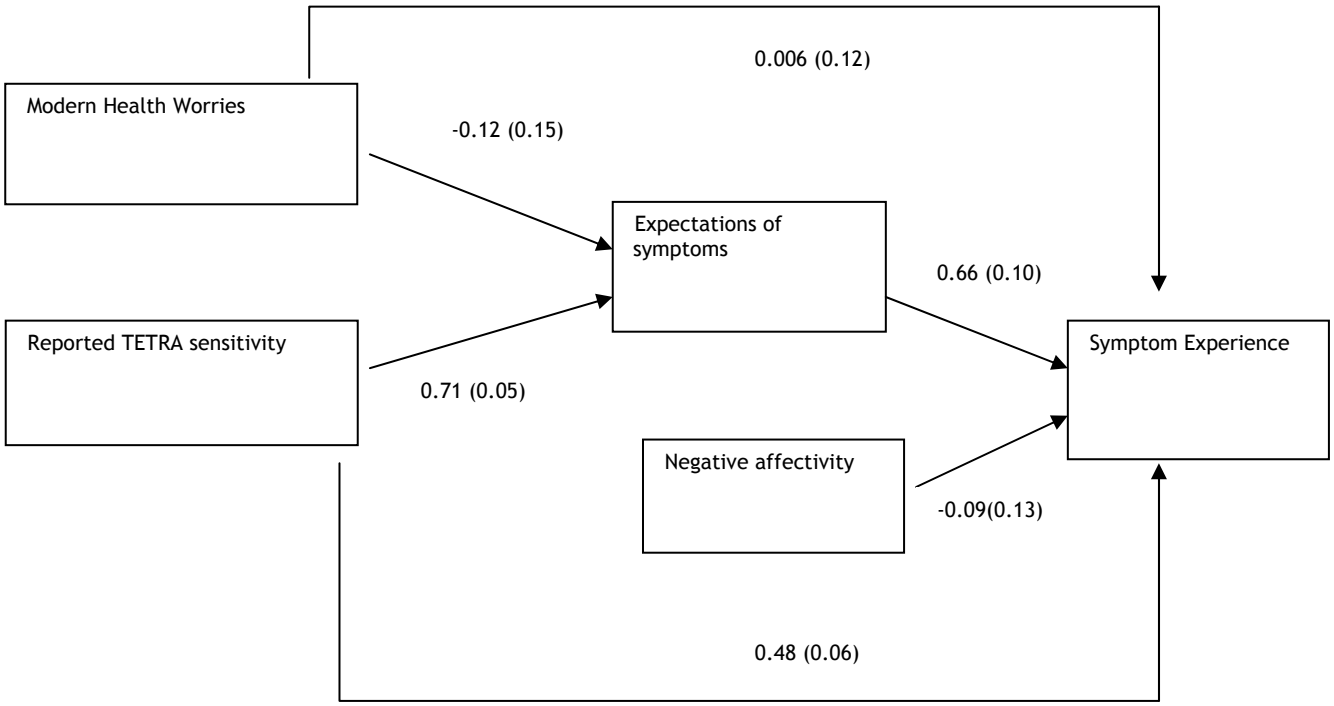

Figure 7. Results of path analysis showing the impact of modern health worries, perceived sensitivity, expectations and negative affect on symptom occurrence (comparable b values are entered in this diagram).

The second logistic regression was performed to assess the impact of concerns about the health effects of radiation and reporting sensitivity to TETRA on the likelihood of expecting headaches at the end of the sham exposure. The significant model as a whole explained between 42% (Cox and Snell R^2) and 56% (Nagelkerke R^2) of the variance in symptom expectancy and correctly classified 85% of cases (x^2 (2, N=120)=66.08, p<0.001). As shown in table 4 only perceived sensitivity to TETRA made a significant contribution to the model.

The third logistic regression was performed to calculate the total effects of concerns about health effects of radiation and reporting sensitivity to TETRA on the experience of headaches at the end of the sham exposure while controlling for negative affect and ignoring the effects of expectations of symptoms. The significant model as a whole explained between 20% (Cox and Snell R^2) and 27% (Nagelkerke R^2) of the variance in symptom expectancy and correctly classified 73% of cases (x^2 3, N=120)=27.55, p<0.001).

Lastly the fourth regression was performed to assess indirect effects of concerns about the health effects of radiation and reporting sensitivity to TETRA on the reporting of headaches during the sham exposure while controlling for negative affect and expectations. The significant model as a whole explained between 28% (Cox and Snell R^2) and 37% (Nagelkerke R^2) of the variance in symptom expectancy and correctly classified 77% of cases (x2 (4, N=120)=39.01, p<0.001).

Figure 7 shows the full path analysis incorporating the effects from each regression and includes transformed b values. In brief, the diagram demonstrated a significant role for perceived sensitivity in determining headache onset during sham exposure, which was largely mediated by greater expectation of headaches.

Psychological variables at baseline

In addition to the 121 participants who attended their first provocation study session, we also received questionnaires from another 133 participants who had contacted us about the provocation study, but who either decided not to participate in the provocation study, could not find time to attend for testing or who did not meet

the inclusion criteria for the provocation study. These additional responses were included when assessing the differences between sensitive and non-sensitive participants in terms of their psychological characteristics. Due to a clerical error, the data for one non-sensitive participant from the provocation study were excluded from these analyses. These results were therefore based on 253 participants (108 sensitive and 145 non-sensitive participants). As with the subset of participants who took part in the provocation experiment, there were no significant differences between the sensitive and non-sensitive samples in terms of most demographic variables ($p>0.05$), although there was a tendency for the non-sensitive participants to have a rank higher than constable (48 higher rank participants, 33%) than the sensitive participants (20 higher rank participants, 19%; $p=0.02$).

With regards to modern health worries, sensitive participants reported more concern about radiation ($t=3.36$, $df=251$, $p=0.001$), tainted foods ($t=2.51$, $df=251$, $p=0.01$) and toxic interventions ($t=2.28$, $df=251$, $p=0.02$) in comparison to non-sensitive participants, but not for pollution ($t=0.37$, $df=251$, $p=0.71$) (see table 5). Sensitive participants recorded significantly worse health than non-sensitive participants for every SF-36 subscale expect for physical functioning ($p<0.05$, table 6). Sensitive participants also experienced significantly higher levels of anxiety and depression compared to non-sensitive participants, and reported higher levels of organisational and operational stress ($p<0.05$, table 7). Sensitive participants were significantly less likely than non-sensitive participants to state that they could choose whether or not to use Airwave in their job, that the introduction of Airwave had been good for the police force or for them as individual police officers, that Airwave was more secure than the old systems or that they were satisfied with the information they had received about Airwave; they were also significantly more likely to say that the introduction of Airwave had made their job more stressful (all $p<0.05$; see table 8).

Pulse and CFF threshold at baseline

Mean pulse rates were not significantly different between the sensitive (65.4 (SD=7.5)) and non-sensitive (65.6 (SD=7.9)) groups ($t=0.14$, $118df$, $p=0.89$). Similarly, there were no significant differences in terms of mean CFF thresholds between sensitive (36.0 (SD=3.3)) and non-sensitive (35.5 (SD=3.0)) groups ($t=0.85$, $118df$, $p=0.40$).

	Sensitive group n=108	Non-sensitive group n=145	Significant test and p- value
Radiation subscale Mean (SD) (1-5) higher-more concern	2.42 (0.82)	2.08 (0.76)	t=3.36 df=251 p=0.001
Environmental pollution subscale Mean (SD) (1-5) higher-more concern	2.69 (0.96)	2.64 (0.87)	t=0.37 df=251 p=0.71
Tainted food subscale Mean (SD) (1-5) higher-more concern	2.80 (1.90)	2.34 (0.94)	t=2.51 df=251 p=0.01
Toxic interventions subscale Mean (SD) (1-5) higher-more concern	2.16 (0.78)	1.94 (0.69)	t=2.277 df=251 p=0.02
Modern health worries total score Mean (SD) (28-140) higher-more concern	69.03 (22.95)	61.84 (18.98)	t=2.70 df=246 p=0.008

Table 5 Means and standard deviation (SD) for the modern health worries subscales. Group comparison with t-test (n=253)

	Sensitive group n=108	Non-sensitive group n=145	Significant test and p-value
SF-36 Physical functioning Mean (SD) 0-100 (better functioning)	93.38 (16.14)	95.41 (7.28)	t=1.34 df=251 p=0.18
SF-36 Role limitations-physical Mean (SD) 0-100 (no limitations)	84.03 (31.04)	91.55 (23.24)	t=2.20 df=251 p=0.03
SF-36 Pain Mean (SD) 0-100 (no pain)	75.83 (21.42)	85.74 (18.73)	t=3.91 df=251 p<0.001
SF-36 General health perceptions Mean (SD) 0-100 (better health)	68.89 (19.58)	73.93 (16.49)	t=2.22 df=251 p=0.03
SF-36 Social functioning Mean (SD) 0-100 (better functioning)	66.64 (19.95)	73.45 (18.06)	t=2.83 df=251 p=0.005
SF-36 Role limitations- emotional Mean (SD) 0-100 (no limitations)	78.50 (34.95)	88.97 (26.07)	t=2.72 df=250 p=0.007
SF-36 Mental health Mean (SD) 0-100 (feeling good)	71.81 (14.50)	77.10 (15.98)	t=2.71 df=251 p=0.007
SF-36 VitalityMean (SD) 0-100 (full vitality)	42.61 16.24)	48.33 (14.95)	t=2.90 df=251 p=0.004

Table 6. Means and standards deviations of SF-36 subscales and HADS for sensitive and non-sensitive participants and group comparisons analysed with t-tests (n=253)

	Sensitive group n=108	Non-sensitive group n=145	Significant test and p- value
HADS anxiety Mean (SD) 0-21 higher anxiety	6.86 (3.86)	4.97 (3.45)	t=4.10 df=251 p<0.001
HADS depression Mean (SD) 0-21 higher depression	4.36 (3.80)	2.70 (3.80)	t=3.81 df=251 p<0.001
Organisational Police Stress Mean (SD) (0-7) higher-more stress	3.50 (1.421)	2.95 (1.09)	t=3.52 df=251 p=0.001
Operational police Stress Mean (SD) (0-7) higher-more stress	2.94 (1.24)	2.42 (1.01)	t=3.66 df=251 p<0.001

Table 7. Means and standard deviation (SD) for PANAS, HADS and Police stress measures. Group comparison with t-tests

Item Mean (SD) (1-7) completely disagree to completely agree	Sensitive group n=108	Non-sensitive group n=145	Significant Test p-value
In my job, I can choose whether or not to use Airwave	1.21 (0.89)	1.86 (1.88)	t =3.33 df=251 p=0.001
The introduction of airwave is good for the Police Force.	4.88 (1.69)	5.70 (1.24)	t=4.46 df=251 p<0.001
On the whole, the introduction of airwave is good for me as a Police Officer.	4.50 (1.82)	5.40 (1.45)	t=4.37 df=251 p<0.001
Airwave seems more secure than the old systems	5.70 (1.26)	6.02 (1.08)	t=2.14 df=251 p=0.033
Having Airwave makes me feel safer when on patrol	4.24 (1.97)	4.45 (1.67)	t=0.90 df=249 p=0.37
The introduction of Airwave has made my job easier	4.61 (1.76)	4.86 (1.54)	t=1.17 df=251 p=0.24
Airwave makes it easier for me to get in touch with others than the old radios.	5.39 (1.70)	5.52 (1.47)	t=0.64 df=251 p=0.52
The introduction of Airwave has increased my workload	3.05 (1.45)	2.92 (1.73)	t=0.63 df=251 p=0.53
The introduction of Airwave has made my job more stressful.	3.35 (1.73)	2.64 (1.73)	t=3.23 df=251 p=0.001
Since the introduction of Airwave, I have been getting too many calls.	2.91 (1.70)	2.64 (1.61)	t=1.29 df=249 p=0.20
In general, I am satisfied with the information that I have received about the new handset.	3.98 (1.78)	4.62 (1.65)	t=2.95 df=251 p=0.003
I am happy that I understand how to use Airwave.	5.07 (1.69)	5.21 (1.64)	t=0.63 df=251 p=0.53
They have made Airwave too complicated to use	3.31 (1.76)	3.03 (1.81)	t=1.22 df=251 p=0.22

Table 8. Mean and standard deviation (SD) of 13 items relating to perceptions of Airwave. Group comparison with t-tests (n=253)

6 Analysis of objectives met

We successfully met all of our objectives.

7 Interpretation

Our provocation study found no robust evidence that a TETRA-like signal with a mean SAR of 1.3 W kg $^{-1}$ could affect symptom reporting. Instead, our CW signal tended to reduce the symptom relating to 'skin itching, tingling, stinging and numbness,' while the addition of a 16Hz component prevented this reduction.

This finding was unexpected, as suggestions that 16Hz signals might be more biologically active than other forms of signal were the original reason for us carrying out this study (Advisory Group on Non-Ionising Radiation, 2001). It is unclear why the opposite might be true. One possibility is that the findings reflect the different peak radiated powers used in our two experimental exposures: while the mean power of both were the same, the pulsing nature of our TETRA signal meant that its peak power was four times greater than that for the CW signal. However, why any impact on subjective symptoms might be more

observable for exposures with a lower peak power is unclear.

That our CW signal produced any effect on symptom occurrence was itself unexpected. Although exposure to radiofrequency fields has been associated with symptom occurrence in several surveys and case studies (Hocking 1998;Oftedal et al. 2000), experimental provocation studies have repeatedly failed to produce replicable evidence showing that radiofrequency fields are the cause of these symptoms (Roosli 2008;Rubin et al. 2005;Rubin et al. 2010). While the majority of these studies have focused on pulsed signals of the type used in mobile phone systems, those that have included CW signals have also typically failed to identify any effects on subjective well-being or related parameters (Roosli 2008;Rubin et al. 2005;Rubin et al. 2010).

Our observation that the effect of CW on skin sensations only occurred in people with self-reported sensitivity to TETRA also contradicts previous studies in this area, which have typically failed to identify any sensitivity to electromagnetic fields amongst individuals who report being sensitive to them (Roosli 2008;Rubin et al. 2005;Rubin et al. 2010). However, our findings were not consistent with the reports of our sensitive participants. First, the direction of the effect that we observed was contrary to that typically reported by people who report sensitivity to electromagnetic fields, with exposure decreasing rather than increasing the likelihood of skin symptoms. Second, while our participants were recruited on the basis of their apparent sensitivity to TETRA, it was CW that appeared to affect them. Third, it was notable that an effect was only observable for skin sensations, whereas our participants reported headache to be the symptom that they most commonly experienced when using TETRA in everyday life. While our results suggest that some people may be sensitive to electromagnetic fields, it appears that not all of the symptoms reported by such people occur as a direct consequence of exposure.

In terms of baseline differences between the groups, we found no evidence of differences with regards to CFF threshold or resting pulse rate. This contrasts with earlier results by other researchers (Lyskov et al. 2001). It is possible that this difference reflects the nature of our sample, which included individuals who were mainly sensitive to only one electrical device as opposed to those have developed more full-blown 'electrosensitivity' (Rubin et al. 2007). If effects such as altered pulse rate and CFF threshold are only apparent in severe forms of the condition, this may imply that they are a result of an individual's deteriorating health. In other words, they may be a consequence, rather than cause, of IEI-EMF. Additional research comparing individuals with IEI-EMF against people with other forms of medically unexplained illness may help to elucidate the relative importance of autonomic nervous system dysfunction still further.

Our identification of several psychological differences between sensitive and non-sensitive participants was consistent with previous theories about the importance of psychological variables as predisposing factors in the aetiology of IEI-EMF (Rubin et al. 2007). In particular, our finding that occupational stress, negative perceptions of airwave, stress associated with airwave, negative mood, and modern health worries were all higher in sensitive officers compared with non-sensitive officers suggests that such factors might play a role in causing people to initially develop symptoms when using a radio and then to attribute those symptoms to the device itself (Rubin et al. 2007). Our analysis of psychological predictors of symptom reporting during the sham condition of our provocation study further suggested that expectation of symptoms, though not negative mood, may also be important in triggering symptoms. The existence of these psychological mechanisms does not preclude the possibility of a biological sensitivity also existing. However, they do indicate the existence of a separate pathway through which symptoms can develop.

Methodological limitations

Several methodological caveats should be considered in relation to our provocation study. First, the power of our analyses was lower than we had hoped. Although we would still have been able to detect a large effect of exposure, similar to the size of effect reported by our sensitive participants in their everyday life, smaller differences, which might still have been of clinical and theoretical relevance, may have been missed.

Second, our study included analyses of several symptoms and it was necessary to adjust for these multiple

comparisons when assessing the significance of our results. We choose a Simes adjustment in order to reduce the chance of reporting a spurious positive finding. Although less conservative than other Bonferroni-type corrections, the Simes adjustment still reduces the possibility of false positive results at the possible expense of producing false negatives (Simes 1986;Rodland 2006). Different adjustments for multiple comparisons, for example estimation of the false discovery rate, may control false positives at the expense of allowing more false negatives. However, given the potential costs of incorrectly asserting that TETRA has an adverse effect, both in terms of unnecessary anxiety for users and opportunity costs arising from attempts to mitigate any effects (e.g. Dolan & Rowley, 2009; Sutton, Saidi, Bickler & Hunter, 1995), we felt that the Simes adjustment was suitable in this instance. If we had made no adjustment, or used a false discovery rate adjustment, then our results would have suggested that in addition to its effects on skin sensations, CW exposure can trigger headaches, fatigue and difficulty concentrating or thinking, effects which were still detectable at twenty four hour follow-up and which were largely reversed by the addition of 16Hz pulsing.

A third limitation is that our sham condition was not zero exposure. As with a previous experiment by our group (Rubin et al. 2006) leakage from the exposure equipment of a CW signal occurred during the sham sessions. However, this leakage was at a very low level, with a mean power 650 times lower than that in the other exposures. It seems unlikely that this would have prevented us from detecting a difference between the sham and CW exposures.
With regards to our psychological and physiological comparisons, the key caveat to consider is that of selection bias. As a self-selected sample, we cannot be sure if our participants were representative of the general population of police officers.

Conclusions
Despite these methodological caveats, our study identified a significant effect of CW exposure on skin sensations in participants who reported sensitivity to TETRA, an effect that was not apparent during TETRA exposure. In our unadjusted analyses, other effects of CW were also identified in both sensitive and non-sensitive participants which were largely reversed by inclusion of 16Hz pulsing. Attempts to replicate these unexpected findings would be beneficial.

In the meantime, our results should be relatively reassuring for users of TETRA radios. Not only did our TETRA-like exposure have no specific adverse effects in comparison to CW, if anything inclusion of 16Hz component appeared to make our signal less biologically active.

8 Future priorities

Our provocation study results relating to the CW exposure were unexpected. An attempt to replicate these findings would be of interest.

9 Publications

The results discussed in this report have not yet been submitted for peer-reviewed publication. However, as part of our work we have updated a previous systematic review of provocation studies for IEI-EMF.

Rubin GJ, Nieto-Hernandez R & Wessely S (2010). Idiopathic environmental intolerance attributed to electromagnetic fields (formerly 'electromagnetic hypersensitivity'): An updated systematic review of provocation studies. *Bioelectromagnetics*, 31, 1-11.

10 Financial summary

Total budget allocated by MTHR: £308,152.50

Total actual spend: £308, 918.96

Overspend (covered in full by King's College London): £766.44

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