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Short-Term Exposure to Mobile Phone Base Station Signals

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The data in the study by Eltiti et al. (2007) do not support their conclusion that

> The present data, along with current scientific evidence, leads to the conclusion that short-term rf-emf [radio frequency electromagnetic fields] exposure from mobile phone technology is not related to the levels of well-being or physical symptoms in IEI-EMF [idiopathic environmental intolerance with attribution to electromagnetic fields] individuals.

In the study by Eltiti et al. (2007), the intensity of the radiation emitted by the mobile phone base station was 1 μW/cm^2 (5 mW/m^2 for 900 MHz and 5 mW/m^2 for 1,800 MHz). The authors assumed that the participants would not react to higher intensities such as 10 or 20 μW/cm^2, or even to intensities up to 900 μW/cm^2, which are used in mobile phone technology.

The exposure durations were too short to produce real effects at the biochemical and clinical levels. Ahmed et al. (2004) and Lai et al. (1992, 1994) concluded that the response depends on the duration of the radiation exposure. After 1 hr of exposure, alterations of certain biochemicals, which could be producing the symptoms, may or may not occur. For example, an increase in acetylcholinesterase activity is responsible for the levels of acetylcholine and with other neurotransmitters responsible for cognitive functions; with further exposure, this activity increases in two areas of the brain, the hippocampus and the striatum. Also, Johansson (2006) reported that electromagnetic fields may stimulate mast cells, which produce histamine, and then symptoms are produced in the skin and other organs.

Furthermore, the effects of electromagnetic fields (Belyav 2005) may be related not only to intensity or duration of exposure but also to other parameters, such as frequency or modulation.

To classify a clinical symptom as psychological, first we must exclude biochemical changes that could be triggered by the electromagnetic fields and cause neurobehavioral responses. This is supported by studies that show changes in neurotransmitters [e.g., acetylcholine (Ahmed et al. 2004), γ-aminobutyric acid (Kolomytkin et al. 1994), glutamate (Wieraszko et al. 2004)], histamine (Johansson 2006), and somatostatin (Johansson 2006)] as well as their correlation with the clinical symptoms.

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Mobile Phone Base Station Exposure and Symptoms

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Eltiti et al. (2007) reported elevated levels of arousal when electromagnetic-hypersensitive subjects were exposed to a UMTS (universal mobile telecommunications system) mobile phone base station signal of 10 mW/m^2. Based on their statistical analysis, they concluded that this observation was likely to be due to the effect of order of exposure rather than the exposure itself. In our view, however, a critical review of their data suggests a different conclusion.

First of all, Eltiti et al. (2007) hypothesized that

> Sensitive participants would report more symptoms and lower levels of well-being during GSM [global system for mobile communication] and UMTS exposure compared to sham.

When dealing with a directional hypothesis, a one-sided statistical test is indicated. According to a one-sided statistical test, differences between sham and UMTS exposure for sensitive subjects regarding anxiety (t-value = 2.89) and tension (t-value = 2.94) are significant, even after applying a Bonferroni correction.

An arguable issue is whether Bonferroni correction should be applied in the first place. The trial was designed to replicate previous findings from a Dutch study (Zwamborn et al. 2003).

Many statisticians may point out that multiple end point correction is not needed under these circumstances. Definitely, a Bonferroni correction, as used in the context of the trial by Eltiti et al. (2007), is too conservative when measuring several symptoms that are very likely to be correlated. The correlation between the outcomes should be taken into account in the multiple end point correction. As a consequence, the reference t-values would be lower, again yielding the conclusion that anxiety and tension are correlated with UMTS exposure.

It is unfortunate that the exposure order among the three conditions was not counterbalanced. As Eltiti et al. (2007) reported, this unbalanced design led to additional variation in the data. We therefore cannot understand why the authors did not include the order of exposure conditions as a factor in their statistical model. Instead, they presented a between-subjects comparison stratified by order [see Table 3 in Eltiti et al. (2007)]. It is true that the differences between sham and UMTS did not reach statistical significance in any of the three sessions. However, it is striking that in each of the three sessions, the arousal score of sensitive individuals was higher for the UMTS condition compared to sham. Pooling the three sessions together would yield a significant difference between sham and UMTS (t-test; p = 0.02). Likewise, a meta-regression of the data from their Table 3 confirms that order (p = 0.043) and exposure condition (p = 0.076) are important factors and should have been considered in the original model.

Finally, given the fact that Eltiti et al. (2007) observed a few more borderline significant effects and that the targeted sample size was not achieved, one would expect a critical discussion about the power of the study, which the authors did not provide.

In summary, a more careful data analysis yields significantly different tension, arousal, and anxiety scores between sham and

UMTS exposure status for sensitive subjects. It seems unlikely that these differences are solely due to order of exposure, as argued by Eltiti et al. (2007) .

We think that results from this study should be interpreted with more caution. Certainly, an association between low-level short-term UMTS mobile phone base station exposure and symptoms is unexpected and contradicts a previous study (Regel et al. 2006). This issue merits further clarification.

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Sensitivity to Mobile Phone Base Station Signals

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Electromagnetic hypersensitivity (EHS) is a potentially highly significant public health problem. Eltiti et al. (2007a) recently concluded that short-term exposure to a GSM (global system for mobile communication) base station–like signal did not affect well-being or physiological functions in individuals, and they dismissed a positive reaction to UMTS (universal mobile telecommunications system) as an artefact.

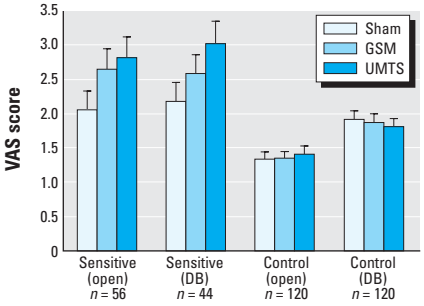


Figure 1. Tension (visual analog scale) scores (mean and SE) from Table 2 of Eltiti et al. (2007). DB, double-blind.

Eltiti et al. (2007a) stated that "[EHS] individuals are unable to detect the presence of rf-emf [radio frequency electromagnetic fields] under double-blind conditions." We believe that this conclusion was erroneous, and that their data show that the EHS individuals reacted to both GSM and UMTS signals, and that this was not due to a nocebo effect.

Figure 1 presents their data [mean and SE from Table 2 (Eltiti et al. 2007a)] and clearly shows that the sensitive group, unlike the control group, was reacting to the exposure, with significant results in both the open provocation (for GSM and UMTS, note the sham; $p < 0.0025$) and the double-blind tests (for UMTS). The results for anxiety and arousal are very similar.

The sensitive group had higher initial levels of anxiety, tension, and arousal. Only a short time elapsed after arrival before testing started. Wever (1979) and others have reported that a period of a few days in a low-EMF environment are necessary before testing for EMF-related changes.

We are puzzled by the receiver operating characteristic (ROC) curves in Figure 2A (Eltiti et al. 2007a). The authors stated that the sensitive individuals were 55.2% correct, yet their curve was mostly below the 50% line. A more standard way of displaying the results would have been helpful. The sensitive group improved its on/off accuracy score after 50 min (55% to 60%), whereas the control group decreased (51% to 50%). The data for these double-blind tests (Fox E, personal communication) show that correct versus incorrect results were 60.6% ($p < 0.005$) for the sensitive group and 49.4% (not significant) for the control group.

Eltiti et al. (2007a) found a large and statistically significant ($p < 0.001$) higher skin conductance in the sensitive group (see their Table 5). Their conclusions do not highlight this difference between the two groups, which may be a key indicator of likelihood of individuals to experience EHS symptoms.

The EHS questionnaire devised by Eltiti et al. (2007b) was to be used for selecting the 132 most sensitive individuals. However, it was not used for this purpose because only 58 people with self-diagnosed EHS applied, and apparently no individuals were rejected because of a low score.

Are provocation studies appropriate for testing for EHS, where there is often a significant time-lag from start of exposure to the start of symptoms? Also, perseveration of symptoms due to physiological arousal caused by traveling to the laboratory is a likely confounder. Any study should be designed to take into account both of these potential problems.

Also, the use of Bonferroni corrections is contentious; uncorrected data should be shown along with corrected data.

The study (Eltiti et al. 2007a) required 66 individuals per group for a power 0.90 to detect a difference between real and sham exposure responses. The authors tested only 44 sensitive individuals under double-blind conditions, which reduced the power to about 0.7. We question the appropriateness of publishing such definite conclusions based on such data, especially with a high-profile media briefing.

Despite limitations, this study of Eltiti et al. (2007a) has produced positive results that support claims that EHS people can be affected by microwave transmissions from mobile phone base stations.

A.C. is employed by EMFields (A&J Philips) to design EMF measurement equipment (EMFields financially supports Powerwatch, a UK advocacy group that promotes a precautionary approach to EMF exposure); A.C. did not receive payment for writing this letter. A.D., serving as an unpaid volunteer, operates and writes for TETRAWatch, a nonprofit organization concerned with the health risks, costs, and effectiveness of TETRA communications antennae in the United Kingdom. D.M. is the founder of EMFacts Consultancy, an advocacy group that produces reports on health issues related to human exposure to electromagnetic radiation. E.O. is on the board of trustees of the EM-Radiation Research Trust, an independent charitable organization whose goal is to provide the facts about electromagnetic radiation and health to the public and the media; she receives no money from the organization. The remaining authors declare they have no competing financial interests.

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Mobile Phone Base Stations: Eltiti et al. Respond

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Three letters have questioned the validity of the conclusions drawn in our recent article on the short-term effects of GSM (global system for mobile communication) and UMTS (universal mobile telecommunications system) base station signals (Eltiti et al. 2007). Most of the concerns are founded in misunderstandings of the study, and we hope to clarify these issues here. We assessed whether people could detect the presence of a 10-mW/m^2 signal over a 50-min period (not 10 μW as claimed by Zinelis). This level of exposure is roughly equivalent to standing within 60 m of a mobile phone base station and was based on prior scientific evidence (Mann et al. 2000). We also measured a range of variables within three classes of response: physiological response, self-reported well-being, and actual symptoms experienced.

We found no evidence that people could detect the presence of the EMF (electromagnetic field) signal, and Cohen et al.'s assertion that "this conclusion is erroneous" is completely unfounded. Their conclusion arises from a misunderstanding of the receiver operating characteristic (ROC) curve analysis. ROC curves and d' values tell us how accurate participants are in discriminating a signal from a nonsignal. This standard psychophysical measure (d') provides a measure of accuracy independent of bias. Thus, a d' score of 0 means that the proportion of hits (respond "on" when on) is the same as for false alarms (respond "on" when off) and indicates that people are unable to detect a signal (Macmillan and Creelman 2005). In this case, the ROC curve will fall roughly across the graph at a 45° angle, (as we found (Eltiti et al. 2007). As shown in Table 1, both the hits and false alarms were not different from what was expected by chance, and this was true for both the sensitive and the control groups. Thus, the comment by Cohen et al. is unfounded and inaccurate.

We measured the following physiological responses: blood volume pulse, heart rate, blood pressure, and skin conductance response (SCR). The SCR in particular is considered to be one of the most sensitive measures of physiological arousal (Curtin et al. 2007). Although the sensitive group was more aroused at baseline than controls—which has been reported many times before—this physiological arousal was not related to the EMF signal. The hyperarousal of the sensitive group is of interest in its own right, as noted in our article (Eltiti et al. 2007). However, we found no evidence that either GSM or UMTS affected any physiological measure.

In our study (Eltiti et al. 2007), participants were free to report any symptoms they experienced at any time during the testing session. The number of symptoms experienced by the sensitive individuals was not, however, related to the presence of an EMF signal. In his letter, Zinelis argues that our statistical power was too low and the length of exposure too short to allow symptoms to emerge. First, the statistical power (0.75) in our study was actually very high for this field of research. Second, extensive pilot testing and interviews with study participants revealed that the people we tested reported that they usually experience their typical symptoms within minutes of being exposed to EMF signals. The fact that the symptoms were elicited under the open provocation, but not in the double-blind session, provides evidence that these sensitive people experienced a number of unpleasant symptoms, but these were not related to the presence of an EMF signal. Thus, our data (Eltiti et al. 2007) contradict the points raised by Zinelis.

All three letters about our article (Eltiti et al. 2007) question the validity of our conclusions with regard to the subjective well-being measures. We did report a number of effects, two of which remained significant following Bonferroni correction. In their letter, Röösli and Huss question whether we should have used such a statistical correction in the current context. This is indeed an important and debatable issue. However, we believe that we took the most reasonable approach, given the weight of the evidence from the other indicators in our own study as well as from the bulk of other research in this area (e.g., for review, see Rubin et al. 2005). To illustrate, previous research has reported positive (e.g., Hietanen et al. 2002), negative (e.g., Zwamborn et al. 2003), and no effect of short-term EMF exposure on health indices (e.g., Lyskov et al. 2001; Regel et al. 2006; Rubin et al. 2006). Thus, the use of two-tailed tests seems most appropriate. If we apply the Tukey-Ciminera-Heyse correction for highly correlated end points, as suggested by Röösli and Huss, we are left with a significant difference in self-reported anxiety [t (43) = 2.89; p = 0.006]

Table 1. d', sensitivity (%), and specificity (%) by exposure duration by group.

	Exposure duration (min)	d'	Sensitivity ("on" when on)	Specificity ("off" when off)
Expected value when people do not know the source of the signal			66.6	33.3
Sensitive group	5	–0.08	66.4	32.7
	50	0.20	69.3	40.9
Control group	5	0.10	51.7	50.1
	50	0.06	48.0	54.3

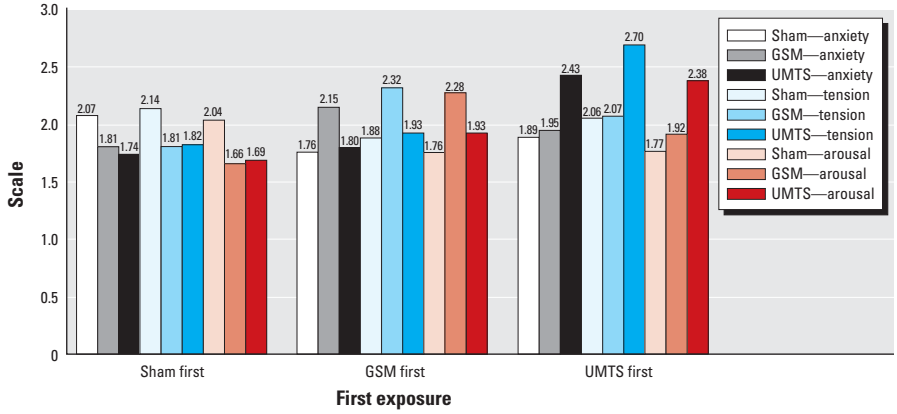


Figure 1. Visual analog scales of anxiety, tension, and arousal by condition by first exposure for all participants.

and tension [t (43) = 2.94; p = 0.005] between the UMTS and sham exposures for the sensitive participants. Also, the magnitude of the effect was very small (< 1 point difference on a 10-point scale). No other differences were significant.

A 2 (group) × 3 (condition) × 6 (exposure order) mixed analysis of variance (ANOVA) for anxiety, tension, and arousal resulted in significant two-way interactions of condition by exposure order for all three visual analogue scales (VAS) [F-values (10, 292) > 3.41; p-values = 0.001), which did not interact with group [F-values (10, 292) < 1.08; p-values > 0.05). This two-way interaction is difficult to interpret given the six levels of exposure order. To aid interpretation, we conducted a series of 2 (group) × 3 (condition) × 3 (first exposure) mixed ANOVAs for anxiety, tension, and arousal. This resulted in significant two-way interactions [F-values (4, 304) > 5.88; p-values = 0.001), but not a three-way interaction [F-values (4, 304) < 1.39; p-values > 0.05). Again, the first exposure did not interact with group. As shown in Figure 1, the significant differences depended on which condition the participant received first. When the first exposure was GSM, the VAS for GSM were higher than for sham [t-values (52) > 3.72; p-values = 0.001); the same was found for UMTS [t-values (52) > 2.66; p-values < 0.01); and sham [t-values (51) > 2.12; p-values < 0.04). None of the other comparisons were significant (Figure 1). This confirms our previous conclusion that difference in self-reported VAS for anxiety, tension, and arousal is attributable to order effects.

In conclusion, we appreciate the opportunity to discuss the interpretation of data in this controversial area. However, in our view the conclusions drawn in our article are fair and accurate, and we do not think that the letters have raised any issues that would lead us to modify those conclusions. As we made clear in our article (Eltiti et al. 2007), we did examine short-term effects of EMF exposure and therefore can draw no conclusions about the possible long-term effects on human health.

The authors declare they have no competing financial interests.

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