Magnetic Fields and the Brain

by Dr Jason Braithwaite

The idea that certain weak magnetic fields could be responsible for haunt-type experiences is gaining currency. There have been several investigations recently that have produced field evidence in favour of the theory. This does not mean that the method of producing such hallucinations is understood. In this article, Jason Braithwaite outlines some of the neurological problems involved in understanding how such a phenomenon might work.

Recent laboratory studies have revealed that human exposure to low-frequency complex electromagnetic fields (EMFs) can induce strange and exceptional hallucinatory experiences under controlled conditions. The implication from these laboratory studies is that such EMFs could underlie spontaneous instances of anomalous cognition that occur in the natural setting. However, although the laboratory based studies show convincingly that magnetic fields can disrupt neural firing patterns; it is less well known exactly how this actually happens. Indeed, there is an emerging debate directed specifically at how these low-amplitude fields could have any implication for neural processing. In this brief paper I outline just a few of my concerns from the perspective of neuroscience.

Over the average 24-hour daily cycle multiple sources of magnetic and electromagnetic fields (EMFs) bombard our brains and our bodies. Although still a contentious areas of research, field studies, correlational and epidemiological studies, are now highlighting a link between EMFs and changes in human biology, neurophysiology, and behaviour. In the laboratory neuroscientists can now artificially induce all manner of hallucinations by applying relatively weak low-frequency and low-amplitude magnetic fields to the outer cortex of the brain (see Persinger, 1999, 1988; Persinger, & Koren, 2001, Persinger, Koren, & O'Conner, 2001; Persinger, &

Richards, 1994, Persinger, Richards, & Koren, 1997). What these studies seem to suggest is that certain magnetic fields may have implications for cognition and behaviour. Although the effect of EMFs on neurophysiology is in little doubt, it is less clear exactly how these low-amplitude EMFs can actually stimulate the brain at all. Regular readers of Anomaly will note that I do generally support the suggestion for a role of EMFs in some haunting / apparitional experiences. However, this does not prevent me from continuing to ask specific questions about how such an account actually works at the neuronal level. That is to say, although I accept that the magnetic fields and EMFs account has a great deal of merit as a useful framework for understanding some strange experiences that does not mean it is without a need for further detail.

Magnetic stimulation and the brain

There are two well-known methods of magnetic brain stimulation: Trans-cranial Magnetic Stimulation (TMS: see Walsh & Pascual-Leone, 2002) and Trans-Cerebral Magnetic Stimulation (TCS: see Persinger, 1999; 1988; Persinger, & Koren, 2001). At the neuronal level, the biophysics of TMS are relatively well known. TMS involves the use of an intense focused magnetic pulse (or series of repetitive pulses rTMS), that are easily capable of penetrating the skull, and induce a large current within neural systems in the outer cortical surface of the brain. Depending on the location chosen, this current can disrupt processing in certain systems creating a kind of temporary 'virtual lesion' or can facilitate processing within a particular network. The amplitudes used are very high and are usually in or around the 1 Tesla range (more than 20,000 times the strength of the earths field). The effects are immediate, with a 1 ms (millisecond) temporal resolution and a 1 cm spatial resolution. In other words the effects occur as the pulse is being applied. Due to the high amplitudes typically used in TMS, the temporal lobes are generally not stimulated as this may induce epileptic fits in participants. Although TMS is used in a different way, and at different amplitudes by clinicians and cognitive scientists, the manner in which TMS actually stimulates neural cortex is the same. That is to say, the biophysics are the same; TMS works by inducing a large and immediate disruptive current in the brain. This will have consequences for the processing of information and can influence visual perception / awareness.

In contrast TCS uses very weak complex magnetic fields that can be used to stimulate all regions of the cortex. Persinger and colleagues (Persinger, 1999, 1988; Persinger, & Koren, 2001; Persinger, & Richards, 1994; Persinger, et al., 1997) have suggested that these magnetic fields can cause complex epileptic-like partial micro-seizures in temporal-lobe regions of neuronal hypersensitive participants. The result is hallucination. The EMFs used in TCS are very weak, generally in the region of 100 - 5000nT, and of low-frequency (typically <30Hz). These low frequency fields are often pulsed say for 1 second every 3 seconds. It has been argued that such field complexity, rather than actual excessive field magnitude, is the crucial factor for inducing many of these types of experience (Persinger, & Koren, 2001; Persinger, & Richards, 1994; Persinger, et al., 1997). Indeed a number of specific and exotic pulse patterns have been generated that vary across a number of dimensions including: (i) the onset ramp times of pulses (the time taken for the pulse to rise to maximum), (ii) their overall amplitudes, (iii) offset ramp times (the time taken for the pulse to drop back to zero), (iv) how this can vary across the pulses in a series of repetitive spikes, and (v) how closely packed a series of pulses are over a particularly time period (see Persinger & Koren, 2001). Importantly, unlike TMS, this method of stimulation is not instantaneous, with participants generally undergoing 15 – 20mins of exposure before the effects on experience are reported.

Furthermore, the spatial resolution of TCS is not as specific as these fields are applied in a much more general way to whole regions (eg. lobes) of the brain at a time. Also it is typical with TCS to reduce sensory input (blindfolds / earmuffs etc) during experimental stimulation.

It is clear from the description above that the methods of stimulation are quite distinct and produce distinct effects. TCS does not seem to induce a direct current in the brain in the manner that the high amplitude TMS is known to do. This implies another mechanism for interacting with the brain. There are other important differences worth noting. In TCS, the sham baseline condition (where no magnetic field is applied, unknown to the participant) often produces a sizable minority of experiences (sometimes in the region of 10% - 15%). These must be due to a combination of expectation and the process of sensory reduction itself producing its own effects. Furthermore, the crucial long (15 – 20 min) exposure time strongly implies a more indirect mechanism. Indeed, when one looks at the figures themselves it becomes obvious that these stimulation techniques are interacting with neural tissue in diverse ways. For instance, it is clear that the amplitudes used in TCS are no where near high enough to induce a direct current in the cortex in any way similar to that of TMS. Indeed, the degree to which such low fields can penetrate the scalp, the skull, cross the air gap, and actually reach the cortex has been questioned by some critics. What is clear is that at the very least, the biophysics of TCS seems distinct to other more traditional methods of stimulation. The stimulatory effects of TCS, though well documented, certainly appear to be more subtle, and indirect.

In terms of an individual neuron, the strength (amplitude) at which it fires is relatively constant under normal conditions. It is an absolute, pre-determined all or none affair. However, the likelihood of that neuron firing or not and the rate of that firing (its frequency) can be altered in some circumstances. At a descriptive level, it would seem that TCS signals closely 'mimic' neuronal activity patterns and hence become integrated into the ongoing perceptual processing represented by a particular neuronal state at that time. What is less clear is how this 'mimicking' and integration process actually comes about. One possibility is that TCS may work initially by variant effects on the hyperpolarisation (decreasing the likelihood of the cell firing) of individual systems of neurons, influencing the likelihood that they may fire or not. This may start a kind of localised cascade effect through discrete neural sub-systems, disrupting the natural temporal firing rate of these systems. One can imagine that by placing an inhibitory neural circuit in an increased state of hyperpolarisation (ie. less likely to fire) one could potentially generate a state of excitation in some circuits. Other things that may be crucial involve effects on certain, specific psychopharmacological agents involved in mediating membrane potentials and synaptic transmission; including the passage of ions within and between neurons. Indeed, in my opinion, the ionic environment within and between neurons may well prove crucial for the initiation and propagation of partial seizure that may then be taken up by other synapse mediated mechanisms (this has been currently overlooked by many researchers).

Persinger (1988; Persinger, & Koren, 2001, Persinger, & Richards, 1994, Persinger, Richards, & Koren, 1997) often goes into great detail concerning how such effects could come about, however it is important to point out that none of those mechanisms are directly supported by the stimulation data so far available. Indeed the claim that TCS stimulates deep inside the temporal lobes and into para-hippocampal regions is also not directly supported by the behavioural data. Recruiting EEG data is not as convincing as might first appear either as these devices record electrical activity on the surface of the cortex only. In other words, EEG activity is a consequence that does not inform the researcher in any way as to the causal mechanisms underlying such activity. It seems that the assumption of the involvement of particular deeply embedded structures is based on the content of the hallucination mapping onto the principal known function of particular structures (eg. hippocampus = memory / imagery, amygdala = emotional responses). There is, of course, nothing wrong with doing this – but it does not directly demonstrate that these EMFs are crucially and exclusively interacting with those structures. Note it is not being suggested that such EMFs are not having an affect, more that the actual mechanism of interaction is less well known and less supported than the existence of the actual effect itself. Basically, the biophysics of TCS are still largely unclear and future research would do well to reappraise the possible mechanisms for magnetic stimulation using these fields.

So what does all this mean for researchers in the field trying to quantify magnetic fields potentially associated with strange haunt-type experiences and events? Well, simply detecting the odd transient pulse in the background field is likely to be of little use in terms of brain stimulation (which means certain popular devices are also worthless: see Braithwaite, 2003). It is also highly unlikely individuals will ever be exposed to fields in the Tesla region from the natural setting; this effectively rules out a biophysical mechanism of direct and instantaneous current inducement in neurons (analogous to TMS). If we assume that the fields used in the laboratory are closely approximate to the important fields available in haunted locations, then it would seem that such fields would need to be present for some time and the individual must be exposed to them for some time (at least for the amplitudes used in the laboratory). This seems to be a perfectly reasonable position to take, in the first instance.

It might also seem reasonable at first to further assume that the larger any ‘pulse’, transient or more stable shift might be, then the greater the chance of stimulation. Although possible, this is not as logical a development as what might first appear. It is important to remember that TCS studies use very low-amplitude fields and get dramatic effects. From this we know that high amplitudes are not necessary at all, at least under those circumstances. What seems more crucial here is the complexity of the fields used; that is how they vary in amplitude over time, phase, frequency, pulse duration, pulse patterns, etc. Of course, the individual would still need to be exposed to these fields for some time (that is to say, it would not be an instantaneous effect), but the crucial factor here seems to be complexity. This increased duration highlights a potential chronic exposure effect in some cases.

Developing these ideas further, we might want to assume that the stronger the magnetic anomaly (be it constant or transient) then the more likely it is to induce physiological changes over a shorter period of time. Persinger (1999) has estimated that in some circumstances such fields in the natural setting would need to be 10 to 50 times stronger than those used in the laboratory, even for hypersensitive individuals. As a crude and general rule this basically equates to fields in the region of 10000 - 50000nT and above as being potentially important (this is on top of any background source).

This may at first seem at odds with the claim that complexity, and not strength, is the important issue. However, the figures given above are a theoretical estimate of the amplitude contained within a field that is still varying in a complex way. So although the figure pertains only to amplitude that should not be taken to mean that the field should only be described in terms of its amplitude. We still need to assume a complex magnetic environment as a context for these values; a field of 50000nT may be distributed across numerous frequencies. A simple sine wave (ie. from mains power supplies) of these magnitudes seem to have no implications for experience – so researchers need to avoid being misled into thinking that 'hotspots' are indicated by high amplitudes alone. Furthermore, medical imaging techniques can use massive simple fields (DC fields in the 2-3 Tesla range) which have no consequence for experience whatsoever. I recently took measurements at a railway station and found AC fields of around 75000nT. I am not aware of multiple strange experiences there (despite the large numbers of people passing through and workers exposed to this level on a daily basis). However, what unites these examples is the fact that the sources produce relative simple magnetic fields of a prime fundamental constant frequency that contains most of the measured energy. These fields look nothing like TCS fields and based on present findings they have few if any implications for cognition and strange experience.

Finally, it may be the case that as TMS and TCS clearly stimulate the brain via distinct biophysical mechanisms, there may be many quite distinct ways for TCS type fields to engage with neural processes. So it may be that there is not one method of interaction at work here. This certainly remains a possibility. Perhaps higher amplitude fields (though still not too high) need to be more 'complex' as the complexity matches brain signals and as such is more likely to be integrated into the current neural state. So here increased complexity compensates for the excessive amplitude, which the brain would normally not accept into its ongoing processing. The higher amplitude may accelerate the rate and propagation of the stimulation through neural architecture. Conversely, low-amplitude fields, though obviously still needing to be very complex, could perhaps be less complex (relatively) and not need to be very strong in order to become assimilated into the neural process. This may happen in a more diffuse, reserved and time-consuming manner. However, the key in both instances is the complexity of the fields involved. These possibilities remain little more than speculations at present. The main point here is that the biophysics of TCS fields are not well known, we would do well to look at these before contemplating too much about the varieties of engagement principles between magnetic fields and the brain.

NB: See pages 3-6 in this issue for a concise description of the magnetic field characteristics that paranormal researchers should be looking for in the field. Ed.

References

Braithwaite, J. J. (2003). The right tools. *Anomaly: Journal of Research into the Paranormal*, 32, 23-32.

Persinger, M. A. (1999). Increased emergence of alpha activity over the left but not the right temporal lobe within a dark acoustic chamber: differential response to the left but not to the right hemisphere to transcerebral magnetic fields. *International Journal of Psychophysiology*, 34, 163-169.

Persinger, M. A. (1988). Increased geomagnetic activity and the occurrence of bereavement hallucinations: Evidence for a melatonin mediated microseizuring in the temporal lobe? *Neuroscience Letters*, 88, 271-274.

Persinger, M. A., & Koren, S. A. (2001). Predicting the characteristics of haunt phenomena from geomagnetic factors and brain sensitivity: Evidence from field and experimental studies.

J. Houran & R. Lange (Eds.), *Hauntings and Poltergeists: Multidisciplinary perspectives* (pp. 179-194.). Jefferson, North Carolina: McFarland & Company, Inc.

Persinger, M. A., Koren, S. A., & O'Connor, R. P. (2001). Geophysical variables and behaviour: CIV. power-frequency magnetic field transients (5 microtesla) and reports of haunt experiences within an electronically dense house. *Perceptual and Motor Skills*, 3(1), 673-674.

Persinger, M. A., & Richards, P. M. (1994). Quantitative electroencephalographic validation of the left and right temporal lobe indicators in normal people. *Perceptual and Motor Skills*, 79, 1571-1578.

Persinger, M. A., Richards, P. M., & Koren, S. A. (1997). Differential entrainment of electroencephalographic activity by weak complex electromagnetic fields. *Perceptual and Motor Skills*, 84(527-536.).

Walsh, V., & Pascual-Leone. (2002). *Transcranial Magnetic Stimulation: A Neurochronometrics of Mind*. Bradford, Cambridge: MIT Press.